Qualitative Modelling of Place Location on the Linked Data Web and GIS

A thesis submitted in partial fulfillment of the requirement for the degree of Doctor of Philosophy

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Abstract

When asked to define where a geographic place is, people normally resort to using qualitative expressions of location, such as north of and near to. This is evident in the domain of social geography, where qualitative research methods are used to gauge people's understanding of their neighbourhood. Using a GIS to represent and map the location of neighbourhood boundaries is needed to understand and compare people's perceptions of the spatial extent of their neighbourhoods. Extending the GIS to allow for the qualitative modelling of place will allow for the representation and mapping of neighbourhoods. On the other hand, a collaborative definition of place on the web will result in the accumulation of large sets of data resources that can be considered "location-poor", where place location is defined mostly using single point coordinates and some random combinations of relative spatial relationships. A qualitative model of place location on the Linked Data Web (LDW) will allow for the homogenous representation and reasoning of place resources. This research has analysed the qualitative modelling of place location on the LDW and in GIS. On the LDW, a qualitative model of place is proposed, which provides an effective representation of individual place location profiles that allow place information to be enriched and spatially linked. This has been evaluated using the application of qualitative spatial reasoning (QSR) to automatic reasoning over place profiles, to check the completeness of the representation, as well as to derive implicit links not defined by the model. In GIS, a qualitative model of place is proposed that provides a basis for mapping qualitative definitions of place location in GIS, and this has been evaluated using an implementation-driven approach. The model has been implemented in a GIS and demonstrated through a realistic case study. A user-centric approach to development has been adopted, as users were involved throughout the design, development and evaluation stages.

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Contents

List of Publications

[1] K. Almuzaini and A. Abdelmoty, “Integrating Qualitative Representation and Reasoning with GIS,” in *the 21st GIS Research UK (GISRUK) conference*, 2013.

[2] K. Almuzaini and A. Abdelmoty, “REASONING WITH PLACE INFORMATION ON THE LINKED DATA WEB,” in *The 15th International Multidisciplinary Scientific GeoConference SGEM 2015*, Book2 Vol. 1, 265-280 pp

[3] A. Abdelmoty and K. Al-Muzaini, “Reasoning with place information on the linked data web,” in *The Second International Conference on Big Data, Small Data, Linked Data and Open Data*, 2016, pp. 48–53.

[4] A. Abdelmoty and K. Almuzaini. "A computational model of place on the linked data web." *International Journal on Advances in Software* 9 (2016): 238-247.

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List of Abbreviations

AGI	Authoritative Geographic Information
API	Application United Interface
CP	Compound Place
DP	Defined Place
GIS	Geographical Information Systems
GPS	Global Positioning System
H	Human experience of space
HTTP	Hypertext Transfer Protocol
LDW	Linked Data Web
LO	Located object
NLP	Natural Language Processing
OGC	Open Geospatial Consortium
OS	Ordnance Survey, a digital mapping agency for the UK
OSM	Open Street Map
OWL	Web Ontology Language
PGIS	Participatory GIS
PL	Places' Locations
PN	Place Notion
QPM-QGIS	Qualitative Place Model for Qualitative GIS
QSR	Qualitative Spatial Reasoning
QSRR	Qualitative Spatial Representation and Reasoning
RCC	Region Connection Calculus
RDF	Resource Description Framework
relLoc	Relative Location Model

RO	Reference Object
RP	Relative Place
SemRelLoc	Semantic Relative Location model
SG	Significances
SP	Singular Place
SPARQ	Spatial Reasoning done Qualitatively (A toolbox for QSR in applications)
SPARQL	SPARQL Protocol and Query Language
TP	Time of perception
URI	Unified Resource Identifiers
URL	Uniform Resource Locators
VGI	Volunteered Geographic Information
W3C	World Wide Web Consortium
XML	Extensible Markup Language

Chapter 1

Introduction

1.1. Overview and Research Context

Place names and qualitative spatial relationships are more cognitively available to users than geographic coordinates of place location, and are therefore more commonly used by users when describing place location. When referring to a geographic place, individuals are not usually able to provide information on the precise location, shape or boundaries of geographic places. They use relative locations that are not necessarily complete, but sufficient to describe the location in the context of use. Depending on the scale of the object's references, different types and meanings of spatial relationships are used. For example, in front of the cinema, at the corner of two streets, and by the bus station are examples of relationships used at micro scales of representation, while inside Cardiff, near the city centre and north of London are examples of larger scales of representation.

The concept of Naive Geography has strongly emerged over recent years, to "captures and reflects the way people think and reason about geographic space and time, both consciously and subconsciously" [1]. Naïve geography advocates incorporating people's perceptions of the geographic world into GISs by enabling qualitative representation and reasoning of this sort of information, thereby making it accessible and negotiable for normal users. Naive Geography is not seen as replacing quantitative methods, but rather as complementary approaches applied when appropriate.

With a proliferation of geographic referencing (geo-tagging) made available on the Web, maps are used as placeholders for personal data, resources and for communication and searching on the Web. The Linked Data Web (LDW) is an evolution of the traditional Web from a global information space of linked documents, to one where both documents and data are linked. A significant amount of mostly qualitative place information is currently being published on this LDW. These are used in turn to define the location of other types of datasets. However, the types of geographic analysis and retrieval functions available to users on the LDW, and on the Web in general, are very limited compared to what is offered by traditional Geographical Information Systems (GIS). This is in part due to the nature of geographic data and the manipulation expected by users, where data on geographic places may be incomplete, with fuzzy or inaccurate representations of location, and the data may also contain errors.

On the other hand, GIS are sophisticated systems that support the representation and manipulation of a detailed geometrical representation of geospatial data, but which cannot cope with incomplete, fuzzy or qualitative representations of place location [2]. Extending GIS through qualitative models of manipulation has been an area of research interest for many years [3], and many works have studied the problems of qualitative spatial representation and reasoning [4]; the representation of fuzzy spatial knowledge [5], and understanding spatial language [6].

Mixed-methods research has also recently emerged, advocating the case for qualitative GIS [7] in the domain of social geography. Here, the integration of qualitative research and GIS analysis functions is needed for the study and interpretation of qualitative geographic data, presented in the form of surveys, interviews and observations. Conventional GIS do not handle the representation and manipulation of this sort of information.

This thesis considers the problem of qualitative representation and manipulation of place information in GIS and on the LDW. On the LDW, quantitative representation of place location, if available, is normally limited to a single point coordinate, while reference to place location is commonly made by statements of qualitative location expressions. GIS, on the other hand, support models of detailed geometrical representation of place location and boundaries.

In this work, a qualitative model of place location is proposed that will:

a) Harness the limited representation location on the LDW to offer a basis for complete unique location representation and reasoning.
b) Provide a basis for mapping a qualitative definition of place location in GIS.

1.2. Motivation

Qualitative place model for the LDW:

One of the 'Linked Data Principles' is to include links to connect the data to allow the discovery of related things. However, identifying links between data items remains a considerable challenge that needs to be addressed [8, 9, 10]. A key research task in this respect is identity resolution, that is, the ability to recognise when two things denoted by two Unified Resource Identifiers (URI) are the same and when they are not. Automatic linking can easily create inadequate links, and manual linking is often too time consuming [11].

Geo-referencing data on the LDW has the potential to address this problem [12], as links can be inferred between data items by tracing their spatial (and temporal) footprints. For example, the BBC uses Resource Description Framework (RDF) [13] place gazetteers as an anchor to relate information on weather, travel and local news [14]. Yet, for geospatial linked data to serve its purpose, links within and amongst the geographic RDF resources need themselves to be resolved. This is to allow place resources to be uniquely identified, so that a place description in one dataset can be matched to another describing the same place in a different dataset. A scheme that allows such links between place resources to be discovered would be a valuable step towards the realisation of the LDW as a whole.

However, several challenges need to be addressed, namely: 1) Location representation of RDF place resources is simple; defined as point coordinates in some resources; defined by extended geometries in others, and sometimes missing all together. 2) Coordinates of locations may not match exactly across data sources, where volunteered data mapped by individuals is mashed up with authoritative map datasets. 3) Non-standardised vocabularies for expressing relative location are used in most datasets, for example, in DBpedia, properties such as dbp:location, dbp-ont:region and dbp-ont:principalarea are used to indicate that the subject place lies inside the object place.

A linked place model on the LDW is needed to allow for the description of unique place location profiles that can be used homogeneously with different types of place resources, and to support qualitative spatial reasoning over place resources.

Qualitative Place Model for GIS:

What distinguishes quantitative spatial data is the means that are available for collecting, organising and analysing this data, and the ability to perform much more manipulation than the qualitative data can. However, in terms of interrogating the data, qualitative data is often much richer and deeper. The author is not comparing between the two forms here, but highlighting the importance of facilitating the use of GIS to deal with qualitative data to elevate the research capabilities of analysing and manipulating such data.

Attempts at qualitative research have been made to perceive and explicate people's experiences of socio-spatial trajectories [7]. Recently, the need to mix qualitative data, resulting from qualitative research and GIS, has emerged to allow for the triangulation and interpretation of this data [15]. Two common strategies are used; the first strategy relies on utilising conventional GIS capabilities for geo-referencing the qualitative data to perform visual analysis, such as the work by Pavlovskaya [16] and Matthews et al [17]. The second strategy relies on adapting GIS to support the spatial representation of qualitative data in a more sophisticated way, for mapping and benefiting from the spatial analytical capabilities of the GIS, to fully interrogate the data. In some cases, extending GIS can be done using some methods of qualitative analysis to achieve both analytical capabilities. On the other hand, in NLP (natural language processing), quantifying spatial prepositions based on the context of use, and modelling the vagueness of their footprints, are the methods typically used to represent natural language in a computational environment.

Several challenges need to be addressed, namely: 1) the notion of 'place' is not materialised in a GIS environment in a systematic way, where efforts have generally dealt with specific cases or scenarios, and some of them are oriented toward supporting modes of analysis from qualitative research (i.e. coding), with less emphasis on geo-referencing qualitative data. 2) Facilitating the definition of place in a GIS environment for non-expert users, as the process shown in the methods examined is often iterative, involving digitising procedures, evaluation and validation during several phases before producing the final GIS representation; it also requires preparation and a level of technical knowledge, which might be problematic for non-expert users. 3) The diversity of descriptions of places' locations that people use is extremely wide-ranging, and this is the case for many different languages, scales and contexts.

A qualitative place model for GIS is needed to produce a definition of the concept of place within a GIS, and to allow the inputting of qualitative expressions of place location, before implementing the treatment of this concept in the GIS in a homogeneous fashion for the treatment of layers and regions, and non-spatial attributes.

The same conceptual model proposed for place definition on the LDW is used for qualitative definition of place in the GIS. Both rely on the qualitative spatial definition of place location. On the LDW, the model is augmented with spatial reasoning methods, while in the GIS application; the model is integrated with embedded quantitative spatial manipulation techniques of the GIS.

1.3. Research Hypothesis

Location is a key identifier of place, and it can be represented both quantitatively and qualitatively. Developing a qualitative model of place location will allow for the effective representation and manipulation of place concepts on the LDW, where quantitative location data are not accessible. In addition, the qualitative modelling of place location will facilitate the definition and manipulation of place in GIS, when no precise quantitative representation of location is available or needed.

1.4. Objectives

1) Identify and study the challenges associated with representing place information on the LDW.
2) Design and develop a qualitative model of place to enable the effective representation of place information on the LDW.
3) Measure the effectiveness of the proposed model for representing different types of place information on the LDW, using realistic data sets.
4) Demonstrate the effectiveness of the proposed model for supporting the retrieval of place information on the LDW, using realistic data sets.
5) Design and implement a qualitative model of place for GIS.
6) Measure the effectiveness of the proposed model for representing the notion of neighbourhood in GIS.
7) Evaluate the effectiveness of the proposed model for representing and manipulating the concept of neighbourhood using realistic case study scenarios.

1.5. Methodology

In the LDW section:

A study of the representation of place location on the LDW was initially undertaken to understand the challenges of the representation. Realistic sample data sets from different data sources have been downloaded and used, where approaches to qualitative spatial representation and reasoning have guided the proposal of a qualitative model of place location. The model was then applied to sample data sets.

The quality of the model has been measured against its effectiveness in the unique representation of place location, and for the extent of coverage of spatial information it is able to provide. Specific semantics of place resources, in particular the significance of the place resource, has been used to adapt the proposed model in order to enhance its effectiveness further. The quality of the model has then been demonstrated by considering the type of information that can be retrieved automatically from the information space.

In the GIS section:

A study of the representation of place in GIS environment was undertaken first, according to two strands of investigation: reviewing the available methods to model place using a mixed-method research approach, and investigating the definition of place as a concept in the literature. This led to identifying the requirements of the project, and forming a general qualitative place model that defines place as a complex entity comprising spatial aspects and qualitative characteristics. The diversity of qualitative expressions of place location, and the importance of the context has been used to specify the qualitative expressions of place location, and this has guided the focus when examining the data from a realistic case study from social geography. Analysing the data (i.e. interviews and side by side with the sketches) has helped to articulate prototypical qualitative expressions of place location within a neighbourhood context. The quality and effectiveness of the model has been validated using an implementation-driven approach. Here, the model has been implemented in a GIS and demonstrated through the case study presented. A user-centric approach to development has been adopted, as users were involved throughout the design, development and evaluation stages.

A proof of concept approach is adopted in the implementation aspects of this project to demonstrate the viability of the methods proposed and to primarily test the conceptual design of the proposed models. Hence, issues of effectiveness and scalability of implemented systems are identified, but are considered to be out of scope of the current thesis.

1.6. Contributions

The main contributions of the research are as follows:

1) The development of a qualitative model of place for the LDW that allows for the unique representation of place resources, and that forms an effective basis for the application of qualitative spatial reasoning.
2) The demonstration of the flexibility of the proposed model, in particular, by considering place type as a variable in the development of the model.
3) The design and implementation of a qualitative place model for GIS.
4) The demonstration of the effectiveness of the model for representing the notion of neighbourhood in GIS.

1.7. Thesis Organisation

The thesis is divided into eight chapters. This chapter has introduced the subject, the motivation for the research, and its scope, hypothesis, objectives, and research methodology and research contributions. The rest of the thesis is organised as follows:

Chapter Two presents the background knowledge and investigates related work on areas related to the topic of the research, such as Linked Data Web technologies, RDF and SPARQL query language. It also includes a discussion of some examples of spatial linked datasets, and focuses on DBpedia, as this is the source used in some of the experimental work in this research. Furthermore, discussions around representing, manipulating and querying RDF place resources on the LDW, including an overview of Volunteered Geographic Information (VGI) and Authoritative Geographic Information (AGI), are set out. Qualitative Spatial Representation and Reasoning (QSRR) has also been reviewed. The chapter concludes by presenting the notion of Qualitative GIS and mixed-method research, including the methods used for mapping/modelling qualitative definitions of place location, and examples of the methods used to quantify spatial language.

Chapter Three presents the proposed Computational Model of Place on the Linked Data Web, that is, the Relative Location Model (*RelLoc*). It provides an explanation and discussion of the model, including how it originated, and how the qualitative spatial reasoning of the model can be applied. It then proposes a further adaptation of the model (*SemRelLoc*) to include semantic aspects of place definition. It also evaluates the application of the models proposed, that is, the basic *RelLoc* model and the *SemRelLoc* model, using two different realistic datasets.

Chapter Four explains the utility of the *RelLoc* model through one possible application to support answering types of spatial queries that contain qualitative spatial relationship constraints. The capacity of the model to successfully prepare the data to answer these types of spatial queries is presented, and various query plans that can be answered are explained. In this chapter, the RelLoc model has been slightly modified to allow the selective application of spatial reasoning.

Chapter Five presents the proposed Qualitative Place Model for Qualitative GIS (QPM-QGIS). It explains and discusses the development of the model, and reviews conceptual models of place as a social and an ontological construct. It also presents an investigation into a realistic mixed-method case study from social geography research, and discusses how the requirements for modelling and mapping place location involved in this domain have been identified. This includes an explanation and discussion of how the prototypical qualitative spatial expressions that are needed to define locations within GIS have been derived.

Chapter Six describes the implementation of a prototype system. It demonstrates the application of the Qualitative Place Model for Qualitative GIS using a practical example. It discusses the implementation of the methodology, and presents an overview of the prototype system's structure and database design, followed by an explanation of the modules included for interpreting and delineating spatial expressions that describe place location. The chapter also includes examples to demonstrate the system's components for data input and retrieval, and manipulation operations.

Chapter Seven evaluates the Qualitative Place Model for the QGIS (QPM-QGIS). The chapter demonstrates the effectiveness of QPM-QGIS as a tool for modelling and manipulating place concepts in a GIS. It provides metrics for measuring the quality of the interpretation of the spatial expressions used to define the location of place through user-based evaluations. This is, firstly, by comparing an expert's own spatial interpretation of neighbourhood extents against those derived automatically from the system, and secondly, by interviewing an expert from the research team to gauge his views on the utility of the proposed representation and the implementation of the framework. A demonstration of the different types of operations that can be carried out on the neighbourhood profiles is also provided.

Chapter Eight provides a review of the way in which the aforementioned research objectives have been addressed, and compiles and summarises the conclusions from the work as a whole, discussing the practical implications of the research and its achievements, and highlighting the potential for extending those achievements in the future.

1.8. Summary

Naive Geography advocates a new generation of GISs that aims to incorporate common-sense reasoning about geographic space and time in a way that mimics human's expression, thinking and reasoning about the geographic world. A valuable and significant amount of mostly qualitative geographic information is currently being published on the LDW. However, the types of geographic analysis and retrieval functions available to users on the LDW are very limited compared to what is offered by traditional Geographical Information Systems (GIS). On the other hand, GIS supports the representation and manipulation of a detailed geometrical representation of geospatial data, but it cannot cope with incomplete, fuzzy or qualitative representations of place location. The motivation and contribution of this thesis along those two research areas have been presented. The objectives were summarised and a plan of presentation of the work done in the rest of the thesis has been outlined.

Chapter 2

Literature Review

2.1. Introduction

Chapter One described how this thesis is centred around modelling place qualitatively in two areas of research, that is, GIS and the Linked Data Web (LDW). This chapter presents a range of background knowledge on the fields related to the subject area, and aspects related to each field. Since place as a notion is a focal point of this research, this chapter starts with a general definition of the concept, before presenting the methods used for representing a place's location, with the main focus on qualitative expression of place location, in addition to an overview of the methods used for quantifying spatial language.

The focus then turns to the first research area to provide background knowledge on the LDW, including its technologies, such as RDF, URI and SPARQL query language, along with some examples. Next, place resources on the LDW are examined, including methods used for representation, manipulation and query RDF place resources. Qualitative Spatial Reasoning and Representation (QSRR) forms part of the work, therefore an outline of QSRR with examples of existing Qualitative Spatial Reasoning (QSR) engine tools (including the one that has been used in this project) is presented.

The focus then turns to the second research area, which is the qualitative place model for GIS. In this part, the notion of Qualitative GIS, as well as its relationship with mixed-methods research is presented. This includes the general types of data collected and analysed in this sort of research. The concept of neighbourhood is explained, and the use of mixed-methods to study neighbourhood, focusing on methods for mapping/modelling neighbourhood in GIS.

According to each section described above, the chapter concludes by identifying the gaps in the literature that have motivated the work in this research.

2.2. Geographic Place

Place is an important concept for a large body of scientific disciplines, practitioners and policymakers. It plays a fundamental role in human geography and urban planning (e.g. [18, 19]); criminology (e.g. [20, 21]), and health (e.g. [22, 23]). Jeff Malpas [24], a philosopher, suggests that "place is perhaps the key term for interdisciplinary research in the arts, humanities and social science in the twenty-first century". Thus, place as a concept is a complicated notion and does not solely imply a definition of spatial aspects; therefore, it is also not the property of geography as a discipline. According to Cresswell [2], place is a broader concept that is commonly utilised and roams quite freely across many disciplines. It is of significance due to linking humans with their environment [25].

Place and space concepts are seen as a continuum of geographic viewpoints that has two extremes, and ranges from the particular and the experiential, to the abstract and the global [26, 27, 28].

It starts by associating geography with human existence, experiences and interaction [29], and at the other extreme, it is a more neutral, objective and absolute view of space such as geometry [30] (see Figure 2.1).

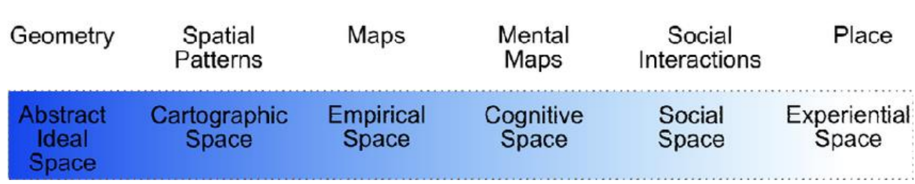


Figure 2.1. The space–place continuum [28]

Reconciling the two extremes of this continuum is a challenge [31, 32] and, therefore, it has been addressed within different research domains. In human geographic traditions, place plays a fundamental role (e.g. [33]), whereas space on the other hand dominates, in particular, GIS and spatial analysis [34, 35, 36].

Place can be conceptually modelled as a social construct, reflecting people's experiences of space and the meanings that are imposed upon this space [37]. It can also be conceptually modelled as an ontological construct describing place location [38]. The political geographer John Agnew has drawn up three essential aspects of place as a “meaningful location” [39]. He suggests that a place is an expressive spot that combines location, locale and sense of place. Cresswell [33, 2], in his book ‘Place’, explains the meaning of these three aspects. The location indicates the ‘where’ of place, that is, the position on the earth’s surface according to a particular set of coordinates and measurable dimensions from other locations. Locale denotes the way a place looks; it refers to the physical settings for social relations, including all visible and perceptible aspects of the surroundings, such as shops, streets or public spaces. A sense of place implies the subjective and sentimental correlation that people have with a place.

The concept of Naive Geography [1] has received much attention recently, including advocating incorporating the concepts and methods people use to deduce information about geographic space and time into GIS. It is the body of knowledge that people have about their surrounding spatial environment. Naive geography is also an area of research that tackles the formal models of the intuitive geographic world. Naive Geography is envisioned to form the basic principles through which the future generation of GIS can be developed in order to capture and reflect human intuition, and therefore be made accessible to a wider range of users (e.g. non-experts and average users) to solve everyday tasks.

Over the last four decades, many aspects of Naive Geography have been considered, but in a piecemeal manner, and it has not been tackled comprehensively. Egenhofer and Mark [1] emphasise that to realise Naive Geography, common-sense reasoning about geographic space and time are a fundamental aspect, and qualitative reasoning methods need to be materialised. This is important for handling partial spatial information, or when only incomplete data sets are to hand. Naive Geography is not envisaged as being a replacement to quantitative methods, but complementary approaches applied as and when required. Thus, the integration of quantitative information into qualitative reasoning is also needed.

2.2.1. Representing Place Location

Place location can be represented qualitatively and quantitatively. It can be defined as an exact position, in the form of GPS coordinates (e.g., 51°29′N 3°11′W), or using natural language descriptions. People are usually not able to provide information on the precise location, shape or boundaries of geographic places; however, they use relative locations, which is not necessarily complete, but sufficient for describing location in the context of use. People may refer to locations by places' names, such as 'Cardiff University', or by associating different references with spatial relationships explicitly, such as 'in front of the cinema', or implicitly: 'Hilton, Cardiff' implying the Hilton hotel in Cardiff. 'In front of the cinema' is a directional relationship with the place, while 'Hilton, Cardiff' has a topological relationship that implies hierarchy. People can also refer to location by providing relatively exact descriptions of locations, for example, by stating an address, for example, 'the place is at 5 High St., near Liberty Square', or pin point it on a map.

Qualitative Expression of Place Location

When describing place location, people more commonly use place names and qualitative spatial relationships. These relationships come in many forms, that is, proximity relationships such as "near", directional relationships such as "in front of" or "north of", and topologic relationships such as "inside". The qualitative nature of these relationships resists geometric interpretation, yet people rarely use metrics to quantify these relationships [40].

For directional spatial relationships, the three reference systems that are utilised in natural language according to [42], terminology can involve intrinsic, relative, or absolute reference systems. An intrinsic reference system relies on the intrinsic direction of the reference entity to project the areas in ‘front of’, ’behind’, ’left of’ or ’right of’ the object. A relative reference frame is focused and oriented on an entity that is not the main entity in the relationship. Finally the absolute reference system, usually aligns the relationship in the cardinal directions independently, and does not rely on the orientation between the objects in the scene; see Figures (2.2) (2.3) and (2.4) respectively.

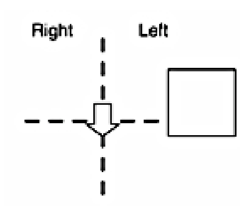


Figure 2.2 The square (i.e. located entity) is to the left of the arrow (i.e. reference entity); the arrow is the anchor of this relationship [43].

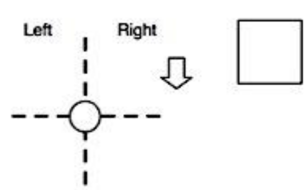


Figure 2.3 The square (i.e. located entity) is located to the right of the arrow, relative to the circle (i.e. the anchor), which is not directly involved in the spatial relationship [43].

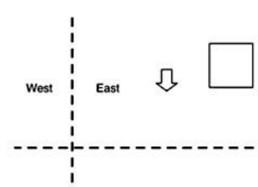


Figure 2.4 The absolute reference frame is independent from the entities in the scene and usually based on the cardinal directions. The square (the located object) is east of the arrow [43].

In natural language, the qualitative spatial relationships (i.e. directional, proximal and topological relationships) are implicitly contained in qualitative expressions of place location, and often encoded using spatial prepositions. There is enormous diversity in the qualitative spatial expressions that people use. The expressions may occur in many different languages (e.g. formal or vernacular), scales and contexts, and this includes people's definition of the environment around them, local searches, or route directions.

Quantifying Spatial Language

In the work of Winter, S. et al., [44], which is an exhaustive study of a project called "Talking About Place", a corpus of place descriptions are collected through a crowdsourcing technique using a bespoke mobile game to record answers to a specific question (e.g. "where are you?"). The project aimed at developing methods for automating the interpretation of descriptions of place locations within a particular context (e.g. receiving calls in an emergency command centre). A total of 2057 unique descriptions of place location were expressed by people within a period of seven months using only one language (namely, English), within a particular city (Melbourne, Australia). The results of the experiment are reported in Richter, D. et al., [45] who state that 93% of the descriptions collected indicate that participants reported their location using addresses, prominent features and spatial relations, and the remaining set included movement information and to some extent complex route descriptions. They also reported that the spatial relationships identified within the descriptions comprise distance (whether quantitative or qualitative); orientation (whether absolute, intrinsic or relative), and topological relationships. 45% of the descriptions contain hierarchical spatial relationships [44] (e.g. the following expression "University of Melbourne, Melbourne, Australia" denotes a hierarchical containment relationship between the places). This suggests that general spatial relationships (i.e. hierarchy, directional and proximal) most likely form the basis of the majority of the spatial descriptions found.

The scale of representation and the context of use may change the meaning of the prepositions. 'The glass can be "near" the computer', 'a person can be wandering "near" the river' and 'Newport is "near" Cardiff'. Although, all these expressions cover a wide range of scales (e.g. table level, ground level or city level) and contexts, they are valid uses of one preposition. Moreover, the boundary between prepositions is unclear, and this is part of the inherent vagueness of spatial language [46]. When a place can be considered 'near' a place, at what point does this place become 'next to' a place?

Hall, M.M, [43] investigated how spatial prepositions are used to describe locations of photographs in image caption contexts, and he has proposed a method for quantifying the spatial vagueness of a number of selected prepositions. In a data-mining experiment, a corpus of roughly 350,000 image captions was extracted from Flickr[1]. Hall found that around three quarters of the captions extracted described the images' locations, using only place names, while the remaining captions contained descriptions of locations using spatial prepositions.

In his work, Hall identified that 'at', 'near',' to', 'on', 'from', 'in', 'north', 'west', 'east' and 'south' are the most frequent prepositions and cardinal directions used. He also carried out two subsequent human-subject experiments in rural and urban environments to investigate how participants interpret spatial prepositions within the context of photographs' locations in different settings. In the rural experiment, Hall investigated the use of the preposition 'near' and the cardinal direction 'north of'; while in an urban experiment, six spatial prepositions were investigated (i.e. use of 'near', 'north of', 'next to', 'at', 'at the corner', and 'between').

Again, the context of use is crucial. The prepositions 'from', ' to', and 'on' are mostly utilised to describe routes and paths [43]. This spatial relationship may imply the meaning of a path-like spatial preposition (i.e. 'between'). One possible evident

[1] Flickr is a website and web services suite created in 2004 for images and videos hosting. For more information refer to https://www.flickr.com/

difference is that the prepositions ‘on’, ‘from’ and ‘to’ clearly identify the start and end points, and the location in between. While ‘between’ does not identify what the start point or the end points are. For example, the expression 'I usually walk between the Castle and the Capitol Shopping Centre’ is a relatively generalised form of the expression ‘I usually walk along Queen Street from the Castle to the Capitol Shopping Centre'.

Another example is the use of the preposition ‘at’, which is ambiguous in the English language (e.g. ‘I am at the Cafe’ may refer to being inside the Cafe having something to eat or drink, or being close to the Cafe waiting for someone). For further details of the preposition ‘at’ see Vasardani, M. et al, [47]. The ‘inside’ interpretation of the preposition ‘at’ can be replaced by a clear containment preposition (e.g. ‘in’ or ‘inside’), and being close to the Café can be replaced by the preposition ‘next to’.

Another study that has attempted to help in solving the problem of creating natural language within GIS is the work of Robinson [48, 49]. Robinson has focused on quantifying the vagueness of spatial relationships within the 'downtown' context by relying on unambiguously specifying the interpretation of spatial relationships by participants. He suggests a semi-automatic interactive method to ask participants a series of yes/no questions (e.g. 'is A near B?’) so that the meaning of the vagueness of the spatial relations concept will decrease.

Place information that is being collected on the LDW is also, in one way, quantitative, that is, involving place coordinates, and in the other parts qualitative, such as qualitative containment spatial relationships within other places. Prior to discussing the nature of representation and manipulation of place resources on the LDW, it is important to provide background information on the LDW, its importance, examples, and technologies used. The next section introduces this information.

2.3. Linked Data Web (LDW)

Linked Data Web (LDW) [50] or the linked data cloud is an evolution of the traditional Web from a global information space of linked documents to one where both documents and data are linked [51, 8]. On a conventional web, the documents are designed for human consumption [52], that is, they are organised as web pages interlinked by html links, and are identified using Uniform Resource Locators (URL) [53]. The LDW project is a structured representation of information that has the mechanisms that can enable data from different sources to be connected, and allow software applications to exchange and process information in a systematic way. For publishing linked data on the web, Tim Berners Lee [9] has summarised the following guidelines. They are also known as linked data principles [51]:

1) “Use URIs as names for things.”
2) “Use HTTP URIs so that people can look up those names.”
3) “When someone looks up a URI, provide useful information.”
4) “Include links to other URIs, so that they can discover more things.”

Thus, a set of technologies is required for storing and retrieving data; for example, XML (Extensible Markup Language)[2], RDF and SPARQL.

RDF is part of the World Wide Web Consortium (W3C) recommendations[3]. It is a data representation model utilised to encode data on the Linked Data cloud [13, 54]. It uses statements to describe facts about real-world entities, and is constructed as triplets of <subject, predicate, object> [55]. The subject is an entity that is uniquely identified by a URI, has predicate(s) describing the object(s) that in turn has/have value(s) (object(s)). The object’s value might be an absolute value such as a string; the name of the capital city of a country or number; the latitude, or it might be another subject (i.e. URI). For example, Table 2.1 shows two RDF statements about Cardiff, Wales. The first statement in the table states that the point represents the location geometry of Cardiff (the entity being described). The second statement points out that Cardiff is part of Wales. For a detailed explanation of the RDF model see [56].

2 https://www.w3.org/XML/
3 http://www.w3.org/

Table 2.1: Two RDFs describe facts about Cardiff; the value in the first RDF is pair of coordinates (i.e. numbers), the second value is another subject entity (i.e. has a URI).

Subject	Predicate (Properties)	Object (Value)
dbpedia:Cardiff	geo:geometry	POINT(-3.1833333969116 51.483333587646)
dbpedia:Cardiff	dbo:isPartOf	dbr:Wales

SPARQL [57] stands for SPARQL protocol and query language, and is part of the World Wide Web Consortium (W3C) recommendations. It is one of the key technologies that enables the retrieval and manipulation of data stored in RDF format. The following example shows a SPARQL query to answer the question: What is the postal code of Cardiff?

Line 1. PREFIX dbpedia: <http://dbpedia.org/resource/>

Line 2. PREFIX dbpo: <http://dbpedia.org/ontology/>

Line 3. SELECT ?o

Line 4. WHERE {dbpedia:Cardiff dbp:postalCode ?o.}

The first two lines denote the name of the spaces used in the query. The “SELECT” clause in line 3 identifies the variables that will appear in the query results. In line four, the clause “WHERE” provides the basic graph pattern to be searched for in a triple form <subject, predicate, object>. The results can also be filtered using the filter function provided.

2.3.1. Place Resources on the LDW

Sources of geographic data on the LDW are either volunteered (crowd sourced) resources, henceforth denoted Volunteered Geographic Information (VGI), created by individuals with only informal procedures for validating the content, or authoritative resources produced by mapping organisations, henceforth denoted Authoritative Geographic Information (AGI). Examples of VGIs are DBpedia, GeoNames, and Open Street Maps (linkedgeodata.org) [58], and examples of AGIs are the Ordnance Survey linked data [59] and the Spanish linked data [60]. Data collected from users on the

Social Web, for example on Twitter and Foursquare, can also be considered VGIs [61, 8].

The volume of VGI resources is increasing steadily, providing a wealth of information on geographic places, and creating detailed maps of the world. DBpedia contains hundreds of thousands of place entities, whose locations are represented as point geometry. GeoNames is a gazetteer that collects both spatial and thematic information for various place names around the world. In both datasets, place location is represented by single point coordinates. While DBpedia does not enforce any constraints on the definition of place location (e.g., coordinates may be missing in place resources), reference to some relative spatial relationships, and in particular to represent containment within a geographic region, is normally maintained. A detailed analysis of the spatial data content of DBpedia can be found in [62, 63]. GeoNames places are also interlinked with each other by defining associated parent places.

In [64], the LinkedGeoData effort is described, where Open Street Map (OSM) data is transformed into RDF and made available on the Web. The data is represented using a relatively simple data model that captures the underlying geometry of the features. It comprises three basic types, nodes (representing points on Earth with longitude and latitude values), ways (ordered sequences of nodes that form a polyline or a polygon) and relations (groupings of multiple nodes and/or ways). Furthermore, [65] presents the methods used to determine links between map features in OSM and equivalent instances documented in DBpedia, as well as between OSM and Geonames. Their matching is based on a combination of the Jaro-Winkler string distance between the text of the respective place names, and the geographic distance between the entities. Example of other work on linking geodata on the Semantic Web is [66], which employs the Hausdorff distance to establish similarity between spatially extensive linear or polygonal features.

DBpedia consists of RDF triples extracted from the "infoboxes" commonly seen on the right hand side of Wikipedia articles. Wikipedia contains over 1,000,000 georeferenced articles, and the DBpedia knowledge base, which has been created by extracting structured information from Wikipedia, currently describes more than 3.4

million things, of which at least 413,000 are places (including 310,000 populated places) [67].

Geonames is a web-based gazetteer that combines information from web users with other more formal and available sources of geographic information from national mapping agencies. It contains around eight million geographical names, of which there are 2.6 million populated places. Other examples of geographic resources include LinkedGeodata project [68], which transforms data from Open Street Map (OSM) project into RDF on the LDW. The following is an RDF triple extract of place names and their locations from Geonames and DBpedia[4]:

GeoNames - Cardiff University

```
<gns:Feature> <RDFNS#about> <http://sws.geonames.org/6697669/>
<http://sws.geonames.org/6697669/> <gns:Name>
<Cardiff University Queens Buildings>
<http://sws.geonames.org/6697669/> <gns:FeatureClass>
        <http://www.geonames.org/ontology#P.PPL>
<http://sws.geonames.org/6697669/>                    <wgs84_pos:lat>
<51.483^^XMLSchema:float>
<http://sws.geonames.org/6697669/>        <wgs84_pos:long>        <-
3.16^^XMLSchema:float>
```

DBpedia - Cardiff

```
<http://dbpedia.org/resource/Cardiff> <wgs84_pos:lat>
   <"51.4852777778"^^http://www.w3.org/2001/XMLSchema#float>
<http://dbpedia.org/resource/Cardiff> <wgs84_pos:long>
   <"-3.18666666667"^^http://www.w3.org/2001/XMLSchema#float>
```

Both Geonames and DBpedia use light-weight ontologies to model place concepts and properties. Geonames classifies geographic entities into nine general groups (called schemes), then further sub-classifies those groups into features. A feature is associated with a point geometry, a name, and a type, from a geographical feature type

[4] {where gns= http://www.geonames.org/ ontology#, dbns =http://dbpedia.org/resource/#, wgs84_pos = http://www.w3.org/2003/01/geo/wgs84_pos# and RDFNS: http://www.w3.org/1999/02/22-rdf-syntax-ns}.

taxonomy, for example, one scheme refers to different types of populated places, another to streams and lakes and another to roads and railroads. The ontology allows the definition of two kinds of spatial relationships between features, namely, parentFeature and nearby.

The parentFeature property is used to encode the containment administrative hierarchy, while the nearby property encodes the nearest feature. The neighbour property is currently used only for features of type of country to identify neighbouring countries. In addition, features are also associated with semantic properties, such as population for a feature of type populated place, or height for the feature type of mountain.

In DBpedia, a class hierarchy is used to describe a place type taxonomy, for example, place, building, hospital, populated_place, municipality and town. Location is defined as a property whose range is a populated_place and is used to associate a geographic entity of the type of place to its contained place. A place can be, but not always, associated with point geometry. Table 2.1 shows an example of the containment relationship, while the following RDF statement is an example that indicates a directional relationship: *<dbpedia:Cardiff; dbpprop:east; dbpedia:Bristol_Channel>*, which means that *Bristol Channel is located in the east direction from Cardiff*.

[69] examined the nature of spatial relationships encoded in 3500 RDF place resources in DBpedia. The data set is made up of all RDFs, in that both subjects and objects are types of place and are located in Wales, and of course, the predicates represent the relationships between them. The result of the analysis shows that there are four types of spatial relationships: directional, containment, external connections and partially overlapping. However, less than 1% of the data reflects directional relationships; less than 0.5% of the data reflects partially overlapping relationships; around 1.3% of the data reflects external connections between line features, and the vast majority of the data, which is more than 97%, reflects containment relationships. However, even though the containment relationships seem to be valuable, they also have some limitations. The hierarchical relationship between places is not always consistent, thus a direct relationship with a place's parent is not recognised. If the

direct parent relationship for each place is maintained, this can be used as a basis for inferring the hierarchal relationship and reason for them.

A common feature among these data resources, as well as most other LDW resources, is the rather limited spatial representation of geographic features, as well as geo-referenced articles as points. A city, a country, a road or a building, for example, are all represented as points. This flattening of the scale's dimension has direct implications for any spatial analysis that can be carried out using it. Also, points are only an approximation of the location and can be inaccurate.

In contrast to VGI resources that manage geographic resources as points (represented by a coordinate of latitude and longitude), AGI resources deal with more complex geometries as well, such as line strings. AGIs tend to utilise well-defined standards and ontologies for representing geographic features and geometries. Efforts have been exerted by Ordnance Survey (OS) to make various geographical datasets available online as RDF triples [11]. Ordnance Survey linked data demonstrates the use of qualitative spatial relations to describe the spatial relationships in its datasets. Two ontologies, the Geometry Ontology and the Spatial Relations Ontology, are used to provide geospatial vocabulary. These ontologies describe abstract geometries and topological relationships (equivalent to RCC8 [70]) respectively.

Some OS products have already been transformed into RDF and are published as open data, for example, the administrative regions for Great Britain extracted from the OS Boundary Lines. The OS also provides a set of ontologies to describe abstract geometries and spatial relationships that are used for modelling some of the data they provide on the LDW [71].

In summary, the spatial representation of place resources in VGI datasets is generally limited to point representation, and is managed within simple ontologies that encode non-spatial semantics and, in some cases, limited spatial relationships. On the other hand, place data provided as AGI tend to present more structured and detailed spatial representations, but is also limited to specific types and scales of representation.

To overcome this limitation, qualitative spatial relationships are used to describe the location. In particular, an explicit containment hierarchy, relating a place to its parent place, is normally maintained, where parent places are instances of populated places. In addition, proximity and cardinal directions are also used to describe neighbouring places and their relative position.

Use of some qualitative spatial relationships has been demonstrated for capturing the spatial structure in some example datasets. The model proposed in this work offers a systematic and homogenous representation of place location that can be consistently applied to VGIs or AGIs, and demonstrates the value of heterogenous qualitative spatial relationships in representing place information on the LDW.

2.3.2. Manipulating and Querying RDF place resources on the LDW

Recently, much work has been done on extending RDF to represent geospatial information, through defining and utilising appropriate vocabularies encoded in ontologies to represent space and time. The work capitalises on specification of standards, defined by the Open Geospatial Consortium (OGC) [72], for modelling core concepts related to geospatial data. Prominent examples are GeoSPARQL, an OGC standard [73] and stRDF/stSPARQL [74]. Both proposals provide vocabulary (classes, properties, and functions) that can be used in RDF graphs, and SPARQL queries to represent and query geospatial data, for example geo:SpatialObject, which contains everything that can have a spatial representation, and geo:Geometry as the superclass of all geometry classes. In addition, geometric functions and topological functions are offered for performing computations, such as geof:distance, and for asserting topological relations between spatial objects, for example dbpedia:Cardiff geo:sfWithin dbpedia:Wales.

Qualitative spatial representation and reasoning (QSRR) are established areas of research [41, 75], whose results have influenced the definition of models of spatial relationships in international standards, for example, OGC models, and commercial spatial database systems (e.g. the Oracle DB system). RCC8, a QSRR model, has recently been adopted by GeoSPARQL [73], and there is ever-increasing interest in coupling QSR techniques with the Linked Geospatial Data that are constantly being made available [74]. On the other hand, LDW reasoning engines have been extended to support qualitative spatial relations, for example, Racerpro [76] and PelletSpatial [77]. The scalability of spatial reasoning is a recognised and reported challenge. Scalable implementations of constraint network algorithms for qualitative and quantitative spatial constraints are needed, as RDF stores supporting Linked Geospatial Data are expected to scale to billions of triples [74]. Lately, promising results have been reported by [78], who proposed an approach for removing redundancy in RCC8 networks, and by [79], who examined graph-partitioning techniques as a method for coping with large networks; in both cases leading to a more effective application of spatial reasoning mechanisms. Finally, qualitative methods have been used to complement existing quantitative methods to represent the geometry of spatial locations. In [80], heterogeneous reasoning methods are proposed, which combine calls between a spatial database system and a spatial reasoning engine implemented in OWL2[5] RL, to check the consistency of place ontologies. In [63], Younis et al described query plans that make use of a combination of qualitative spatial relationships associated with place resources in DBpedia, and detailed representations of geometry maintained in a spatially indexed database for answering complex queries.

Using hybrid query methods, [62] combines high quality detailed representations of geometry form OS OpenData with quantitative and qualitative spatial data encoded in RDF predicates of DBpedia. She combined the DBpedia geometric data and OS data to compute containment and proximity relationships. Besides that, she combined the quantitative geo-spatial methods with qualitative containment RDF predicates of DBpedia to enhance answering containment queries. To support answering directional queries, she created quantitative models of the qualitative spatial directional RDF predicates of DBpedia.

[5] OWL 2 (Web Ontology Language): is an ontology language for the Semantic Web with formally defined meaning. It provides classes, properties, individuals, and data values and stored as Semantic Web documents. For further detail see http://www.w3.org/TR/owl2-overview/

In both of the above cases, qualitative reasoning was limited by the fragmented and scarce availability of spatial relationships to work on. The qualitative scheme of representation of place location proposed in this work addresses this issue, and provides a novel method for defining spatial relationships that is designed to support and facilitate the effective use of qualitative spatial reasoning on the LDW. The next section presents the background knowledge related to the field of Qualitative Spatial Reasoning.

2.3.3. Qualitative Spatial Representation and Reasoning

A large body of research has been undertaken over the past decade in the field of qualitative spatial representation and reasoning (QSRR), with the aim of deriving compositions of spatial relationships between different objects in space. They are methods for reasoning about space and spatial relationships without resorting to computational geometry. Several works have studied the representation of different types of spatial relationships, and complete and sound sets of relationships have been reported for different types of simple geometric shapes. [4] provide a detailed survey of the field.

Widely accepted formalisms for qualitative spatial representation include a mathematical approach based on the 9-intersection model [81] and logic-based approach, stemming from parallel research efforts in the AI community, resulting in the Region Connection Calculus (RCC). In practice, RCC and the 9-intersection model produce an identical set of eight (jointly exhaustive and pair wise disjoint JEPD) relations between two regions, albeit using different relationship terminology. Of the two models, the 9-intersection has the more intuitive and commonly used terminology that is adopted in GIS and spatial databases [82]. Approaches to the representation of other types of qualitative spatial relationships, namely, size, proximity and directional relationships, have also been pursued [83].

SPARQS is an example of a QSR engine tool has been innovated by [84] for the automatic extraction of implicit qualitative spatial relationships to complement quantitative approaches in large spatial databases. It has been implemented to demonstrate the validity of a new approach to the automatic derivation of composition tables, for representing and reasoning over arbitrarily shaped objects in space. The spatial reasoning toolbox SparQ [85] is another example that has been developed to bring qualitative reasoning closer to applications. It provides the ability to connect quantitative and qualitative information, constraint-based qualitative reasoning, and analysing qualitative calculi, to help in developing new calculi. It also allows users to specify their own calculi or take advantage of the existing calculi provided by the toolbox. The SparQ has been used in the experimental works described in this thesis.

2.4. Mixed-Methods Research and Qualitative GIS

Quantitative methods are types of closed-ended information that can be measured using instruments, or collected through a structured format of interviews and/or observations [86]. Quantitative methods provide information that is numerical and can be reduced to aggregated information [87], and then made available for statistical analysis [86]. On the other hand, qualitative methods fall into four major forms of open-ended qualitative data, that is, observations, interviews, documents, and audio-visual material [88].

According to Creswell, J. W. [86]:

> "Mixed-method study is one in which the researcher incorporates both qualitative and quantitative methods of data collection and analysis in a single study."

Geographical Information Systems (GIS) are sophisticated systems that support the representation and manipulation of geographic information, represented in quantitative formats. Extending GIS with qualitative models of representation and manipulation has been an area of research interest for many years [3]. Attempts at qualitative research have been made to perceive and explicate people's experiences of socio-spatial trajectories [7]. The need to mix qualitative data presented in the form of surveys, interviews, sketch maps and mental maps, resulting from qualitative research and GIS, has emerged to allow for the triangulation and interpretation of this data [15].

In the field of social geography, mixed-methods research has recently emerged, and many researchers in this domain advocate the case for qualitative GIS. For example, Cieri [89]: mapping waypoints; Kwan and Lee [90]: 3D GIS geo-visualisation of human activity patterns: Winchester [7]: examining changing schools; Matthews et al. [17]: Geo-ethnography; McLafferty S, [91]: women and GIS; Pain et al. [92]: Qualifying GIS and the effect of street lighting on crime and fear; Kwan and Ding [15]: the geo-narrative approach, and Jung [93]: the imagined grid approach.

The basic idea behind Qualitative GIS is the integration of various forms of knowledge, and findings from different techniques, which is at the heart of mixed methods research. This integrative method of building strong interpretations in research is what has positioned qualitative GIS within a mixed methods approach. The following section provides an explanation of the mixed-methods used to study neighbourhood.

2.5. Using Mixed-Methods to Study Neighbourhood

Goodchild [25] asserts that the term 'place' is commonly used in the sense of belonging to a community or neighbourhood, implicitly denoting an informal relationship between the individual and the place of residence. Neighbourhood denotes a sort of complex relationship between the physical aspect of ‘place’ and the significances that are associated with it. According to Agnew [39] and Cresswell [2], a place is an expressive location that combines spatial aspects (i.e. position and physical settings) and a sense of place. However, in the case of neighbourhood, the perception of spatial aspects is likely to be specific to the individual and dependent on the time of perception, and is perhaps inherently ambiguous for others [25].

Neighbourhoods can be categorised according to multiple hierarchical levels [94]. One possible classification noted by Suttles [95], and adapted by Kearns and Parkinson [96] and Lupton [97], is that neighbourhoods can be perceived on three levels:

1. The home area, which has a psycho-socio purpose, promotes belonging and trust, and represents the person's values and building relations with others
2. The locality, which is the place of residential activities
3. The urban district or region, which provides a wider landscape of social and economic opportunities

As stated above, the perception of neighbourhood is conceptual, but it is also dynamic, as the definition of this type of place is inherently changeable. Neighbourhood is envisaged according to the individuals who live or work in it, and this may change according to the type of neighbourhood and time of perception. Thus, a person might have his or her own definition of neighbourhood at a given time, which might differ from his or her perception at another time. This individualistic perception is applicable to all the spatial components that make up the definition of neighbourhood, namely, its boundary and its constituent place components. Thus, for an individual, multiple instances of neighbourhoods can be used to define his or her association with place over time, as shown in Figure 2.5.

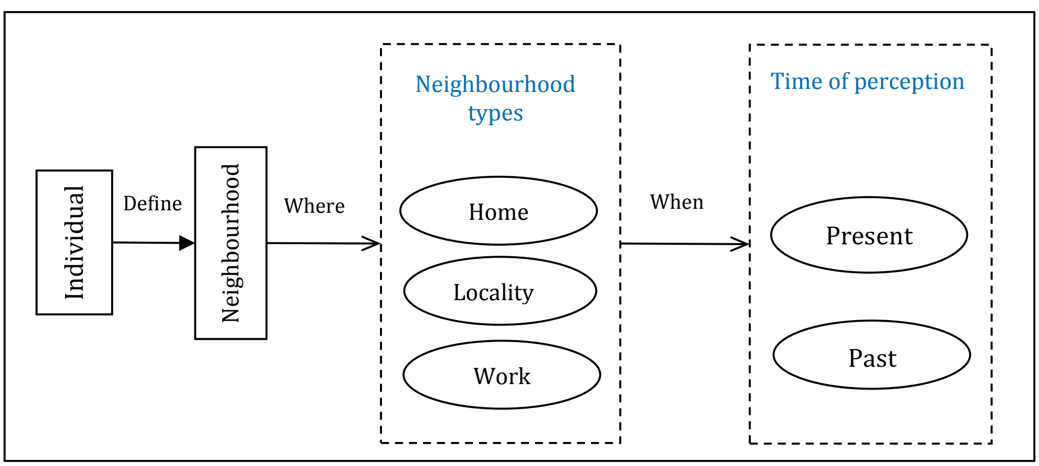


Figure 2.5 The constituents of neighbourhood definition and the links between them

The significance of the use of neighbourhood as a geographical unit for measuring the impact of several factors on people's lives is evident in a wide range of research [98, 99, 100]. To name a few examples, the work of Osgood and Anderson [101], and Silver and Miller [102], examined the impact of neighourhood on delinquent behaviour, and Ainsworth [103] studied the effects of neighbourhoods on educational achievement. Others studied its impact on low birth weight [104]; on depression, Ross et al. [105], and on childhood development, Goldfeld et al. [106]. However, the conceptualisation of the concept of neighbourhood remains a challenge [107].

Methods for modelling and mapping neighbourhoods can broadly be classified into those that: a) use existing administrative divisions as a backdrop on which to delineate the neighbourhood boundaries and b) those that strive to closely map the perception of individuals' definitions of the extent of neighbourhood within a participatory GIS.

Exploiting readily available geographic datasets (e.g. enumeration district or postcode datasets) is a useful generic approach to mapping neighbourhoods [108], that may be used when no precise boundary data can be derived. However, this approach can fail to capture socially meaningful definitions of the neighbourhood, to people who seldom associate their perception of place with hard-defined map boundaries [97, 23]. The next sections demonstrate various approaches used to map people's perceptions.

2.5.1. Participatory GIS

Participatory GIS (PGIS) was the earliest attempt at representing qualitative data in GIS. This method allows respondents to directly demarcate their neighbourhood themselves using a mapping system. In fact, this pioneering approach has motivated many subsequent studies that have attempted to represent people's perceptions within a participatory research framework [109]. Harris et al [110], for example, examined how respondents' diverse perceptions can be outlined in sketches, and then how these drawings can be transformed into quantitative form within GIS to assist studies and public policy formation. This kind of qualitative GIS research has been promoted and spread due to its value within research, as, in some cases, it complements the knowledge acquired, or it verifies the results of studies using multiple data sources [15].

Two common strategies are used by researchers to incorporate qualitative spatial information into GIS by themselves: The first approach, denoted the homogeneous approach, relies on the geo-visualisation capability of the current GIS (e.g., [16, 17]) for representing the qualitative data to perform visual analysis, such as visual comparisons, or some simple spatial analysis. The second strategy, denoted the hybrid approach, relies on extending or adapting conventional GIS to support the spatial representation of qualitative data, often by splitting the representation of the data between more than one system.

2.5.2. Homogeneous Approaches to Qualitative GIS

In this approach, the GIS is used for both mapping place information, as well as for some limited qualitative analysis. Cieri [89], for example, collected qualitative data on spaces in a city that respondents identified as important social sites, and she also collected the GPS waypoints for these locations. These points were then plotted on conventional GIS before hyperlinking the participants' narratives to these locations (see Fig 2.6).

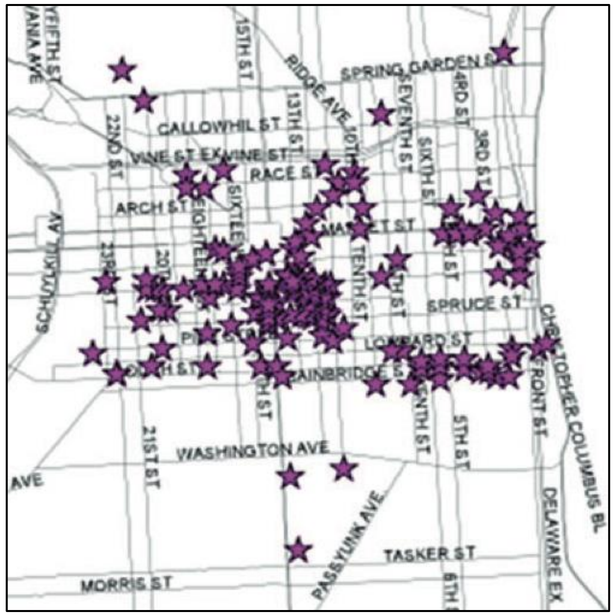


Figure 2.6 Places of interest to respondents, which have been mapped and noted using conventional GIS [89].

Similarly, the work of Burgess, et al. [23] has included carrying out participatory mapping exercises to map respondents' local knowledge of their neighbourhood to explore social cohesion. In this study, by using Google Earth[6], the hand sketches of the respondents were transformed into quantitative geometric forms on a mapping system to see how each respondent defined the boundary of his/her neighbourhood.

The process is often iterative, involving digitising procedures, evaluation, and validation during several phases, before producing the final GIS representation. In addition, the process requires preparation and a level of technical knowledge, which might be problematic for non-expert users.

Kwan and Ding [15] proposed a geo-narrative approach, where a GIS was extended by implementing a place model that represents space and its relevant characteristics using 3D GIS-based time-geographic methods to geo-visualise the movements of people through time and space(see Figure 2.7). The extension, which was implemented in ArcGIS using Visual Basic[7], enabled some qualitative analysis methods

6 https://www.google.com/earth/
7 Visual Basic is a programming language provided by Microsoft, was used to customise ArcGIS.

to be carried out, that is, coding the data and inductive analysis of individuals' narratives and biographies.

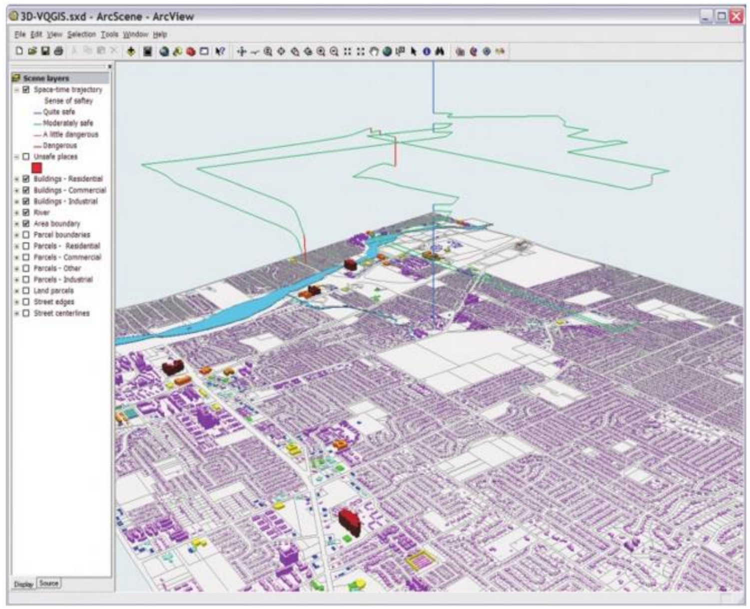


Figure 2.7 The life path of a respondent [15]; the line in the 3D scene represents the route and sequence of places that the respondent has visited, while the expressed meanings are indicated through the colour variation

Modelling place location in this work focuses on showing the respondents' life paths by representing significances (i.e. emotions evoked by places and activities carried out), the time dimension according to specific dates or times of the day, and visited locations. The approach represents movements in space and time, and human factors and significances; however, it deals with very specific research cases, and was primarily developed to support modes of analysis from qualitative research (i.e. narrative analysis).

In addition to the aforementioned limitations the above approaches mostly deal with specific cases or scenarios, and do not provide general methods for realising the notion of neighbourhood in a GIS environment in a systematic way.

2.5.3. Hybrid Approaches to Qualitative GIS

In this approach, the GIS is used for spatial data presentation and analysis, and is integrated using a different system for specialised qualitative data analysis.

Jung [93], proposed a system, namely CAQ-GIS, whereby both Computer-Assisted Qualitative Data Analysis Software (CAQDAS) and GIS are used to explore, code, and analyse data simultaneously (see Figure 2.8). The data model in the GIS was modified to enable the storage of qualitative data and interpretive codes. A separate layer, denoted the 'Imagined Grid', was created in the GIS to locate and display qualitative data for geo-visualisation purposes and to enable its geo-referencing.

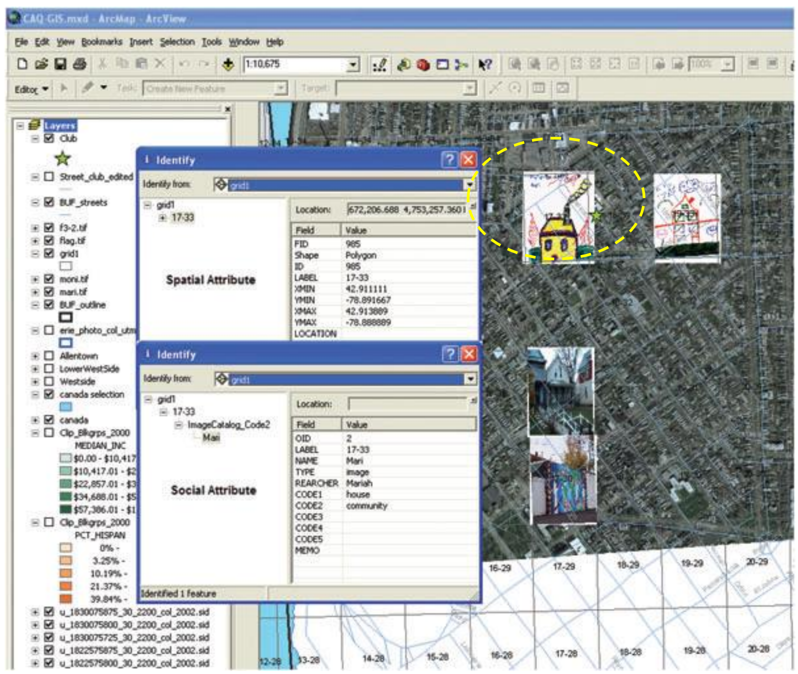


Figure 2.8 Retrieving data from the Imagined Grid and the Hybrid Relational Database [111]

The aim was to analyse respondents' definitions (i.e. children) and meanings of 'community' to identify a common definition of 'community', and to identify the material spaces that the children recognised as important to their community. The hybrid relational database that was created to link the qualitative data and codes with GIS is shown in Figure 2.9.

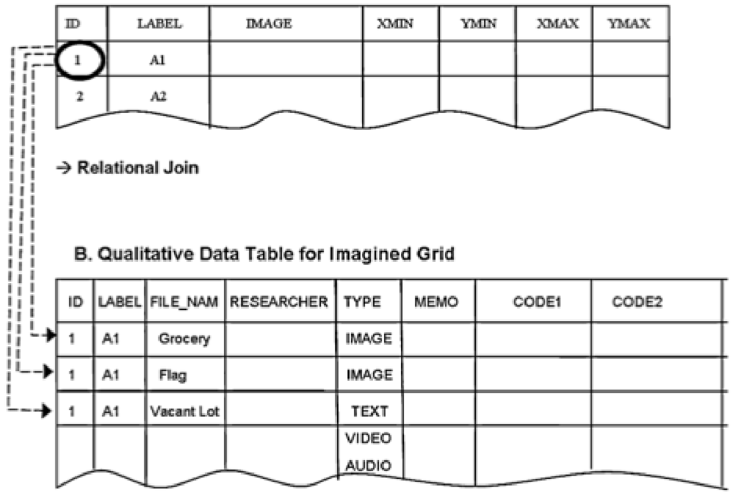


Figure 2.9 Hybrid relational database linking GIS with qualitative data [111]

Jung and Elwood [111] admit the redundancy involved in coding data and storing it in two systems, which may create problems in maintaining consistency. In addition, it might be necessary during any long-term qualitative research effort to revisit and re-code specific data, as new ideas or patterns emerge.

The approach is primarily oriented toward supporting modes of analysis from qualitative research (i.e. coding), with less emphasis on geo-referencing qualitative data.

2.6. Literature Gap Analysis

Many researchers have studied the notion of place, and there is consensus that 'place' is a complex notion and does not solely imply a definition of spatial aspects. Many studies have relied mainly on modelling the concept of place as a social construct, reflecting people's experiences of place location, and this comprises modelling the human actors, time of perception, significances and spatial aspects. Other studies have relied on defining it as an ontological construct describing place location.

Representing a combination of the two definitions would provide a more complete representation of place in GIS. This point is also in agreement with several studies [39, 33, 2] that suggest that a place is an expressive site that combines location, locale (i.e.

ontological construct; settings) and a sense of place (i.e. time of perception and significances related to individuals). This is also in agreement with the notion of Naive Geography, which advocates materialising common-sense reasoning about geographic space and time in a way that mimics the way people express, think and reason about the geographic world.

This work will consider qualitative modelling of place from two different but related contexts. Firstly, a qualitative place model in GIS will be studied to generate a definition of the concept of place in GIS. The main focus here is the automatic generation of place location definition from qualitative expressions of locations provided by humans and represented within a GIS. Secondly, a qualitative place model on the LDW will be designed to capture a uniform representation of place location using the quantitative representation of location available.

So far, previous research works have examined the problem of extending GIS using qualitative models of place from the point of view of enabling the GIS to perceive and explicate people's experiences of socio-spatial trajectories [7] (i.e. individualised perceptions of place location and its qualitative characteristics). In doing so, there is a need to map qualitative place data presented in the form of surveys, interviews, sketch maps and mental maps, resulting from the qualitative research on GIS [15].

Most studies have relied mainly on utilising existing administrative divisions (e.g. enumeration districts or postcode datasets) as a backdrop on which to delineate the place location (e.g. community or neighbourhood boundaries). This is a useful generic approach to mapping place [108], which may be used when no precise boundary data can be derived. However, this approach may fail to capture socially meaningful definitions of the place from people who seldom associate their perception of place with hard-defined map boundaries.

Other studies have strived to closely map the perception of individuals' definitions of place location within a participatory GIS, and these attempts can be categorised into two common strategies. The first strategy, known as the hybrid approach, relies on extending or adapting conventional GIS to support the spatial representation of qualitative data, often by splitting the representation of the data between GIS and another system; for example, the work by Jung [93], in which both Computer-Assisted Qualitative Data Analysis Software (CAQDAS) and GIS are used to explore, code, and analyse data simultaneously. However, as [111] admits, there is some redundancy involved in coding data and storing it on two systems, which may create problems in maintaining consistency.

This approach is primarily oriented toward supporting modes of analysis from qualitative research (e.g. coding), with less emphasis on geo-referencing qualitative data, which results in a primitive representation of place location on a GIS.

The second strategy, known as the homogeneous approach, relies on the geo-visualisation capability of the current GIS (e.g., [16, 17]) for representing the qualitative data to perform visual analysis, such as visual comparisons, or some simple spatial analysis. In this approach, the GIS is used to define place location, as well as for some limited qualitative analysis, such as the work by Pavlovskaya [16] and Matthews et al [17].

However, these efforts have used simple point representation for geo-referencing qualitative data, and in many cases this is not sufficient enough to model personalised definition of place location, such as in the case of mapping a community or neighbourhood, where in some cases spatial analysis is needed, such as finding the intersections between places' footprints. Other research has involved participatory mapping exercises to map people's local knowledge about their places, such as the work of Burgess, et al. [23], to see how each respondent defines the boundary of his/her neighbourhood.

Nonetheless, the process is often iterative, involving digitising procedures, evaluation, and validation during several phases, before producing the final GIS representation. In addition, the process requires preparation and a level of technical knowledge, which might be problematic for non-expert users. Also, in most of these studies, the mapping procedure usually does not maintain a fixed measurement for the delineation of a place footprint. For example, projecting the footprint of spatial relationships such as locations 'in front of' a place or 'behind' a place may vary from one respondent to another, and therefore the delineation, retrieval and manipulation may not be performed in a systematic and constant manner.

These approaches mostly deal with specific cases or scenarios, and do not provide general methods for realising the notion of place in a GIS environment. Therefore, there is a gap in representing people's perceptions of place (i.e. defining personalised spatio-temporal aspects and associating qualitative characteristics) in a GIS in a systematic way. Thus, there is a need to enable GIS to carry out the automatic interpretation of respondents' descriptions of place location, to facilitate its use by non-expert users, and to model the concept of place.

The LDW is considered a valuable place resource, and a significant amount of mostly qualitative geographic information is currently being published. These are used in turn to define the location of other types of datasets. However, the types of spatial analysis and retrieval functions available to users on the LDW are very limited compared to what is offered by traditional Geographical Information Systems (GIS). This is in part due to the nature of geographic data and the manipulation expected by users, where data on geographic places may be incomplete, with fuzzy or inaccurate representations of location, and the data may also contain errors.

One of the LDW principles is to include links to connect the data to allow the discovery of related things. However, identifying links between data items remains a considerable challenge that needs to be addressed [8, 9, 10]. A key research task in this respect is identity resolution, that is, the ability to recognise when two things denoted by two URI are the same and when they are not. Automatic linking can easily create inadequate links, and manual linking is often too time consuming.

Thus, there is a need to improve and find mechanisms that can enable data from different sources to be connected, and allow software applications to exchange and process information in a systematic way. Geo-referencing data on the LDW can address this problem [12], as links can be inferred between data items by tracing their spatial (and temporal) footprints.

However, a common feature among most LDW resources is the rather limited spatial representation of geographic features, as well as geo-referenced articles as points. A city, a country, a road or a building, for example, are all represented as points. This flattening of the scale's dimension has direct implications for any spatial analysis that can be carried out using it. Moreover, it is managed within simple ontologies that encode non-spatial semantics and, in some cases, limited spatial relationships. Other place resources tend to present more structured and detailed spatial representations, but are also limited to specific types and scales of representation.

Thus, there is a need to qualitatively describe place location. In particular, an explicit containment hierarchy, and relating a place to its parent place, as it is normally maintained, in addition to using the proximity and cardinal direction relationships to describe neighbouring places. This will allow unique qualitative place descriptions to be created, and will therefore allow the application of QSR to qualitatively reason and infer links between place resources.

2.7. Discussion

The work presented in this thesis targets qualitative place modelling in GIS and in LDW: A qualitative place model to generate a definition of the concept of place in GIS, focusing on the definition of place location from qualitative expressions of locations to attain a quantitative definition, and a qualitative place model on the LDW to serve the definition of place location from the quantitative representation available to enable qualitative representation. According to the literature, there are some gaps that need to be addressed:

There is a need to model the concept of place in GIS:

There is a need to have a generic approach to representing people's perceptions of place (i.e. defining personalised spatio-temporal aspects and associating qualitative characteristics) in GIS in a systematic way.

There is a need to represent qualitative description of place location in GIS:

There is a need to extend the GIS to allow the inputting of people's descriptions of place location and to carry out automatic interpretation of these descriptions (i.e. from qualitative form to geometry), thereby facilitating the use of the GIS by non-expert users.

There is a need to qualify place resources on the LDW:

There is a need to define place location uniquely to allow the realisation of the spatial aspects of the place concept (defining the location and the locale), and this will be based on the definition of the qualitative spatial relationships (i.e. hierarchy, proximity and directional relationships) of a place according to the direct parent and neighbouring places.

There is a need to spatially link place resources on the LDW:

There is a need to spatially link place resources on the LDW to allow the tracing of spatial footprints and to satisfy the requirements of the application of Qualitative Spatial Reasoning (QSR) over place resources to infer links.

Chapter 3

Linked Model of Place for the LDW

3.1. Introduction

In this chapter, a computational qualitative model of place for the Linked Data that enforces an ordered representation of relative spatial relationships between places is proposed. The development of the model involves; a conceptual model to capture a qualitative representation of the spatial structure of place location to create unique place location profiles. These profiles allow place information to be linked spatially and to be explored more fully and more consistently than what is currently possible on the LDW. This is tested by the application of qualitative spatial reasoning over the model to check the completeness of the place location profile. The chapter describes the model and presents the experimental results, which demonstrate the effectiveness of the model for realistic examples of geospatial RDF resources. A proof of concept implementation of the proposed model is developed and used to illustrate the quality of the proposed approach.

3.2. Problem statement

One of the 'Linked Data Principles' involves including links to connect the data in order to allow for the discovery of related things. However, identifying links between data items remains a considerable challenge that needs to be addressed [9, 10, 8]. A key research task in this respect is identity resolution, that is, to recognise when two things denoted by two URIs are the same and when they are not. Automatic linking can easily create inadequate links, and manual linking is often too time consuming [11]. Geo-referencing data on the LDW can address this problem [12], as links can be inferred between data items by tracing their spatial (and temporal) footprints. For example, the BBC uses RDF place gazetteers as an anchor to relate information on weather, travel and local news [14].

Yet for geospatial linked data to serve its purpose, links within and amongst the geographic RDF resources need themselves to be resolved. This is to allow place resources to be uniquely identified so that a place description in one dataset can be matched to another describing the same place in a different dataset. A scheme that allows such links between place resources to be discovered would be a valuable step towards the realisation of the LDW as a whole.

In this work, a unique place location profile is used as a key identifier for place resources, and the question that needs to be addressed is how location can be used to define a linked place model that can enable place resources to be uniquely identified on the LDW.

Several challenges need to be addressed, namely: 1) The location representation of RDF place resources is simple; defined as point coordinates in some resources, and detailed; defined using extended geometries in others, and sometimes missing altogether. 2) Coordinates of locations may not match exactly across data sources, where volunteered data mapped by individuals is mixed up with authoritative map datasets. 3) Non-standardised vocabularies for expressing relative location is used in most datasets, for example in DBpedia, properties such as dbp:location, dbp-ont:region and dbp-ont:principalarea are used to indicate that the subject place lies inside the object place.

To help address this problem, a linked place model is proposed that uses qualitative spatial relationships to describe unique place location profiles, as previously presented in [8]. The profiles do not rely on the provision of exact geometries, and hence can be used homogeneously with different types of place resources. They can be expressed as RDF statements and can thus be integrated directly into the resource descriptions. The rationale behind the choice of links to be modelled is primarily twofold: to allow for a sensible unique description of place location, and to support qualitative spatial reasoning over place resources.

The model has been further adapted to consider the semantic aspects of a place location definition. In particular, the notion of salience of place has been used to scope the type of relationships used in the location expressions in the defined place profiles. It has been shown how the proposed representation scheme is flexible, to allow for the encoding of relevant location expressions, whilst also retaining the power of spatial reasoning within the proposed framework.

The value of the linked place model has been illustrated by measuring its ability to make the underlying RDF graph of geographic place resources browsable. Samples of realistic geographic linked datasets have been used in the experiments presented, and the results demonstrate significant potential value from the methods proposed.

3.3. A Linked Place Model For The Linked Data Web

A Relative Location model (*RelLoc*) is proposed here to capture a qualitative representation of the spatial structure of place location. Two types of spatial relations have been used, which are as follows:

1) Containment relationships, to record that a parent place directly contains a child place; that is, one-step hierarchy. For example, for three places representing a district, a city and a country, the model will explicitly record the relationships: *inside (district, city)* and *inside (city, country)*, but not *inside (district, country)*.

2) Direction-proximity relationships, to record the relative direction location of its nearest neighbouring places for every place. The directional frame of reference can be selected as appropriate. For example, for a 4-cardinal direction frame of reference, a place will record its relative directional

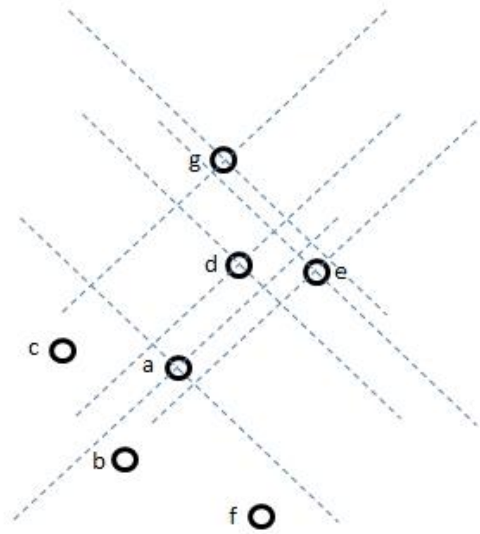
relationship with its nearest neighbour in four directions.

For a given set of places (*Pl*), let *DirPr* be the set of all direction-proximity relations between instances of places in *Pl,* as defined above, and let *Con* be the set of containment relations between instances of places in *Pl,* as defined above. Then, *RelLoc(Pl)* is defined as a tuple *RelLoc(P l): = (P l, D, C),* where: $D \in DirPr$ and $C \in Con.$ *Rnn(x, y)* is used to denote that *x* is the nearest neighbour from the direction *R* to object *y*. For example, $Nnn(pl_1,pl_2)$ indicates that pl_1 is the nearest neighbour from the north direction to pl_2, and so on. Note that it is possible for two or more objects to be equidistant from a certain direction to the reference place location, and thus either of them can be chosen to be the nearest neighbour in the model. Ultimately, this will not have an effect of the correctness of the modelled relations.

To illustrate the model, consider the scene in Figure 3.1, which consists of a set of places, *a* to *f*, with a 4-cardinal direction frame of reference overlaid for some places in the scenes. A representative point is used to define the place location. It is further known that places represented as points *a, b, c, e* are inside *d* and places *d, f* are inside *g*. The full set of relationships used to model the scene is given in the table in Figure 3.1(b). Note that in some cases, no relationship can be found, for example, there are no neighbours for object c in the westerly direction, as shown in Figure 3.1(a).

3.3.1. Spatial Reasoning with the Relative Location Model

Qualitative spatial reasoning (QSR) can be applied over the relative location model to infer more of the implicit spatial structure of place location. QSR tools can be utilised to propagate the defined relationships and derive new ones between places in the scene. QSR takes advantage of the transitive nature of the partial or total ordering of the quantity of space in order to infer new information from the raw information presented. In particular, the transitive nature of some spatial relationships can be used to directly infer spatial hierarchies, for example, containment and cardinal direction relationships.



(a)

Set of spatial relations to model relative location
Nnn (d, a), Snn (b, a), Wnn (c, a), Enn (e, a)
Nnn (g, d), Snn (a, d), Wnn (c, d), Enn (e, d)
Nnn (g, c), Snn (b, c), Enn (a, c)
Nnn (a, b), Enn (f, b)
Nnn (a, f), Wnn (b, f)
Nnn (g, e), Snn (b, e), Wnn (d, e)
Snn (d, g)
in (a, d), in (b, d), in (c, d), in (e, d),
in (d, g), in (f, g)

(b)

Figure 3.1 (a) An example map scene with a set of places represented as points (b) Set of direction, proximity and containment relations chosen to represent relative locations in the proposed model

The scope of the model is deliberately focused on general containment relationships, while ignoring other possible topological relationships, such as overlap or touch. Hence, building containment hierarchies are straightforward using the transitivity rules:

$$inside(a, b) \wedge inside(b, c) \rightarrow inside(a, c) \text{ and } contains(a, b) \wedge contains(b, c) \rightarrow contains(a, c)$$

In the case of directional relationships, more detailed spatial reasoning can be applied using composition tables. Table 3.I shows the composition table for a 4-cardinal direction frame of reference between point representations of spatial objects.

Table 3.1 Composition table for 4-cardinal direction relationships

	N	*E*	*S*	*W*
N	*N*	*N* ∨ *E*	*All*	*N* ∨ *W*
E	*N* ∨ *E*	*E*	*S* ∨ *E*	*All*
S	*All*	*S* ∨ *E*	*S*	*S* ∨ *W*
W	*W* ∨ *N*	*All*	*W* ∨ *S*	*W*

In considering the entries of the composition tables, some of those entries provide definite conclusions from the composition operation, that is, the composition result is only one relationship (emboldened in the table), and other entries are indefinite and result in a disjunctive set of possible relationships, for example, the composition:

$$N\ (a, b) \wedge E\ (b, c) \rightarrow N\ (a, c) \vee E\ (a, c)$$

Spatial reasoning can be applied to the linked place model using different strategies. The most straightforward is through deriving the algebraic closure, which means completing the scene by deriving all possible missing relationships between objects.

Table 3.2 Result of reasoning with cardinal relationships for the place model in Figure 3.1.

	a	b	c	d	e	f	g
a	-	**N**	**E**	**S**	*W*	**N**	*S*
b	**S**	-	**S**	*S*	**S**	**W**	*S*
c	**W**	*W*	-	**W**	W	*N* ∨ *W*	*S* ∨ *W*
d	**N**	*N*	*E*	-	**W**	*N*	**S**
e	**E**	*N*	*E*	**E**	-	*N*	*S*
f	*S*	**E**	*S* ∨ *E*	*S*	*S*	-	*S*
g	*N*	*N*	**N**	**N**	**N**	*N*	-

Path-consistency algorithms for deriving the algebraic closure have been implemented using various tools, for example in the SparQ spatial reasoning engine

[85]. Table 3.2 shows the results of this operation for the example scene in Figure 3.1. Explicit relationships are shown in bold and the remaining relationships are inferred by spatial reasoning. As can be seen in the table, using the 19 relationships defined for the model in Figure 3.1(b), reasoning made it possible to derive a further 19 definite relationships, completing over 90% of the possible relationships in the scene.

3.3.2. Applying the Relative Location Place Model on the LDW

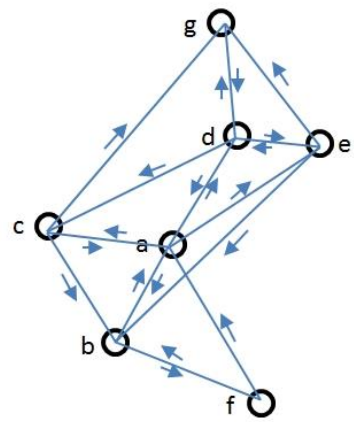
The underlying structure of any expression in RDF is a collection of triples, each consisting of a subject, a predicate and an object. A set of such triples is called an RDF graph, in which each triple is represented as a node-arc-node link, and each triple represents the statement of a relationship between the subjects and objects, denoted by the nodes, that it links. The meaning of an RDF graph is the conjunction (logical AND) of the statements corresponding to all the triples it contains.

The *RelLoc* place model can be interpreted as a simple connected graph with nodes representing place resources, and edges representing the spatial relationships between places. Thus, the realisation of the place model for a specific RDF document of place resources is a subgraph of the RDF graph of the document. The *RelLoc* RDF graph is completely defined if RDF statements are used to represent all spatial relationships defined in the model, for example for the scene in (Figure 3.1), 25 RDF statements are needed to encode the cardinal (19) and containment (6) relationships in the table in Figure 3.1(b).

Let *Pl* be a finite set of place class resources defined in an RDF data store and *DirPr(Pl)* defines the cardinal direction relationships between members of *Pl,* and *Con(Pl)* describes the containment relationships between members of *Pl* as defined by the relative location model above.

A *RelLoc* subgraph $G_L = (V_L, E_L)$ is a simple connected graph that models *Pl*, where: $V_L = Pl$ is the set of nodes, $E_L = \{DirPr(Pl) \cup Con(Pl)\}$ is the set of edges labelled with the corresponding direction and containment relationships.

Note that there exists a subgraph of G_L for every place $pl \in Pl$, which represents the subset of direction-proximity and containment relationships that completely define the relative location of *pl*. Thus, a location profile for a particular place $pl \in Pl$ can be defined as $L_{pl} = \{DirPr_{pl}, Con_{pl}\}$. L_{pl} is the restriction of L to *pl*, where $DirPr_{pl}$ and Con_{pl} defines direction proximity and containment relations respectively between *pl* and other places in *Pl*, as specified by the model.



(a)

	a	*b*	*c*	*d*	*e*	*f*	*g*
a	-	1	1	1	1	0	0
b	1	-	0	0	0	1	0
c	1	1	-	0	0	0	1
d	1	0	1	-	1	0	1
e	0	1	0	1	-	0	1
f	1	1	0	0	0	-	0
g	0	0	0	1	0	0	-

(b)

	a	*b*	*c*	*d*	*e*	*f*	*g*
a	-	*N*	*E*	*S*	0	*N*	0
b	*S*	-	*S*	0	*S*	*W*	0
c	*W*	0	-	*W*	0	0	0
d	*N*	0	0	-	*W*	0	*N*
e	*E*	0	0	*E*	-	0	0
f	0	*E*	0	0	0	-	0
g	0	0	*N*	*N*	*N*	0	-

(c)

Figure 3.2 (a) A graph representing the sample map scene from Figure 3.1. (b) Adjacency matrix for the location graph representing nearest neighbour relationships. (c) Adjacency-orientation matrix representing nearest neighbour and directional relationships.

For example, the location profile for place (a) in Figure 3.1 is the set of statements describing the relations:

$$N(d, a), S(b, a), W(c, a), E(e, a), in(a, d).$$

The *RelLoc* graph can be represented by a matrix to register the adjacency relationship between the place and its nearest neighbours. The scene in Figure 3.1 is shown as a graph with nodes and edges in Figure 3.2(a) and its corresponding adjacency matrix is shown in (b). The fact that two places are neighbours is represented by a value (1) in the matrix or by a value (0) otherwise. Values of (1) in the matrix can be replaced by the relative orientation relationship between the corresponding places, as shown in Figure 3.2(c) and the resulting structure is denoted *Adjacency-Orientation Matrix*.

3.3.3. A Semantic Place Model

So far, the *RelLoc* place model has considered distance and directional relationships as the primary factors for specifying place location. The importance of a place or its salience is another factor that is useful to consider. The salience of a place can be described from a personal or from an absolute point of view.

On a personal level, many factors can influence the importance of a place to an individual [112]. This includes: a) place dependence: how far the place satisfies the individual's behavioural goals as compared to other alternative (e.g., [113, 114]); b) place affect: reflecting the emotional or affective bond between an individual and a place (e.g., [114, 115]), and c) place social bonding: reflecting the importance of social relationships and the context within which they occur. The specific settings of the place share the meanings attributed to them by the individual's social environment (e.g., [116, 114]).

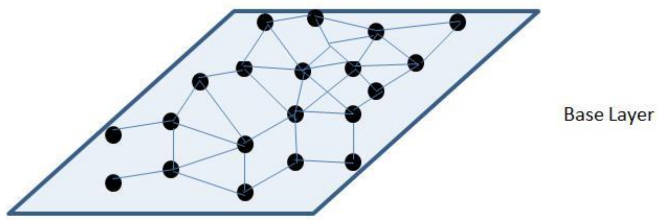
On an absolute level, the salience of a place can be defined as being irrelevant to the attachment to specific individuals. For example, Hall, Smart and Jones [117] consider salience to be a factor in defining the place location when devising methods for automatic caption generation for images (or photographs). In their work, the equation that determines the set of relative places to choose from in a particular image caption is a combination of an equal number of "ways" (highways, roads, paths, ⋯) and other places, ordered by their relative salience. A salience value is, in turn, a measure of how close the location of a place is to the image (i.e., its distance from the image), and its popularity (i.e., how well known the place is). The latter factor can be derived automatically from the Web, for example from the counts of place mentions on Flickr, Wikipedia and web pages [43].

The basic *RelLoc* place model can be adapted to handle different possible semantics of place, such as place type, activities carried out in a place, or place salience. The adapted model will henceforth be denoted Semantic Relative Location model, or *SemRelLoc*. Hence, in *SemRelLoc*, a layer of salient places (i.e. landmarks in the surrounding area) is first extracted from the base map layer, and this acts as the anchor for the place location definition. Thus, the algorithm for defining the relative location model is applied between: a) all places in the salient feature layer, and b) every place in the remaining set of places in the base map layer and the salient place layer only.

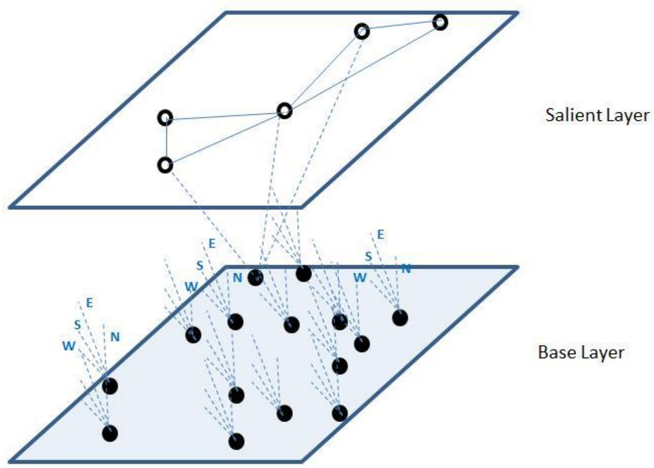
Considering the schematic map examples in Figure 3.3: (a) places on the map are not distinguished by any specific property, and relationships between them are defined using *RelLoc*. In (b), a salient place layer is filtered out and used as a basis for the *SemRelLoc* model. The selection of places in this layer can be chosen to serve the application in context, for example, as a selection of particular place types, or specific place instances with high popularity, or even those of relevance to a particular individual. Note that in (b) spatial relationships are defined only with reference to the salient place instances, and no relationships are defined amongst the remaining places on the base map layer, as will be described below.

Let *SalientPl* be a finite set of place resources defined as a subset of all places *Pl* in an RDF data store, and $\overline{SalientPl}$ be the rest of places remaining on the base layer (i.e., {Pl\SalientPl}.

A semantic relative location *SemRelLoc* subgraph $G_L = (V_L, E_L)$ is a simple connected graph that models *Pl*, where: $V_L = SalientPl$ is the set of nodes, $E_L = \{DirPr(SalientPl)\ U\ DirPr(\overline{SalientPl})\ U\ Con(Pl)\}$ is the set of edges labelled with the corresponding direction and containment relationships. *DirPr(SalientPl)* is the set of direction-proximity relationships between places on the salient feature layer. $DirPr(\overline{SalientPl})$ is the set of direction-proximity relationships between the rest of the places on the base layer and the places on the salient layer. Hence, no interrelationships are defined between places on the base layer itself.



(a)



(b)

Figure 3.3 (a) Schematic of a sample base map layer (b) Salient place layer filtered out

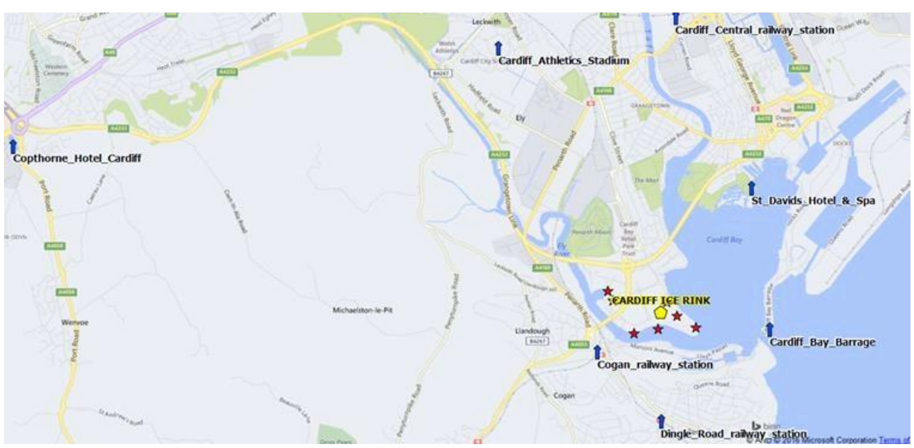
Note that there exists a subgraph of G_L for every place $pl \in Pl$, which represents the subset of direction-proximity and containment relationships that completely define the relative location of *pl*. Thus, a semantic location profile for a particular place $pl \in Pl$ can be defined as follows:

$$L_{pl} = \begin{cases} \{DirPr_{SalientPl}, Con_{pl}\} & , if\ pl \in\ Salientpl \\ \{DirPr_{\overline{SalientPl}}, Con_{pl}\} & , \forall pl \in\ \overline{Salientpl} \end{cases}$$

Figure 3.4(a) shows a section of the Cardiff Bay area in Cardiff, Wales. A set of places is shown around the place: 'Cardiff Ice Rink'. Figure 3.4(a) shows the set of places chosen to describe the location with the original *RelLoc* model, while in 3.4(b) a set of some selected salient features (hotels, museums, railway stations, etc.) around the place are shown. These are used to describe the location using *SemRelLoc*. Table 3.3 lists the set of location expressions defined by both models. While both are topologically correct, the location expressions of the *SemRelLoc* model can be considered more meaningful and useful for general contexts.

SemRelLoc offers two potential advantages over *RelLoc*: a) more meaningful place location expressions, using selected relevant place instances, and b) potentially a more economical data model to manage and reason with.

(a)



(b)

Figure 3.4 Sample map scene with places defining the location of “Cardiff Ice Rink”: a) with *RelLoc* model, and b) with *SemRelLoc*

Table 3.3 Location expressions defining the place ”Cardiff Ice Rink” in both the RelLoc and SemRelLoc models

RelLoc Model

Wharf Disused N Cardiff Ice Rink
Slipway NE Cardiff Ice Rink
BT Data Centre Cardiff Bay E Cardiff Ice Rink
Watkiss Way SE Cardiff Ice Rink
Planet Ice Cardiff Arena SW Cardiff Ice Rink
Weighbridge W Cardiff Ice Rink
Cardiff Bay Yacht Club NW Cardiff Ice Rink

SemRelLoc Model

Dingle Road railway station N Cardiff Ice Rink
Cogan railway station NE Cardiff Ice Rink
Copthorne Hotel Cardiff E Cardiff Ice Rink
Cardiff Athletics Stadium SE Cardiff Ice Rink
Cardiff Central railway station S Cardiff Ice Rink
St. Davids Hotel and Spa SW Cardiff Ice Rink
Cardiff Bay Barrage W Cardiff Ice Rink

The number of predefined relationships remains constant, as every place will have a set of statements defining its proximity and direction relationships. However, spatial reasoning with the semantic location graph can be more efficient with the reduction of the variety of modelled edges between places. In the following section, the effectiveness of spatial reasoning with *SemRelLoc* will be compared against the basic *RelLoc* model.

3.4. Application and Evaluation

The main goal of the Linked Place model is to provide a representation of place location on the LDW that allows place information to be linked effectively and consistently. The effectiveness of the proposed model can be evaluated with respect to two main aspects: firstly, whether it provides a sound definition of place location to test the correctness of the place location profiles; secondly, whether it provides a complete definition of place location, that is, whether a complete relative location graph can be derived using the individual place location profiles.

The soundness of the location profiles is assumed, as it essentially relies on the validity of the computation of the spatial relationships. Issues related to the complexity of this process are discussed in the next section.

Here, the completeness aspect of the model will be evaluated. An individual place location profile defined using the model represents a finite set of spatial relationships between a place and its nearest neighbours and direct parent. The completeness of the model can be defined as the degree to which these individual profiles can be used to derive implicit links between places not defined by the model. The model is entirely complete if a full set of links between places can be derived using automatic spatial reasoning, that is, the model can produce a complete graph if there is a defined spatial relationship between every place in the dataset and every other place.

A system has been developed that implements the Linked Place model and further builds an enriched model using spatial reasoning for evaluation purposes, as shown in Figure 3.5. The process starts by collecting all the RDF place resources in a scene. The RelLoc model is then applied to construct a Linked Place Model for the scene that is then processed using QSR to infer qualitative spatial links between all place resources in the scene.

Although similar, in the case of the Enriched Linked Place Model (i.e. SemRelLoc), there are some differences. The RDF place resources are split into two layers: a layer of salient places acting as the anchor for the rest of the places, and a layer for other places. Thus, in the place model construction phase, the algorithm for defining the relative location model is applied between: a) all places in the salient feature layer only to produce all the place profiles that contain direction-proximity relationships between the salient features; and b) all other places in the remaining set on the base map layer and the salient place layer to produce all the profiles that contain direction-proximity relationships between the remaining set of places and salient features. Once the Enriched Linked Place Model has been constructed, only the place resources resulting from the salient features are processed using QSR to infer the links between them.

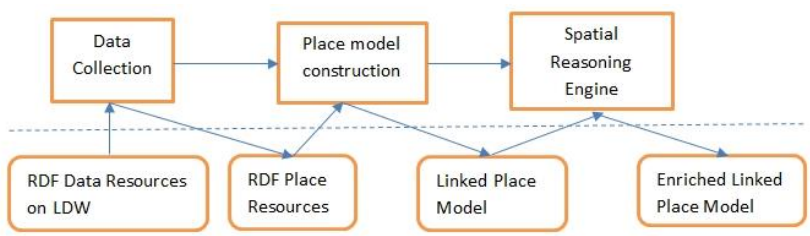


Figure 3.5 Components of the developed system used to implement the linked place model

3.4.1. Evaluation of the Relative Location Place Model

Two datasets were used in this experiment, DBpedia [67] and the Ordnance Survey open data (i.e. Boundary-Line data set) [118]. These were chosen as they exhibit different representations of place resources on the LDW and are typical of VGIs and AGIs respectively. A description of the datasets used is presented below, along with the results of the application of spatial reasoning over the constructed linked place models.

DBpedia Dataset

A sample dataset containing all places in Wales, UK, has been downloaded from DBpedia using the SPARQL [57] query in Figure 3.6. A total of 489 places were used, for which a relative location graph of 2751 direction-proximity relations was constructed. Completing the graph resulted in 116403 relationships, out of which 50340 relations are definite (defining only one possible relationship).

```
prefix d: <http://dbpedia.org/ontology/>
prefix :<http://dbpedia.org/resource/>
prefix prop: <http://dbpedia.org/property/>
prefix geo: <http://www.w3.org/2003/01/geo/wgs84_pos#>

select ?place  (MAX(?lat) as ?lat)(MAX(?long) as ?long)
where{
?place ?ontology ?resource.
?place a d:Place.
?place geo:lat ?lat.
?place geo:long ?long.
filter ( ?resource = :Wales or ?resource = "Wales"@en )
}
group by ?place
order by ?place
```

Figure 3.6 SparQL query used to extract place data from DBpedia

Note that some of the indefinite relationships involve a disjunction of two relationships, for example, {*N, NW*} or {*E, SE*} and some are a disjunction of three relationships, for example, {*N, NE, NW*} or {*NE, E, SE*}. In both cases, relationships can be generalised to a "coarser" directional relationship, for example {*NE, E, SE*} can be generalised to a general East relationship. These results are considered useful and have therefore been filtered out in the presentation. The remaining results are disjunctions of unrelated directions, for example {*N, NE, E*}, and are thus considered to be ambiguous. A summary of the results is shown in Table 3.4. Using the Linked Place Model it is possible to describe nearly half of the possible relationships precisely (45.6%), as well as nearly all of the rest of the scene (54.22%), with some useful generalised directional relationships.

Table 3.4 Results of reasoning applied on the DBpedia dataset.

Defined	Definite	2-Relations	3-Relations	Others
2751	50340	63148	28	136
2.36%	43.24%	54.22%	0.02%	0.12%

Ordnance Survey Dataset

The Boundary-line dataset (i.e. administrative boundaries) for Wales was downloaded from the Ordnance Survey open data web site [118]. The data shows a range of local government administrative and electoral boundaries. Figure 3.7 shows the relative location graph constructed for the Unitary Authority dataset for Wales. Dashed edges have been used to indicate that relationships (and inverses) are defined both ways between the respective nodes, but only one relationship has been used to label the edge in the Linked Place model. The set contains 22 regions, for which 73 direction-proximity relations were computed. The reasoning applied to this set of relationships produced the results shown in Table 3.5.

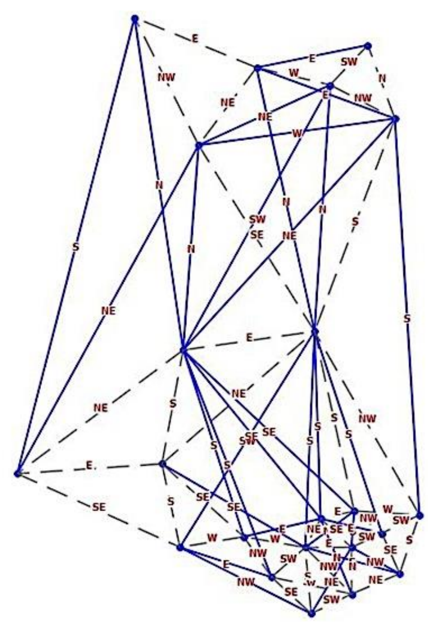


Figure 3.7 Linked Place Graph for the Unitary Authorities in Wales from the Ordnance Survey dataset

Table 3.5 Results of reasoning applied to the ordnance survey dataset

Defined	Definite	2-Relations	3-Relations	Others
73	94	64	0	0
31.6%	40.69%	27.7%	0	0

The above results can be used to describe the effectiveness of the linked place model in terms of the information content it was able to deduce using the ratio of the number of defined relations to the number of deduced relations. A summary is presented in table 3.6.

Table 3.6 Summary of the results of the experiment

	Defined / Definite	Defined / Useful
DBpedia	0.054	0.024
OS	0.78	0.32

3.4.2. Evaluation of the Semantic Place Model

The value of the *SemRelLoc* model primarily lies in its ability to deliver flexible and meaningful place location expressions. Here, its effectiveness has also been evaluated with respect to spatial reasoning. An experiment has been carried out using a sample point of interest dataset obtained from the Ordnance Survey, which records information on places and place types in the city of Cardiff, Wales, UK. A set of approximately 300 places was chosen from five unitary authorities in South Wales (Cardiff, Newport, Caerphilly, Vale of Glamorgan and Rhondda). Salient features were chosen based on popular place types, including hotels, museums, hospitals, castles and railway stations. A map of the area chosen is shown in Figure 3.8, with the salient (red/dark) and other places (white) highlighted.

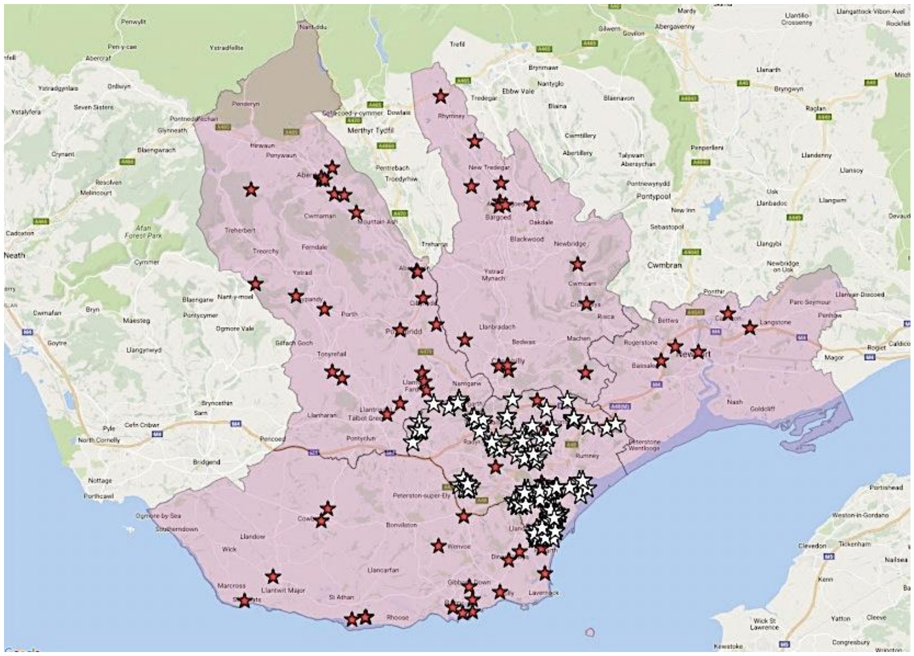


Figure 3.8 A map scene with a sample set of point of interest places in South Wales, UK. Red/dark stars represent salient features and white stars represent all other places

Table 3.7 shows the result of applying spatial reasoning on the complete graph on the salient feature layer only. A total of 108 places were used, for which a relative location graph of 538 direction-proximity relations was defined. Completing the graph resulted in 5778 relationships, out of which 3261 (56%) relationships are definite (defining only one possible relationship), and a further 2515 (44%) are useful 2-relations. Thus, using *RelLoc* on the salient feature layer, and by defining only 8% of relations, meant it was possible to derive almost the entire scene using useful location expressions.

Table 3.7 Results of reasoning applied to the salient feature layer only

Defined	Definite	2-Relations	3-Relations
538	3261	2515	2
8.52%	51.63%	39.81%	0.031%

With the *SemRelLoc* model, no relationships have to be predefined between the base layer places. Every place on the base layer is instead linked to places on the salient feature layer. Thus, for the complete map of places shown in Figure 3.8, a further 181 other places were added to the scene, and 1331 predefined proximity direction relationships have been defined by the model. Completing the graph resulted in 29403 relationships, out of which 12939 (44%) are definite, and a further 15454 (53%) are useful 2-relations. Thus, by using the *SemRelLoc* model, and defining only 5% of the possible relationships between places in the map scene, it has been possible to complete the whole graph and derive over 96% of all possible relationships between all places.

The results demonstrate that the application of spatial reasoning to the adapted semantic model is as effective as with the basic model. Further research can now be directed at the scalability of the framework with respect to both representation and reasoning on the Linked Data Web.

Table 3.8 Results of reasoning applied to the whole map scene with *SemRelLoc*

Defined	Definite	2-Relations	3-Relations or more
1331	12939	15454	1010
4.52%	44%	52.56%	3.44%

A sample set of the relationships defining the location of "Techniquest": an educational charity in the Cardiff Bay area, Wales, UK, resulting from the application of spatial reasoning on the salient features on the map in (Figure 3.8) is provided in appendix A.

3.5. Summary

One of the 'Linked Data Principles' is to include links to connect data items to allow the discovery of related things. Identity resolution is a key research task in this respect. In this work, geographic references to place have been used to link different data items, thus enhancing the utility of these datasets on the LDW by allowing tracing of their spatial footprints. The challenges when representing place data using the simple model of RDF to represent spatial relationships between locations have been investigated.

To establish a consistent method for identification, a linked place model is presented that injects certain types of spatial semantics into the RDF graph underlying the place data. Specific types of spatial relationships between place nodes can be added to the graph to allow the creation of individual place location profiles that fully describe the relative spatial location of a place. It is further shown how the enriched relative location graph can allow the application of QSR to derive implicit spatial links to produce even richer place descriptions. Salience of place has also been introduced as a means of scoping out relevant and meaningful place location expressions. The representation scheme has been adapted to allow for the flexible choice of place instances to be used in the model. The results obtained from the evaluation experiments demonstrate possible significant value in the proposed model.

Chapter 4

Querying Place Information on the LDW

4.1. Introduction

The previous chapter presented the proposed model for the computational place model on the LDW, and also demonstrated the application and evaluation of the model. This chapter explains the utility of the model for supporting the retrieval of place information using the place model. A selective approach is used to the basic model to reduce the workspace for the application of QSR, and also to constrain the search space for answering qualitative spatial queries. A set of possible types of queries are identified and defined that utilise the capacity of model to represent the different types of qualitative spatial relationships between place entities. Query plans are devised for each query and then applied on a realistic sample data set for demonstration.

4.2. An Adapted Relative Location Model

The basic RelLoc model proposes that each place profile has a parent (i.e. direct container) and direct neighbours in each cardinal direction. While, the application of qualitative spatial reasoning (QSR) assists the inference of a complete set of relationships between each object and all other objects. This establishes qualitative spatial links between all objects in the scene. However, description of the complete graph resulting from the application of the spatial reasoning is not practically possible for large scenes and the resulting information may not be needed. Hence, a more selective approach to using the reasoning with the relative location model is used in the chapter to demonstrate the utility of the place model for supporting the search and retrieval of place information.

Here, the representation scheme in the RelLoc model is modified to constrain the space of relationships between places, namely to define a proximity and direction relationships between places that are located within a direct parent/container objects only, as described below.

The approach assumes the existence of data layers that can be used to identify containment relationships, such as the OS administrative boundaries data sets for the UK. The model is defined as follows.

For a given set of places *Pl*, the basic *RelLoc* model is defined as the following tuple:

RelLoc (Pl): = (Pl, D, C), where: D $\in$ *Direction-Proximity and C* $\in$ *Containment,*

R_{nn} (x, y) is used to denote that x is the nearest neighbour from the direction R to object y.

For a given set of places Pl = {pl_1, pl_2, pl_3, pl_4, c_1, c_2}, where: pl_1, pl_2, p_3 and p_4 $\in$ simple level, and c_1 and c_2 $\in$ container level. The modified RelLoc model adds one condition to the above relation as follows:

R_{nn} (x, y), where: {x and y $\subset$ C_i}, denotes that x is the nearest neighbour from the direction R to object y, and x and y must have the same direct container.

To illustrate the new representation scheme, consider the scene in Figure 4.1 that consists of sets of places representing three levels, simple level as children places (i.e. places 1 to 8), direct container level as parents (i.e. places A and B) and direct container of the parents as grandparent level with a 4-cardinal direction frame of reference overlaid for some places in the scenes. A representative point is used to define the place location. It is further known that places represented as points 1, 2, 3 and 4 are inside B, and 5, 6, 7 and 8 places are inside A, and A and B are inside GP. The full set of relationships used to model the scene is given in Table (4.1). Note that in some cases, no relation can be found due to the containment restriction, e.g., there are no neighbours for object 4 from the west direction.

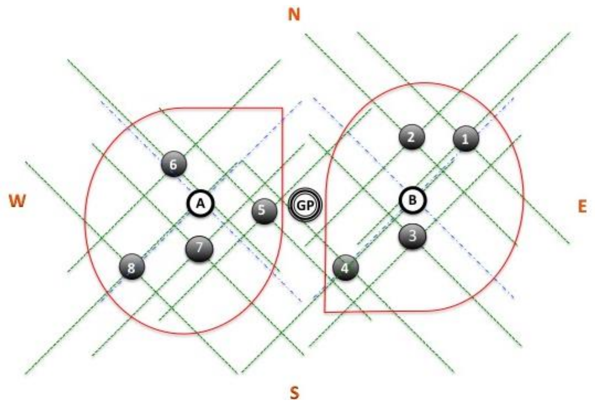


Figure 4.1 A graph representing an example map scene with a set of places represented as points

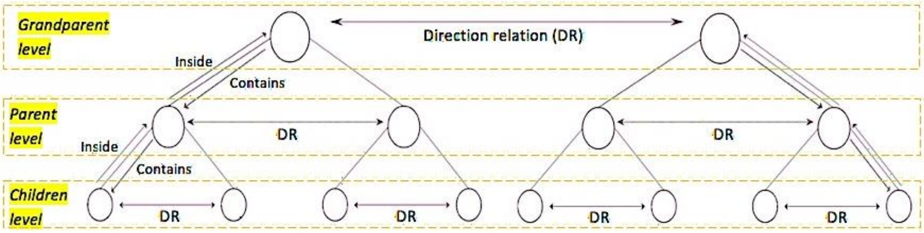


Figure 4.2 A graph representing the connections between entities in different levels, and how the proximity-directional relationship connections are restricted by containment relationships

Table 4.1 Set of direction, proximity and containment relations chosen to represent relative locations in the proposed modified model.

Set of spatial relations to model relative location
N_{nn} (6, 8), E_{nn} (7, 8)
N_{nn} (6, 7), W_{nn} (8, 7), E_{nn} (5, 7)
S_{nn} (7, 6), E_{nn} (5, 6)
W_{nn} (7, 5)
N_{nn} (2, 4), E_{nn} (3, 4)
N_{nn} (2, 3), W_{nn} (4, 3)
S_{nn} (3, 2), W_{nn} (1, 2)
S_{nn} (3, 1), W_{nn} (2, 1)
in (1, B), in (2, B), in (3, B), in (4, B)
in (5, A), in (6, A), in (7, A), in (8, A)
W_{nn} (A, B)
E_{nn} (B, A)
in (A, GP), in (B, GP)

Qualitative spatial reasoning can be applied over the results separately to infer more of the implicit spatial structure of place location. For example, the simple level points are divided into two groups based on the containment relationship. This allows the application of the reasoning over each group individually.

After eliminating the inverse relations, 4 unique directional-proximity relationships have been found for the first set, and 4 unique directional-proximity relationships for the second set. The QSR engine inferred 6 relations for each set, including those produced by the application of the model. Table 4.2 and 4.3 below show the composition tables for a 4-cardinal direction frame of reference between point representations of spatial objects for the two sets.

Table 4.2: Result of reasoning with cardinal relations for places inside parent place (A)

	5	6	7	8
5	-	W	W	W
6	E	-	S	S
7	E	N	-	E
8	E	N	W	-

Table 4.3: Result of reasoning with cardinal relations for places inside parent place (B)

	1	2	3	4
1	-	W	S	$W \vee S \vee SW$
2	E	-	S	S
3	N	N	-	E
4	$E \vee N \vee NE$	N	W	-

4.3. Spatial Queries over the Qualitative Place Model

Possible spatial queries that can be implemented over the proposed qualitative place model can be identified, as listed in Table 4.4. In the table, `Container' is used to denote a place that can act as a parent to other places and `Simple' is used otherwise. 'Dir' refers to the direction relationship used and 'In' indicates that a place is inside a place. The 'near' relationship is used here to denote the closest places to the reference place (i.e. nearest). The extent of proximity is gradually relaxed within the search strategies used in the query plans described below.

Table 4.4: List of possible queries on the qualitative place model

Query	LO	Spatial RS	RO	Example
1	Simple	Near	Simple	Landmarks near Millennium Stadium
2	Simple	Dir	Simple	Landmarks north of St. Davids Hotel & Spa
3	Simple	Near	Container	Landmarks near the Cathays Ward
4	Simple	Dir	Container	Landmarks north of the Butetown Ward
5	Simple	In	Container	Landmarks inside the Cathays Ward
6	Container	Near	Simple	Wards near Millennium Stadium
7	Container	Dir	Simple	Wards north of Millennium Stadium
8	Container	Near	Container	Wards near the Cathays Ward
9	Container	Dir	Container	Wards north of the Cathays Ward
10	Container	In	Container	Wards in the city of Cardiff

In what follows, query plans are devised for each of the queries in Table 4.3 and a demonstration of their application is presented using a realistic data sets from DBpedia and the Ordnance Survey OpenData sets. A schematic representation of the data sets used and the type of relationship extracted using the adapted RelLoc model is shown in Figure 4.3. A detailed description of the data sets is given in Appendix B.

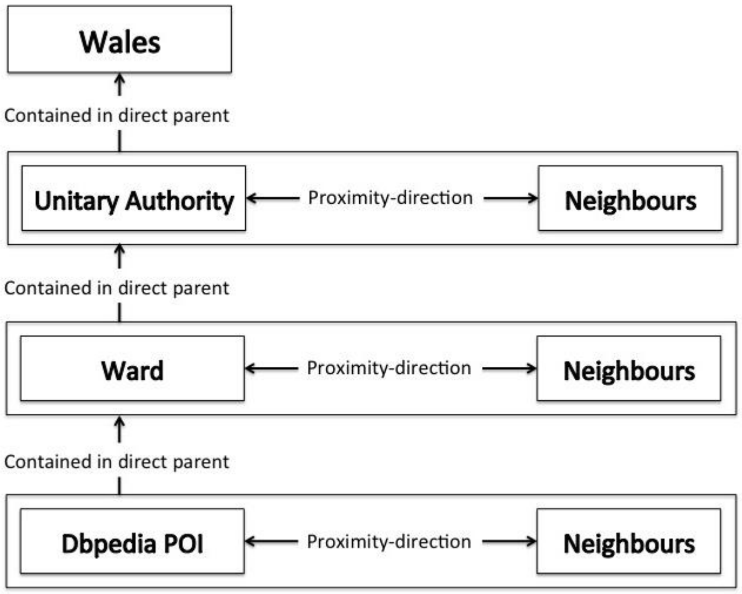


Figure 4.3 The data sets used in the experiment and the relationships computed between the data types.

By applying the framework on the datasets, the spatial relationships in the scene were constructed based on the modification of the RelLoc model and recorded in RDF format as "Subject; Predicate; Objects"[8]. The following processes were carried out:

I. The hierarchy relationships between two levels, that is, the Wales region and the 22 UA regions were computed and recorded in RDF such as (Cardiff (pp) Wales), which means that Wales contains Cardiff.

II. Then, the proximity-directional relationships within one level, that is, between the UA regions dataset within the direct parent (i.e. Wales) were computed and recorded in RDF such as (Cardiff (e) Newport), which denotes that Newport east Cardiff. The process produced 73 directional relationships between the UAs. Further details on the results are provided in (section 3.3).

III. The hierarchy relationships between two levels, the UA regions and wards were calculated, in which for each ward a direct UA container was computed and recorded. For example, (Cathays_ED (pp) Cardiff), which

[8] The hierarchy predicates are presented as ((ppi)), which means that a place 'contains', or (pp), which means that the object place 'is contained' [70]. The proximity-directional predicates are presented as (N, S, E, W, NE, NW, SE, SW).

conveys that 'Cardiff' contains 'Cathays'. As a result of the process a total of 855 hierarchy relationships was constructed. Figure 4.4 shows the distributions and the numbers of the wards within their relevant UA regions. Table 4.5 shows sample of the RDFs generated by the approach for the containment relationships of wards within two UA regions (i.e. Cardiff and Newport).

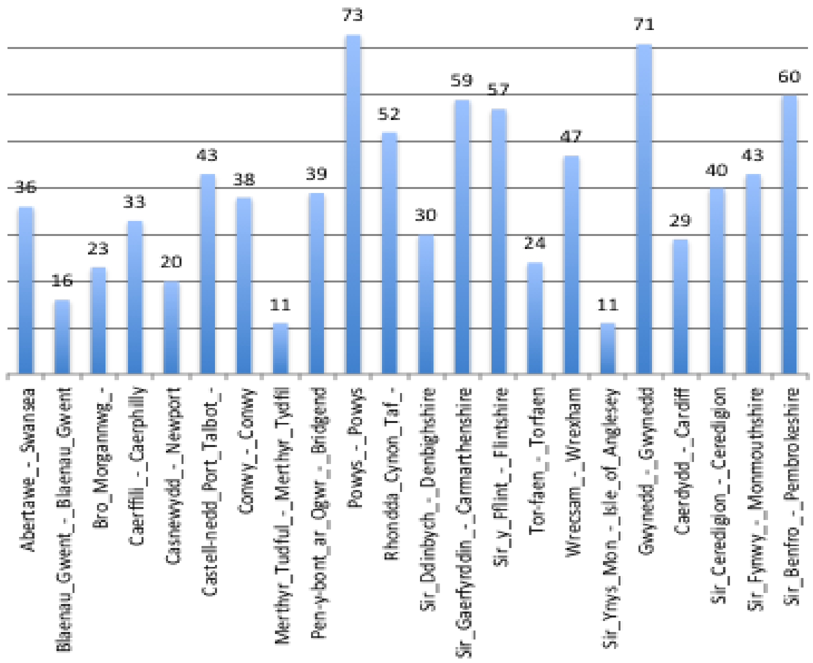


Figure 4.4 Distributions of wards within their relevant UA

Table 4.5 Sample of RDFs denoting containment relationships between two UAs and their children

Swansea UA and its children	Cardiff UA and its children
Abertawe_-_Swansea (ppi) Fairwood_ED	Caerdydd_-_Cardiff (ppi) Cathays_ED
Abertawe_-_Swansea (ppi) Cockett_ED	Caerdydd_-_Cardiff (ppi) Adamsdown_ED
Abertawe_-_Swansea (ppi) Clydach_ED	Caerdydd_-_Cardiff (ppi) Riverside_ED
Abertawe_-_Swansea (ppi) Penclawdd_ED	Caerdydd_-_Cardiff (ppi) Heath_ED
Abertawe_-_Swansea (ppi) Gower_ED	Caerdydd_-_Cardiff (ppi) Cyncoed_ED
Abertawe_-_Swansea (ppi) Mawr_ED	Caerdydd_-_Cardiff (ppi) Butetown_ED

IV. Then, the proximity-direction relationships within one level between wards datasets, but in a constrained way, that is, between wards whose parent is the same UA, were calculated and separately recorded. For example, (Cathays_ED (W) Riverside_ED) means that 'Riverside' is to the west direction from 'Cathays', where both have to be within the same container. This constraint is given in the previous step by the production of the RDFs that record containment relationships, that is, (Cathays_ED (pp) Cardiff) and (Riverside_ED (pp) Cardiff).

Applying the model on wards within Cardiff, which are 29 wards, has produced 114 directional relationships between them. Again, this procedure helps to apply the spatial reasoning in a constrained way instead of applying it over the whole wards in Wales. The step has two main advantages, reduces the cost of the reasoning process and identifies the complete graph of all spatial relations between objects for a subset scene. Table 4.6 shows sample of the RDFs generated by the approach for the proximity-directional relationships between wards that only contained by their direct container (i.e. wards within Cardiff UA).

Table 4.6 Sample of proximity-direction relationships generated by the approach between wards those only within the direct parent, that is, Cardiff UA.

(Grangetown_ED	(N)	Riverside_ED)
(Grangetown_ED	(NE)	Cathays_ED)
(Grangetown_ED	(SE)	Butetown_ED)
(Riverside_ED	(S)	Grangetown_ED)
(Riverside_ED	(NW)	Llandaff_ED)
(Riverside_ED	(W)	Canton_ED)
(Riverside_ED	(N)	Llandaff_North_ED)
(Riverside_ED	(NE)	Gabalfa_ED)
(Riverside_ED	(E)	Cathays_ED)
(Gabalfa_ED	(W)	Llandaff_ED)
(Gabalfa_ED	(SW)	Riverside_ED)
(Gabalfa_ED	(NW)	Llandaff_North_ED)
(Gabalfa_ED	(S)	Cathays_ED)
(Gabalfa_ED	(NE)	Heath_ED)
(Adamsdown_ED	(SE)	Splott_ED)
(Adamsdown_ED	(NW)	Cathays_ED)
(Adamsdown_ED	(N)	Plasnewydd_ED)
(Adamsdown_ED	(NE)	Penylan_ED)
(Adamsdown_ED	(S)	Butetown_ED)
(Plasnewydd_ED	(W)	Cathays_ED)
(Plasnewydd_ED	(S)	Adamsdown_ED)
(Plasnewydd_ED	(E)	Penylan_ED)
(Plasnewydd_ED	(N)	Cyncoed_ED)

V. Again, the hierarchy relationships between two levels, that is, the community wards and the DBpedia POI where computed and in RDF format were also recorded. For example, (Cathays_ED (ppi) Capitol_Centre) denotes that 'Cathays' contains the 'Capitol_Centre'. Figure 4.5 shows the distributions and the numbers of the POI within their relevant wards in Cardiff UA. Table 4.7 shows sample of the RDFs generated by the approach for the containment relationships of POI within one ward (i.e. Cathays ward).

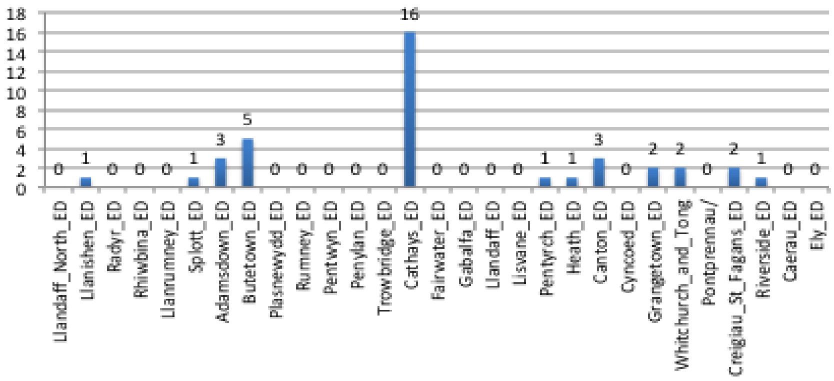


Figure 4.5 POI Distributions within their relevant wards

Table 4.7 Sample of containment relationships generated for Cathays ward and its children.

(Cathays_ED	(ppi)	Altolusso)
(Cathays_ED	(ppi)	Capitol_Centre)
(Cathays_ED	(ppi)	Cardiff_Arms_Park)
(Cathays_ED	(ppi)	Cardiff_Marriott_Hotel)
(Cathays_ED	(ppi)	Cardiff_Story)
(Cathays_ED	(ppi)	Cardiff_town_walls)
(Cathays_ED	(ppi)	Firing_Line:_Cardiff_Castle_Museum_of_the_Welsh_Sold)
(Cathays_ED	(ppi)	Helmont_House)
(Cathays_ED	(ppi)	Hilton_Cardiff)
(Cathays_ED	(ppi)	Meridian_Gate_Cardiff)
(Cathays_ED	(ppi)	Millennium_Stadium)
(Cathays_ED	(ppi)	Motorpoint_Arena_Cardiff)
(Cathays_ED	(ppi)	National_Museum_Cardiff)
(Cathays_ED	(ppi)	New_Theatre_Cardiff)
(Cathays_ED	(ppi)	St_Davids_Cardiff)
(Cathays_ED	(ppi)	Womanby_Street)

VI. Lastly, the proximity-direction relationships in one level, that is, between the POIs, but in a constrained way, that is, between POIs whose parent is the same ward (i.e. within a container), were separately calculated and recorded. For example, (Cardiff_Marriott_Hotel (w) Millennium_Stadium) means that 'Millennium_Stadium' is to the west direction from

'Cardiff_Marriott_Hotel', where, both are within the same container as the containment relations have been defined by the RDFs (Cathays_ED (ppi) Millennium_Stadium) and (Cathays_ED (ppi) Cardiff_Marriott_Hotel).

Table 4.8 shows sample sets of the relationships generated by the basic RelLoc model that defines nested hierarchy relationships between three levels; a simple (i.e. POI), direct container (i.e. Cathays_ED) and parent of the container (i.e. Cardiff), as well as proximity-directional relationships for the different levels.

Table 4.8 List of containment relationships between three levels of representation, and Proximity-directional relationships between places in each level

(Cathays_ED	(pp)	Cardiff)
(Cathays_ED	(SW)	Grangetown_ED)
(Cathays_ED	(W)	Riverside_ED)
(Cathays_ED	(N)	Gabalfa_ED)
(Cathays_ED	SE	Adamsdown_ED)
(Cathays_ED	(E)	Plasnewydd_ED)
(Cathays_ED	(NE)	Cyncoed_ED)
(Cathays_ED	(S)	Butetown_ED)
(Cathays_ED	(ppi)	Altolusso)
(Cathays_ED	(ppi)	Capitol_Centre)
(Cathays_ED	(ppi)	Cardiff_Arms_Park)
(Cathays_ED	(ppi)	Cardiff_Marriott_Hotel)
(Cathays_ED	(ppi)	Cardiff_Story)
(Cathays_ED	(ppi)	Cardiff_town_walls)
(Cathays_ED	(ppi)	Firing_Line:_Cardiff_Castle_Museum_of_the_Welsh_Sold)
(Cathays_ED	(ppi)	Helmont_House)
(Cathays_ED	(ppi)	Hilton_Cardiff)
(Cathays_ED	(ppi)	Meridian_Gate_Cardiff)
(Cathays_ED	(ppi)	Millennium_Stadium)
(Cathays_ED	(ppi)	Motorpoint_Arena_Cardiff)
(Cathays_ED	(ppi)	National_Museum_Cardiff)
(Cathays_ED	(ppi)	New_Theatre_Cardiff)
(Cathays_ED	(ppi)	St_Davids_Cardiff)
(Cathays_ED	(ppi)	Womanby_Street)

Based on the above steps for data preparation, the application of the QSR was used when needed for answering some particular types of queries. The relevant results of the applications of the model or the QSR that were used to answer each query are provided in each query plan section.

4.4. Query Plans

4.4.1. Query 1

The first query is to find located object (LO) near reference object (RO), where both LO and RO are simple place objects. The query can be formulated as follows:

Find near (LO, RO);

Where

{RO isa simplePlace, LO isa simplePlace, LO-type isa LO.type}

Basic search:

The basic algorithm will return all the places of type LO that are within the parent of the RO.

Begin:
Get RO */*the name of the RO place*/*
Get LO-type */*the type of the LO place*/*
Set LOs *= list( ) /*resulting list of places*/*
Set $\boldsymbol{P_{RO}}$ *=* ***Get RO.parent*** */* direct container place of RO*/*
Set $\boldsymbol{CP_{RO}}$ *= list (*$\boldsymbol{P_{RO}}$***.children****) /*list of children of RO-Parent*/*
Loop *over childPlace in* $\boldsymbol{CP_{RO}}$***:***
If childPlace.type = ***LO-type***
LOs*.add (childPlace)*
End if
End loop
Return LOs
End

Extended search:

This step extends the search to the neighbours of the parent of RO to find all places of type LO inside these neighbours.

Begin:
Set $\boldsymbol{NP_{RO}}$ *= list (*$\boldsymbol{P_{RO}}$***.neighbours****) /*list of neighbours of* $\boldsymbol{P_{RO}}$**/*
Loop *over NP in* $\boldsymbol{NP_{RO}}$
Set CNP *= list (N****P.children****) /*list of children of* $\boldsymbol{NP_{RO}}$**/*
Loop *over childPlace in* ***CNP:***
If childPlace.type = ***LO-type***
LOs*.add (childPlace)*
End if
End loop
End loop
Return LOs
End

Example:

Find Point of interests (POI) near Millennium Stadium?

Basic Search:

The algorithm first returns Cathays as the parent Ward of the *Millennium Stadium* then it returns the all places of type POI inside Cathays as shown in Figure (4.6).

(Cathays_ED	(ppi)	Altolusso)
(Cathays_ED	(ppi)	Capitol_Centre)
(Cathays_ED	(ppi)	Cardiff_Arms_Park)
(Cathays_ED	(ppi)	Cardiff_Marriott_Hotel)
(Cathays_ED	(ppi)	Cardiff_Story)
(Cathays_ED	(ppi)	Cardiff_town_walls)
(Cathays_ED	(ppi)	Helmont_House)
(Cathays_ED	(ppi)	Hilton_Cardiff)
(Cathays_ED	(ppi)	Meridian_Gate_Cardiff)
(Cathays_ED	(ppi)	Millennium_Stadium)
(Cathays_ED	(ppi)	Motorpoint_Arena_Cardiff)
(Cathays_ED	(ppi)	National_Museum_Cardiff)
(Cathays_ED	(ppi)	New_Theatre_Cardiff)
(Cathays_ED	(ppi)	St_Davids_Cardiff)
(Cathays_ED	(ppi)	Womanby_Street)

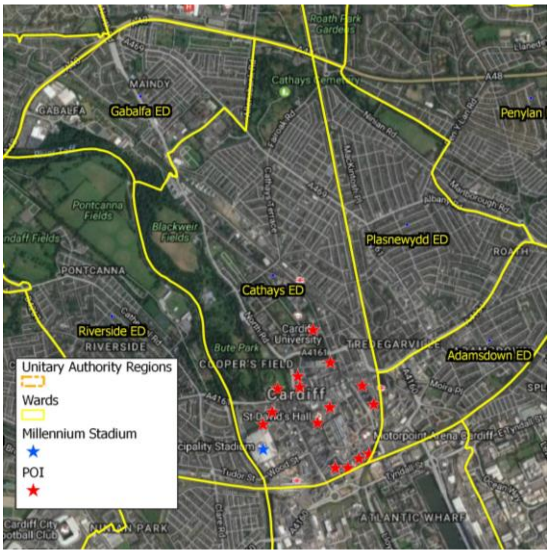


Figure 4.6 Points of interest inside Cathays

Extended search

The search is extended in the next step by searching for POI inside the direct neighbour wards of Cathays, as shown in Figure (4.7). Note that some Wards; Gabalfa, Plansewydd and Cyncoed do not have places of type POI in the dataset.

(Cathays_ED	(SW)	Grangetown_ED)
(Cathays_ED	(W)	Riverside_ED)
(Cathays_ED	(N)	Gabalfa_ED)
(Cathays_ED	(SE)	Adamsdown_ED)
(Cathays_ED	(E)	Plasnewydd_ED)
(Cathays_ED	(NE)	Cyncoed_ED)
(Cathays_ED	(S)	Butetown_ED)
(Grangetown_ED	(ppi)	Beacon_Hill_Powys)
(Grangetown_ED	(ppi)	Cardiff_International_Pool)
(Riverside_ED	(ppi)	St_Marys_Church_Pembroke)
(Adamsdown_ED	(ppi)	Childrens_Hospital_for_Wales)
(Adamsdown_ED	(ppi)	Holland_House_Cardiff)
(Adamsdown_ED	(ppi)	Ty_Pont_Haearn)
(Butetown_ED	(ppi)	Mermaid_Quay)
(Butetown_ED	(ppi)	Pierhead_Building)
(Butetown_ED	(ppi)	St_Davids_Hotel_&_Spa)
(Butetown_ED	(ppi)	Techniquest)
(Butetown_ED	(ppi)	Wales_Millennium_Centre)

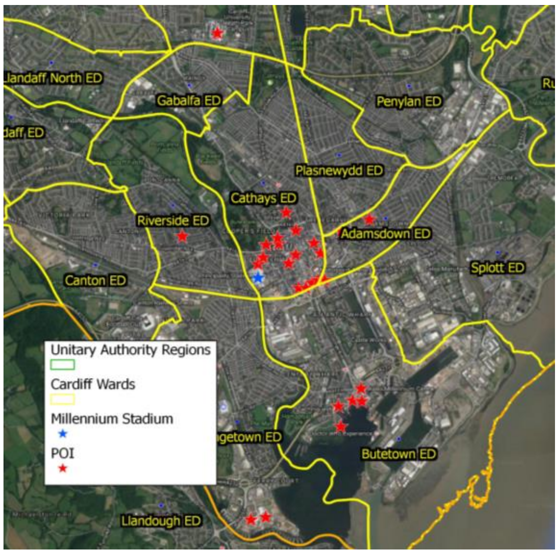


Figure 4.7 Results of the extended search showing all POI in the Wards around Cathays

4.4.2. Query 2

The second query is to find LO at a given direction from a RO, where both LO and RO are simple place objects. The query can be formulated as follows:

Find dir (LO, RO);

Where

{RO isa simplePlace, LO isa simplePlace, LO-type isa LO.type}

Basic search:

The basic algorithm returns all places of type LO that are located at a particular direction from RO inside the parent of the RO.

```
Begin:
    Get RO/*the name of the RO place*/
    Get LO-type /*the type of the LO place*/
    Set LOs = list( ) /*resulting list of places*/
    Set P_RO = Get RO.parent /* direct container place of RO*/
    Set CP_RO = list (P_RO.children) /*list of children of RO-Parent*/
    Loop over childPlace in CP_RO
        If childPlace.type = LO-type AND dir(childPlace, RO)
            LOs.add (childPlace)
        End if
    End loop
    Return LOs
End
```

Extended search:

This step extends the search to the neighbours of the parent in the direction required.

```
Begin:
    Set NP_RO = list (P_RO.neighbours) /*list of neighbours of P_RO*/
    Loop over NP in NP_RO Parent_neighbour
        If dir(NP, P_RO)
            Set CNP = list (NP.children) /*list of children of NP*/
            Loop over childPlace in CNP
                If childPlace.type = LO-type
                    LOs.add (childPlace)
                End if
            End loop
        End if
    End loop
    Return LOs
End
```

Example:

Find Landmarks north of St. Davids Hotel & Spa?

Basic Search:

The algorithm first returns Butetown as the parent Ward of the *St. Davids Hotel & Spa* then it returns the all places of type *Landmarks* inside Butetown north of *St. Davids Hotel & Spa* as shown in Figure 4.8.

(Butetown_ED (ppi) St_Davids_Hotel_&_Spa)
(Butetown_ED (ppi) Mermaid_Quay)
(Butetown_ED (ppi) Pierhead_Building)
(Butetown_ED (ppi) Techniquest)
(Butetown_ED (ppi) Wales_Millennium_Centre)

(St_Davids_Hotel_&_Spa (ne) Mermaid_Quay)
(Techniquest (s) St_Davids_Hotel_&_Spa)
(Wales_Millennium_Centre (sw) St_Davids_Hotel_&_Spa)
(Pierhead_Building (sw) St_Davids_Hotel_&_Spa)

Figure 4.8 Landmarks that are located north of St. Davids Hotel & Spa and inside Butetown Ward

Extended search

The search is extended in the next step by searching for Landmarks inside the north neighbour wards of Butetown, as shown in Figure 4.9.

(Butetown_ED (NE) Splott_ED)
(Butetown_ED (NW) Riverside_ED)
(Butetown_ED (NW) Cathays_ED)
(Butetown_ED (N) Adamsdown_ED)

(Splott_ED (ppi) RAF_Pembrey)
(Riverside_ED (ppi) St_Marys_Church_Pembroke)
(Adamsdown_ED (ppi) Childrens_Hospital_for_Wales)
(Adamsdown_ED (ppi) Holland_House_Cardiff)
(Adamsdown_ED (ppi) Ty_Pont_Haearn)
(Cathays_ED (ppi) Altolusso)
(Cathays_ED (ppi) Capitol_Centre)
(Cathays_ED (ppi) Cardiff_Arms_Park)
(Cathays_ED (ppi) Cardiff_Story)
(Cathays_ED (ppi) Cardiff_town_walls)
(Cathays_ED (ppi) Helmont_House)

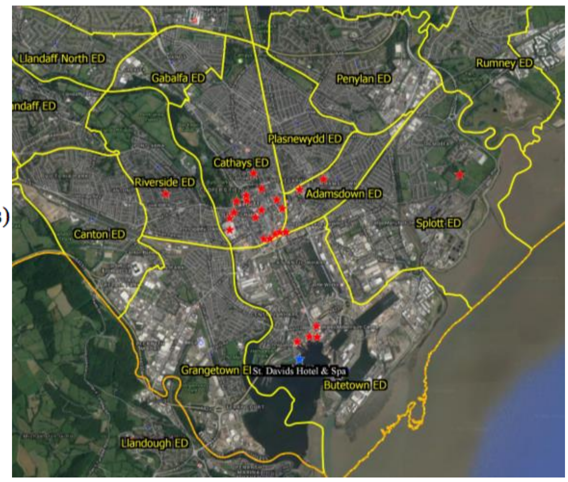


Figure 4.9 Results of the extended search showing all landmarks in the Wards north Buterown

4.4.3. Query 3

The third query is to find LO in simple level near a container RO. The query can be formulated as follows:

Find near (LO, RO);

Where

{RO isa containerPlace, LO isa simplePlace, LO-type isa LO.type}

Basic search:

The basic algorithm will return all the places of type LO that are within the RO itself.

```
Begin:
    Get RO /*the name of the RO place*/
    Get LO-type /*the type of the LO place*/
    Set LOs = list( ) /*resulting list of places*/
    Set CRO = list (RO.children) /*list of children of RO*/
    Loop over childPlace in CRO
        If childPlace.type = LO-type
            LOs.add (childPlace)
        End if
    End loop
    Return LOs
End
```

Extended search:

This step extends the search to the neighbours of the RO to find all places of type LO inside these neighbours.

```
Begin:
    Set NRO = list (RO.neighbours) /*list of neighbours of RO*/
    Loop over NP in NRO
        Set CNP    = list (NP.children) /*list of children of NP_RO*/
        Loop over childPlace in CNP
            If childPlace.type = LO-type
                LOs.add (childPlace)
            End if
        End loop
    End loop
    Return LOs
End
```

Example:

Find Landmarks near the Cathays Ward?

Basic Search:

The algorithm returns all places inside Cathays Ward that of type Landmarks as illustrated in Figure 4.10.

(Cathays_ED	(ppi)	Altolusso)
(Cathays_ED	(ppi)	Capitol_Centre)
(Cathays_ED	(ppi)	Cardiff_Arms_Park)
(Cathays_ED	(ppi)	Cardiff_Marriott_Hotel)
(Cathays_ED	(ppi)	Cardiff_Story)
(Cathays_ED	(ppi)	Cardiff_town_walls)
(Cathays_ED	(ppi)	Helmont_House)
(Cathays_ED	(ppi)	Hilton_Cardiff)
(Cathays_ED	(ppi)	Meridian_Gate_Cardiff)
(Cathays_ED	(ppi)	Millennium_Stadium)
(Cathays_ED	(ppi)	Motorpoint_Arena_Cardiff)
(Cathays_ED	(ppi)	National_Museum_Cardiff)
(Cathays_ED	(ppi)	New_Theatre_Cardiff)
(Cathays_ED	(ppi)	St._Davids_(Cardiff))
(Cathays_ED	(ppi)	Womanby_Street)

Figure 4.10 All places that of Landmark type that are located near Cathays Ward

Extended search

The search is extended in the next step by searching for Landmarks inside the neighbour wards of Cathays, as shown in Figure 4.11.

(Cathays_ED	(SW)	Grangetown_ED)
(Cathays_ED	(W)	Riverside_ED)
(Cathays_ED	(N)	Gabalfa_ED)
(Cathays_ED	SE	Adamsdown_ED)
(Cathays_ED	(E)	Plasnewydd_ED)
(Cathays_ED	(NE)	Cyncoed_ED)
(Cathays_ED	(S)	Butetown_ED)
(Grangetown_ED	(ppi)	Cardiff_International_Pool)
(Adamsdown_ED	(ppi)	Childrens_Hospital_for_Wales)
(Adamsdown_ED	(ppi)	Holland_House_Cardiff)
(Adamsdown_ED	(ppi)	Ty_Pont_Haearn)
(Butetown_ED	(ppi)	Mermaid_Quay)
(Butetown_ED	(ppi)	Pierhead_Building)
(Butetown_ED	(ppi)	St_Davids_Hotel_&_Spa)
(Butetown_ED	(ppi)	Techniquest)
(Butetown_ED	(ppi)	Wales_Millennium_Centre)
(Riverside_ED	(ppi)	St_Marys_Church_Pembroke)

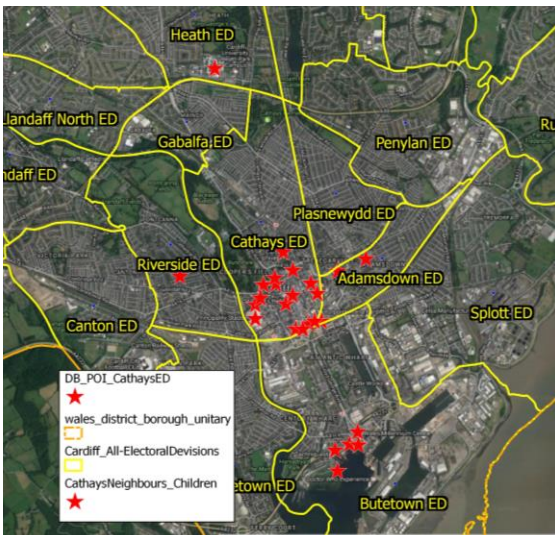


Figure 4.11 Results of the extended search showing all landmarks in the wards neighbouring Cathays Ward

4.4.4. Query 4

The fourth query is to find simple LO at a given direction from a container RO. The query can be formulated as follows:

Find dir (LO, RO);
Where
(RO isa containerPlace, LO isa simplePlace, LO-type isa LO.type)

Basic search:

The basic algorithm will return the direct neighbours of the RO that are located at a given direction from it, to find all places of type LO inside these neighbours.

Begin:
Get RO*/*the name of the RO place*/*
Get LO-type */*the type of the LO place*/*
Set LOs = *list( ) /*resulting list of places*/*
Set NRO *= list (**RO.neighbours**) /*list of neighbours of **RO***/*
Loop *over nROin* ***NRO***
If dir(*nRO, RO)*
Set CnRO *= list (Cn**RO.children**)*
Loop *over C in* ***CnRO***
If C.type = ***LO-type***
LOs*.add (C)*
End if
End loop
End if
End loop
Return LOs
End

Extended search:

This step extends the search to the neigbours of RO within its direct parent.

Begin:
Set P_{RO} ***= Get RO.parent*** */* direct container place of the RO*/*
Set CP_{RO} *= list (*P_{RO}***.children****) /*list of children of RO-Parent (i.e. places in the same level of RO)*/*
Loop *over* cP_{RO} *in* CP_{RO}
If dir(cP_{RO} ***, RO)***
Set cP_{RO} *= list (*cP_{RO}***.children****) /*list of the children of* CP_{RO}**/*
Loop *over childPlace in* cP_{RO}
If childPlace.type = ***LO-type***
LOs*.add (childPlace)*
End if
End loop
End if
End loop
Return LOs
End

Example:

Find Landmarks north of the Butetown Ward?

Basic Search:

The algorithm first returns the direct neighbours of the Butetown Ward that are located at north direction from it, then it returns the all places of type *Landmarks* inside these neighbours. Figure 4.12 demonstrates the result.

(Butetown_ED	(NE)	Splott_ED)
(Butetown_ED	(NW)	Riverside_ED)
(Butetown_ED	(NW)	Cathays_ED)
(Butetown_ED	(N)	Adamsdown_ED)
(Splott_ED	(ppi)	RAF_Pembrey)
(Riverside_ED	(ppi)	St_Marys_Church_Pembroke)
(Adamsdown_ED	(ppi)	Childrens_Hospital_for_Wales)
(Adamsdown_ED	(ppi)	Holland_House_Cardiff)
(Adamsdown_ED	(ppi)	Ty_Pont_Haearn)
(Cathays_ED	(ppi)	Altolusso)
(Cathays_ED	(ppi)	Capitol_Centre)
(Cathays_ED	(ppi)	Cardiff_Arms_Park)
(Cathays_ED	(ppi)	Cardiff_Story)
(Cathays_ED	(ppi)	Cardiff_town_walls)
(Cathays_ED	(ppi)	Helmont_House)

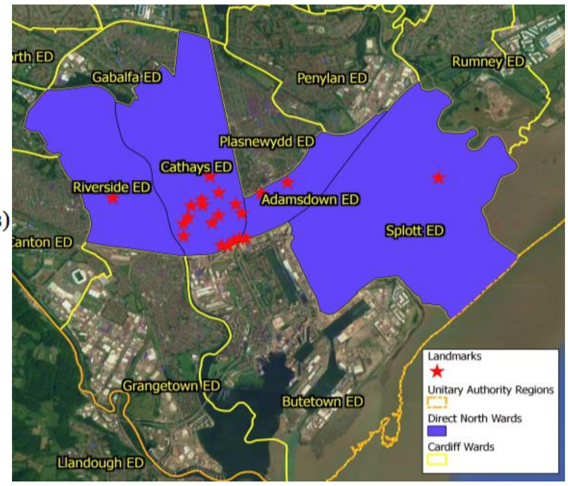


Figure 4.12 All Landmarks that are located north of Butetown Ward

Extended search

The search is extended in the next step by searching for Landmarks inside all wards that are located at the north direction from Butetown Ward and within Cardiff UA (the direct container of the RO), as shown in Figure 4.13.

(Butetown_ED	(nw)	Gabalfa_ED)
(Butetown_ED	(n)	Penylan_ED)
(Butetown_ED	(ne)	Trowbridge_ED)
(Butetown_ED	(n nw)	Heath_ED)
(Butetown_ED	(nw)	Llandaff_North_ED)
(Butetown_ED	(n nw)	Rhiwbina_ED)
(Butetown_ED	(n ne)	Llanrumney_ED)
(Butetown_ED	(ne)	Rumney_ED)
(Butetown_ED	(n nw)	Plasnewydd_ED)
(Butetown_ED	(ne)	Splott_ED)
(Butetown_ED	(n)	Adamsdown_ED)
(Butetown_ED	(nw)	Riverside_ED)
(Llandaff_ED	(se)	Butetown_ED)
(Radyr_ED	(se)	Butetown_ED)
(Pentyrch_ED	(se)	Butetown_ED)
(Pentwyn_ED	(s)	Butetown_ED)

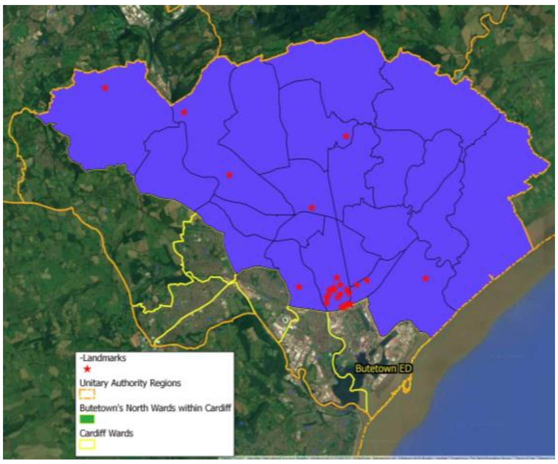


Figure 4.13 Results of the extended search showing all landmarks in the wards north of Butetown within Cardiff

4.4.5. Query 5

The fifth query is to find simple LO that of a given type inside a container RO. There is one search method can be carried out by the approach to answer this query. The query can be formulated as follows:

Find inside (LO, RO);
Where
{RO isa containerPlace, LO isa simplePlace, LO-type isa LO.type}

Basic search:

The basic algorithm will return all the places of type LO that are within the RO.

```
Begin:
    Get RO /*the name of the RO place*/
    Get LO-type /*the type of the LO place*/
    Set LOs = list( ) /*resulting list of places*/
    Set CRO = Get RO.children /* direct children place of RO*/
    Loop over childPlace in CRO
        If childPlace.type = LO-type
            LOs.add (childPlace)
        End if
    End loop
    Return LOs
End
```

Example:

Find Landmarks inside the Cathays Ward?

Basic Search:

The algorithm first returns the children of the Cathays Ward, then it returns the places of type *Landmarks* inside Cathays as shown in Figure 4.14.

(Cathays_ED	(ppi)	Altolusso)
(Cathays_ED	(ppi)	Capitol_Centre)
(Cathays_ED	(ppi)	Cardiff_Arms_Park)
(Cathays_ED	(ppi)	Cardiff_Marriott_Hotel)
(Cathays_ED	(ppi)	Cardiff_Story)
(Cathays_ED	(ppi)	Cardiff_town_walls)
(Cathays_ED	(ppi)	Helmont_House)
(Cathays_ED	(ppi)	Hilton_Cardiff)
(Cathays_ED	(ppi)	Meridian_Gate_Cardiff)
(Cathays_ED	(ppi)	Millennium_Stadium)
(Cathays_ED	(ppi)	Motorpoint_Arena_Cardiff)
(Cathays_ED	(ppi)	National_Museum_Cardiff)
(Cathays_ED	(ppi)	New_Theatre_Cardiff)
(Cathays_ED	(ppi)	St._Davids_(Cardiff))
(Cathays_ED	(ppi)	Womanby_Street)

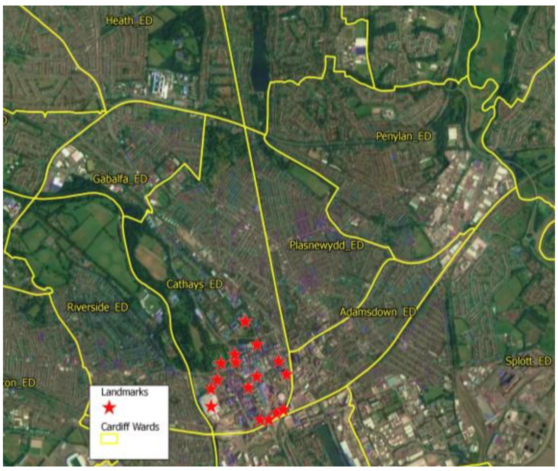


Figure 4.14 All Landmarks that are located inside Cathays Ward

4.4.6. Query 6

The sixth query is to find container located object (LO) near simple reference object (RO). The query can be formulated as follows:

Find near (LO, RO);

Where

{RO isa simplePlace, LO isa containerPlace, LO-type isa LO.type}

Basic search:

The basic algorithm will return all the places of type LO that directly neighbour the parent of the RO.

```
Begin:
    Get RO /*the name of the RO place*/
    Get LO-type /*the type of the LO place*/
    Set LOs = list( ) /*resulting list of places*/
    Set P_RO = Get RO.parent /* direct container place of RO*/
    Set NP_RO = list (P_RO.neighbour) /*list of neighbours of RO-Parent*/
    Loop over neighbourPlace in NP_RO
        Set CNP_RO = list (NP_RO.children) /*list of children of a
        neighbour of RO-Parent */
        Loop over neighbourChildPlace in CNP_RO
            If neighbourChildPlace.type = LO-type
                LOs.add (neighbourChildPlace)
            End if
        End loop
    End loop
    Return LOs
End
```

Extended search:

This step extends the search to all places of type LO within the parent of the parent of RO.

```
Begin:
    Set PP_RO = Get RO.parent.parent /* direct container place of RO-
    Parent */
    Set CPP_RO = list (PP_RO.children) /*list of children of container place of
    RO-Parent*/
    Loop over childPlace in CPP_RO
        If childPlace.type = LO.type
            LOs.add (childPlace)
        End if
    End loop
    Return LOs
End
```

Example:

Find Wards near Millennium Stadium?

Basic Search:

The algorithm first returns Cathays Ward as the parent Ward of the Millennium Stadium then it returns all direct neighbour Wards of Cathays as shown in Figure 4.15.

(Cathays_ED (W) Riverside_ED)
(Cathays_ED (NW) Gabalfa_ED)
(Cathays_ED (E) Adamsdown_ED)
(Butetown_ED (NW) Cathays_ED)
(Canton_ED (NE) Cathays_ED)
(Grangetown_ED (N) Cathays_ED)
(Heath_ED (S) Cathays_ED)
(Plasnewydd_ED (W) Cathays_ED)

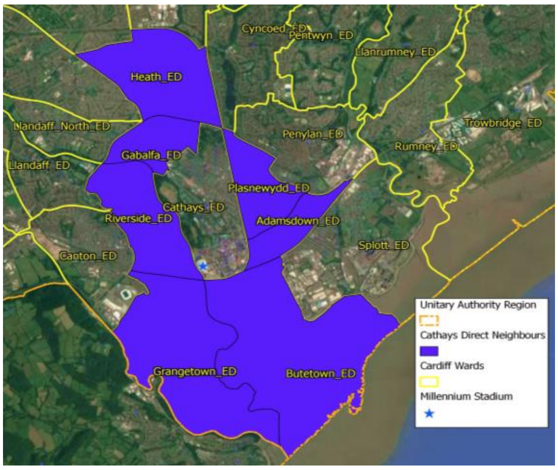


Figure 4.15 All wards that are directly neighbouring Cathays Ward

Extended search

The search is extended in the next step by searching for all wards inside Cardiff (i.e. the parent of the parent of the RO, as shown in Figure 4.16.

(Gabalfa_ED (se) Cathays_ED)
(Penylan_ED (sw) Cathays_ED)
(Trowbridge_ED (w) Cathays_ED)
(Heath_ED (s) Cathays_ED)
(Llandaff_North_ED (e se) Cathays_ED)
(Rhiwbina_ED (s se) Cathays_ED)
(Llanrumney_ED (sw) Cathays_ED)
(Rumney_ED (w) Cathays_ED)
(Plasnewydd_ED (w) Cathays_ED)
(Splott_ED (w) Cathays_ED)
(Adamsdown_ED (w) Cathays_ED)
(Riverside_ED (e) Cathays_ED)
(Grangetown_ED (n) Cathays_ED)

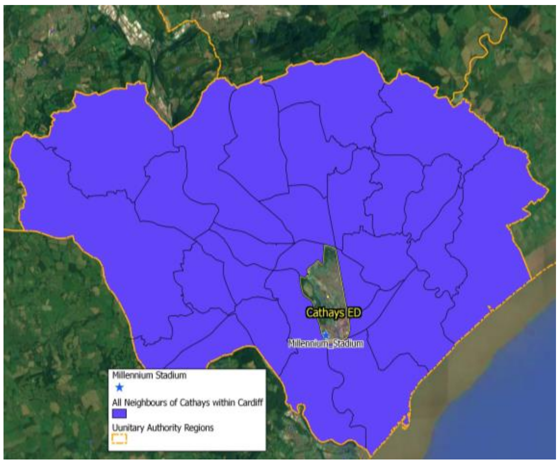


Figure 4.16 Results of the extended search showing all neighbouring wards of Cathays Wards within Cardiff

4.4.7. Query 7

This query is to find container located object (LO) at a given direction from simple reference object (RO). The query can be formulated as follows:

Find dir (LO, RO);

Where

{RO isa simplePlace, LO isa containerPlace, LO-type isa LO.type}

Basic search:

The basic algorithm will return all places of type LO that are directly neighbouring the parent of the RO and are located at the given direction from it.

Begin:
Get RO/*the name of the RO place*/
Set P_{RO} = Get RO.parent /* direct container place of RO*/
Get LO-type /*the type of the LO place*/
Set LOs = *list( ) /*resulting list of places*/*
Set DNP_{RO} = *list (**P_{RO}.directNeighbour**) /*list of the direct neighbours of RO-Parent*/*
Loop *over DNP in* ***DNP_{RO}***
If the DNP.type = ***LO-type*** *AND dir(DNP,* ***P_{RO}****)*
LOs*.add (DNP)*
End if
End loop
Return LOs
End

Extended search:

This step extends the search to all neighbour places of the parent of RO that are of type LO and are within the container of the parent of the RO, located at the given direction.

Begin:
Set PP_{RO} = Get RO.parent.parent /* direct container place of RO-Parent */
Set CPP_{RO} = *list (**P_{RO}.children**) /* list of children of the container place of RO-Parent*/*
Loop *over CPP in* ***CPP_{RO}***
If *CPP.type =* ***LO-type and*** *CPP.direction =* ***Z***
LOs*.add (CCP)*
End if
End loop
Return LOs
End

Example:

Find Wards north of Millennium Stadium?

Basic Search:

The algorithm first returns Cathays Ward as the parent Ward of the Millennium Stadium then it returns all direct neighbour Wards of Cathays that are located at north direction from Cathays as shown in Figure 4.17.

(Cathays_ED (ppi) Millennium_Stadium)
(Heath_ED (S) Cathays_ED)
(Penylan_ED (SW) Cathays_ED)
(Cathays_ED (NW) Gabalfa_ED)

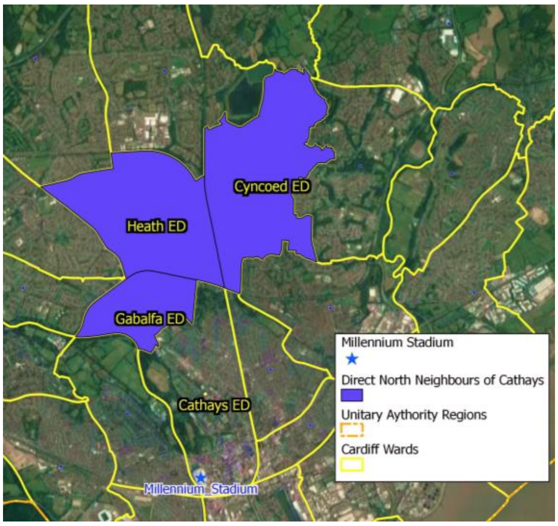


Figure 4.17 Wards that are directly neighbouring Cathays Ward (i.e. the parent of Millennium Stadium) from the north direction

Extended search

The search is extended in the next step by searching for all wards located at north direction from the Cathays Ward within Cardiff, as shown in Figure 4.18.

(Gabalfa_ED (se) Cathays_ED)
(Penylan_ED (sw) Cathays_ED)
(Rhiwbina_ED (s se) Cathays_ED)
(Llanrumney_ED (sw) Cathays_ED)
(Pentwyn_ED (sw) Cathays_ED)
(Cyncoed_ED (s sw) Cathays_ED)
(Lisvane_ED (s sw) Cathays_ED)
(Llanishen_ED (s) Cathays_ED)
(Llandaff_North_ED (e se) Cathays_ED)
(Llandaff_ED (e se) Cathays_ED)
(Radyr_ED (e se) Cathays_ED)
(Creigiau_-_St_Fagans_ED (e se) Cathays_ED)
(Pentyrch_ED (e se) Cathays_ED)
(Pontprennau_-_Old_St_Mellons_ED (sw) Cathays_ED)

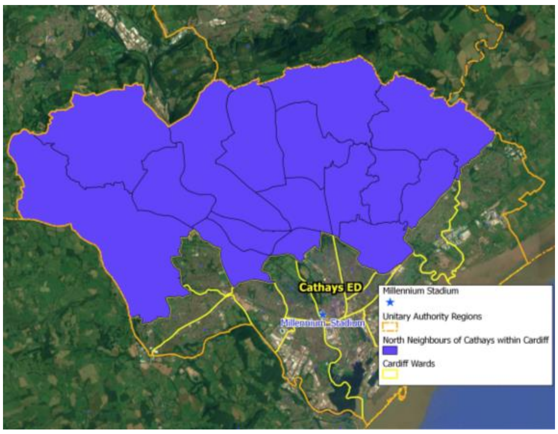


Figure 4.18 Results of the extended search showing all north neighbour wards of Cathays Wards within Cardiff

4.4.8. Query 8

This query is to find located object (LO) near reference object (RO), where both LO and RO are container place objects. The query can be formulated as follows:

Find near (LO, RO);

Where

{RO isa containerPlace, LO isa containerPlace, LO-type isa LO.type}

Basic search:

The basic algorithm will return all places of type LO that are directly neighbouring the RO.

```
Begin:
    Get RO/*the name of the RO place*/
    Get LO-type /*the type of the LO place*/
    Set LOs = list( ) /*resulting list of places*/
    Set DNRO = list (RO.directNeighbour) /*list of the direct neighbours
    of RO*/
    Loop over DNRO in DNRO
        If the DNRO.type = LO-type
            LOs.add (DNRO)
        End if
    End loop
    Return LOs
End
```

Extended search:

This step extends the search to all neighbour places of the RO that are of type LO and are within the direct parent of the RO.

```
Begin:
    Set P_RO = Get RO.parent /* the RO-Parent */
    Set CP_RO = list (P_RO.children) /* list of children of RO-Parent*/
    Loop over CP in CP_RO
        If CP.type = LO-type
            LOs.add (CP)
        End if
    End loop
    Return LOs
End
```

Example:

Find Wards near the Cathays Ward?

Basic Search:

The algorithm directly returns the Cathays Ward direct neighbour Wards, as shown in Figure 4.19.

(Cathays_ED (W) Riverside_ED)
(Cathays_ED (NW) Gabalfa_ED)
(Cathays_ED (E) Adamsdown_ED)
(Butetown_ED (NW) Cathays_ED)
(Canton_ED (NE) Cathays_ED)
(Grangetown_ED (N) Cathays_ED)
(Heath_ED (S) Cathays_ED)
(Plasnewydd_ED (W) Cathays_ED)

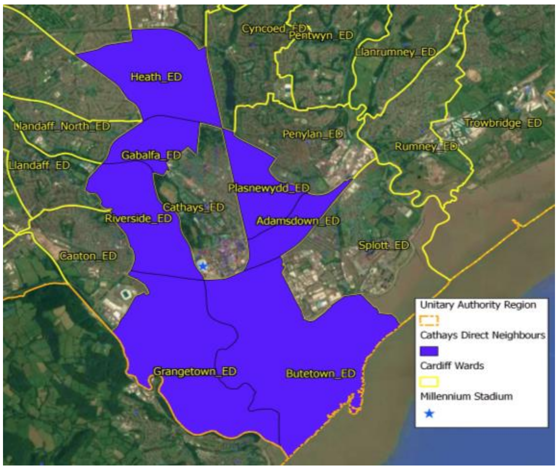


Figure 4.19 All direct neighbour wards to Cathays

Extended search

The search is extended in the next step by searching for all wards inside Cardiff (i.e. the parent of Cathays Ward (i.e. the RO), as shown in Figure 4.20.

(Gabalfa_ED (se) Cathays_ED)
(Penylan_ED (sw) Cathays_ED)
(Trowbridge_ED (w) Cathays_ED)
(Heath_ED (s) Cathays_ED)
(Llandaff_North_ED (e se) Cathays_ED)
(Rhiwbina_ED (s se) Cathays_ED)
(Llanrumney_ED (sw) Cathays_ED)
(Rumney_ED (w) Cathays_ED)
(Plasnewydd_ED (w) Cathays_ED)
(Splott_ED (w) Cathays_ED)
(Adamsdown_ED (w) Cathays_ED)
(Riverside_ED (e) Cathays_ED)
(Grangetown_ED (n) Cathays_ED)

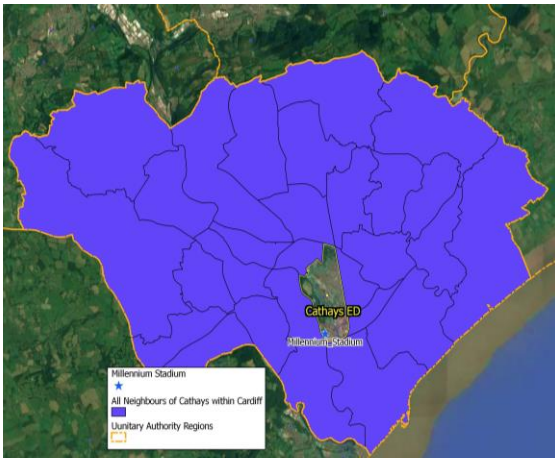


Figure 4.20 Results of the extended search showing all neighbour wards of Cathays Wards within Cardiff

4.4.9. Query 9

This query is to find located object (LO) at a given direction from reference object (RO), where both LO and RO are container place objects. The query can be formulated as follows:

Find dir (LO, RO);

Where

{RO isa containerPlace, LO isa containerPlace, LO-type isa LO.type, direction isa Z}

Basic search:

The basic algorithm will return all places of type LO that are directly neighbouring the RO and are located at the given direction from it.

Begin:
Get RO*/*the name of the RO place*/*
Get LO-type */*the type of the LO place*/*
Get Z */*the specified direction*/*
Set LOs = *list( ) /*resulting list of places*/*
Set DNRO *= list (**RO.directNeighbour**) /*list of the direct neighbours of RO*/*
Loop *over DNRO in* ***DNRO:***
If the DNRO.type = ***LO-type*** *AND DNRO.direction =* ***Z***
LOs*.add (DNRO)*
End if
End loop
Return LOs
End

Extended search:

This step extends the search to all places of the RO that are of type LO and are within the parent of the RO, located at the given direction.

Begin:
Set P_{RO} *=* ***Get RO.parent*** */* direct RO-Parent */*
Set CP_{RO} *= list (*P_{RO}***.children****) /* list of children of the RO-Parent*/*
Loop *over CP in* CP_{RO}
If *CP.type =* ***LO-type and*** *CP.direction =* ***Z***
LOs*.add (CP)*
End if
End loop
Return LOs
End

Example:

Find Wards north of the Cathays Ward?

Basic Search:

The algorithm directly returns the neighbour Wards of Cathays Ward that are located at the north direction from it, as shown in Figure 4.21.

(Heath_ED	(S)	Cathays_ED)
(Penylan_ED	(SW)	Cathays_ED)
(Cathays_ED	(NW)	Gabalfa_ED)

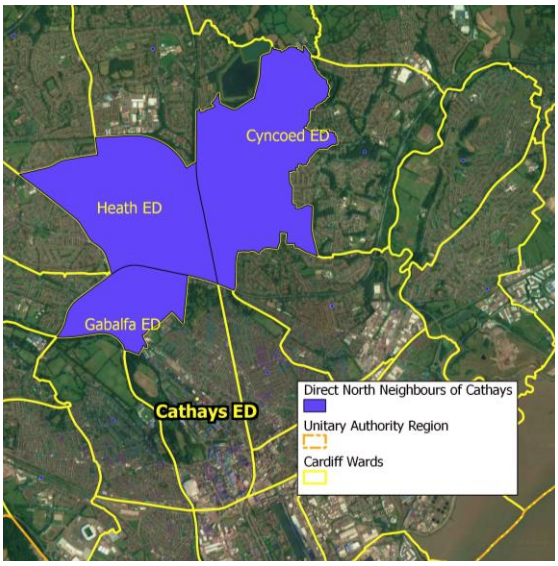


Figure 4.21 Direct neighbour wards at north direction from Cathays Ward

Extended search

The search is extended in the next step by searching for all wards located at north direction from the Cathays Ward within Cardiff, as shown in Figure 4.22.

(Gabalfa_ED (se) Cathays_ED)
(Penylan_ED (sw) Cathays_ED)
(Rhiwbina_ED (s se) Cathays_ED)
(Llanrumney_ED (sw) Cathays_ED)
(Pentwyn_ED (sw) Cathays_ED)
(Cyncoed_ED (s sw) Cathays_ED)
(Lisvane_ED (s sw) Cathays_ED)
(Llanishen_ED (s) Cathays_ED)
(Llandaff_North_ED (e se) Cathays_ED)
(Llandaff_ED (e se) Cathays_ED)
(Radyr_ED (e se) Cathays_ED)
(Creigiau_-_St_Fagans_ED (e se) Cathays_ED)
(Pentyrch_ED (e se) Cathays_ED)
(Pontprennau_-_Old_St_Mellons_ED (sw) Cathays_ED)

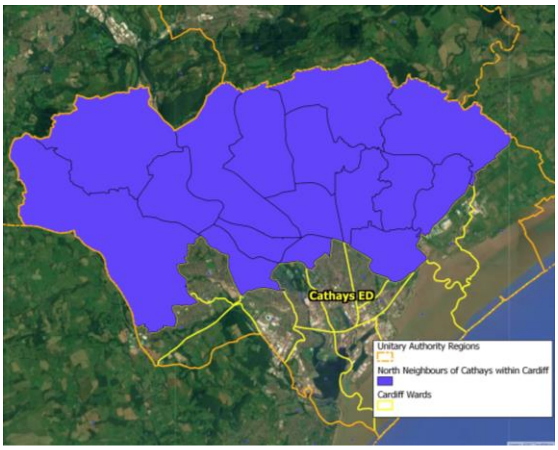


Figure 4.22 Results of the extended search showing all north neighbour wards of Cathays Wards within Cardiff

4.4.10. Query 10

This query is to find LO that of a given type inside a RO, where both are container object places. There is one search method can be carried out by the approach to answer this query. The query can be formulated as follows:

Find inside (LO, RO);

Where

{RO isa containerPlace, LO isa containerPlace, LO-type isa LO.type}

Basic search:

The basic algorithm will return all the places of type LO that are within the RO.

Begin:
- ***Get RO*** */*the name of the RO place*/*
- ***Get LO-type*** */*the type of the LO place*/*
- ***Set LOs =*** *list () /*resulting list of places*/*
- ***Set CRO*** *=* ***Get RO.children*** */* direct children place of RO*/*
- ***Loop*** *over childPlace in* ***CRO:***
  - *If childPlace.type =* ***LO-type***
    - ***LOs****.add (childPlace)*
  - *End if*
- *End loop*
- ***Return LOs***

End

Example:

Find Wards in the city of Cardiff?

Basic Search:

The algorithm first returns Cardiff as the parent of the wards, then it returns all the children that of type Wards as shown in Figure 4.23.

(Caerdydd_-_Cardiff (ppi) Lisvane_ED)
(Caerdydd_-_Cardiff (ppi) Ely_ED)
(Caerdydd_-_Cardiff (ppi) Creigiau/St_Fagans_ED)
(Caerdydd_-_Cardiff (ppi) Pentyrch_ED)
(Caerdydd_-_Cardiff (ppi) Grangetown_ED)
(Caerdydd_-_Cardiff (ppi) Splott_ED)
(Caerdydd_-_Cardiff (ppi) Rumney_ED)
(Caerdydd_-_Cardiff (ppi) Trowbridge_ED)
(Caerdydd_-_Cardiff (ppi) Caerau_ED)
(Caerdydd_-_Cardiff (ppi) Fairwater_ED)
(Caerdydd_-_Cardiff (ppi) Llandaff_ED)
(Caerdydd_-_Cardiff (ppi) Radyr_ED)
(Caerdydd_-_Cardiff (ppi) Canton_ED)
(Caerdydd_-_Cardiff (ppi) Riverside_ED)

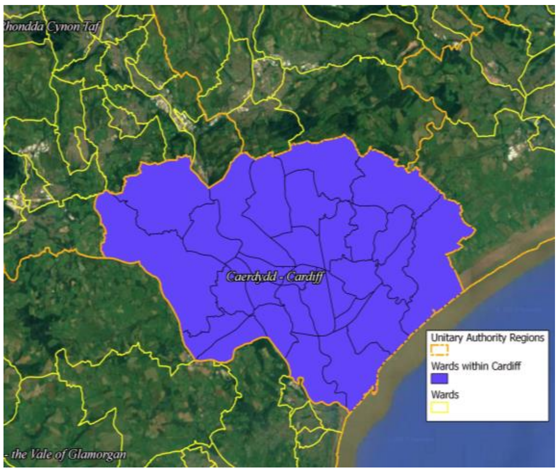


Figure 4.23 All wards within Cardiff City

4.5. Summary

A selective approach to constraining the space of relationships between places has been employed in the basic RelLoc model, namely, to define proximity and directional relationships between places that are located within a direct contained area. The update model provides a reduced workspace for the application of QSR, and also constrains the search space for answering qualitative spatial queries. The approach allows a systematic mechanism to support the search and retrieval of place information. The capacity to model the data has been successfully presented and demonstrated with different types of geographic queries including qualitative spatial constraints and executed using appropriate query plans.

Chapter 5

Qualitative Place Model for Qualitative GIS

5.1. Introduction

In this chapter, a Qualitative Place Model for qualitative GIS (QPM-QGIS), which allows extending conventional GIS to support the representation and manipulation of description of place location, is proposed. The development of the model involved three approaches. Firstly, conceptual models of place as a social and an ontological construct are reviewed. Secondly, approaches to the definition of place location in the literature are considered. Thirdly, a mixed-method case study from social geography research is used to identify the requirements of researchers for modelling and mapping place location as expressed by participants involved in this domain. Then, the conceptual model of place is revisited for the final development.

5.2. Problem statement

Place descriptions are complex spatial expressions that refer to locations through place names, such as 'Cardiff Central Station', or by associating different references with spatial relationships explicitly, such as 'in front of the cinema', or implicitly such as 'Hilton, Cardiff', implying the Hilton hotel in Cardiff.

In natural language, a place name is a direct way of indicating the location and helping others to realise the spatial footprint. When referring to 'Hilton, Cardiff ' as a location, for example, using its name, this indicates a definite location with a definite boundary. However, when defining a place location based on its qualitative spatial relationships with other places, people most likely do not express place location with pinpoint accuracy, but sufficiently describe the location in the context of use. They do not indicate a definite location with a definite boundary using coordinates or geometrical expressions, for example they may use the expression: ‘I'm wandering between the museum and the main university building’.

The scale of the objects’ references and the meanings of the spatial relationships that are used are important, for example ‘in front of the cinema’, ‘inside the student union’ and ‘next to the bus station’ are examples of expressions that use relationships at micro scales of representation; while inside Cardiff, near the city centre and north of London are examples of larger scales of representation. Current GIS do not support the representation and manipulation of these sorts of qualitative expressions of place location.

Qualitative spatial relationships come in many forms, that is, proximity relationships such as “near”, directional relationships such as “in front of” or “north of”, and topological relationships such as “inside”. Cohn and Renz [41] claim that reasoning with such qualitative spatial relationships is a challenge. The qualitative nature of these spatial relationships resists geometric interpretation, and yet people rarely use metrics to quantify these relationships [40].

GIS are sophisticated systems that support the representation and manipulation of quantitative spatial data. However, to many researchers who are interested in the notion of place, this neglects other qualitative spatial representation and characteristics of place, and this is considered to be a shortcoming [119].

Extending GIS with qualitative models of manipulation has been an area of research interest for many years, and many studies have addressed the problems of qualitative spatial representation and reasoning [4]; the representation of fuzzy spatial knowledge [5], and understanding spatial language [6]. However, the practical realisation of their integration with GIS has not yet been addressed.

Mixed methods research has also recently emerged, advocating the case for qualitative GIS [7] in the domain of social geography. Here, the facilitation of GIS for the modelling and manipulation of qualitative spatial data is needed for the study and interpretation of qualitative spatial information, presented in the form of surveys, interviews and observations. Again, the representation and manipulation of this sort of information is not handled in the current literature on GIS. A detailed review of the work related to the methods used is provided later on in this chapter.

This chapter is concerned with creating a qualitative place model that can be exploited for the purposes of representing and manipulating qualitative spatial expressions that constitute spatial aspects of place location. The motivation here is to provide a method for representing the notion of 'place' within a GIS environment.

5.3. Conceptual Modelling of Place

Place is an important concept for a large body of scientific disciplines, practitioners and policymakers. It is of significance in linking humans with their environment [25]. Place plays a fundamental role in human geography and urban planning (e.g., [18, 19]); criminology (e.g. [20, 120, 21]), and health (e.g. [22, 23]). Jeff Malpas [24], suggested that the "place is perhaps the key term for interdisciplinary research in the art, humanities and social science in the twenty-first century". According to Cresswell [119] place is a broader concept that is commonly utilised and roams quite freely across many disciplines. Thus, place, as a concept, is a complicated notion and does not solely imply a definition of the spatial aspects, and thus it is also not the property of geography as a discipline. Place is an expressive site that combines location, locale (i.e. ontological construct; settings) and a sense of place (i.e. time of perception and significance to individuals).

5.3.1. Place as a Social Construct

Although the word 'place' has since ancient times been associated with documenting geography, for the past four decades, the term has been realised differently. A substantial body of the literature on this topic (e.g., [29, 18, 121, 122]) has established that this understanding contradicts the complexity of the concept of 'place'. A common theme in this range of literature is that they clearly describe the notion of place (PN) as a reflection of human (H) experience of space, that is, places' locations (PL) and the significances (SG) that are imposed upon this space [37].

The political geographer John Agnew has drawn up three essential aspects of place as a "meaningful location" [39]. He suggests that a place is an expressive spot that combines the following:

- Location
- Locale
- Sense of place

Cresswell [119], in his book the 'Place', explains the meaning of these three aspects. The location indicates the 'where' of place, that is, the position on the earth's surface according to a particular set of coordinates and measurable dimensions from other locations. Locale denotes the way a place looks; it refers to the physical settings for social relations, including all visible and perceptible aspects of the surroundings such as shops, streets or public spaces. A sense of place implies the subjective and sentimental correlation that people have with a place. Modelling the spatial aspects of 'place' as a concept, that is, location and locale, is the main focus of this work. Hence, if PL stands for the spatial aspects of place and SG stands for all aspects defining the sense of place, a simple notion of place can be described as follows:

$$PN\ (H) = \{PL, SG\}$$

People perform habitual aspects of their lives in space. To a great extent, such spaces are unique to the individuals who practice certain habits or activities. These spaces are likely to be changeable according to the time of perception (TP), as habits can change, or people may migrate [25]. This implicitly means that this perception most likely differs from others' perceptions. Thus, this highlights the vital role of time as a key factor, and also the essential role of the human factor in the formation of place.

Thus, a personal notion of place, describing a personal perception of place location and its significances at a particular time point, can be written as follows:

$$PN\ (H) = \{PL, SG, TP\}$$

5.3.2. Place as an Ontological Construct

Human descriptions of places' locations normally take the form of linguistic expressions [44]. When people describe a place they very rarely use geometrical expressions, but often refer to places' names and/or qualitative spatial relationships between places ([123, 124, 42, 125, 44]).

Place descriptions are complex spatial expressions referring to locations by places' names, such as 'Cardiff Central Station', or by associating different references with spatial relationships explicitly, such as 'in front of the cinema', or implicitly: 'Hilton, Cardiff' implying the Hilton hotel in Cardiff. 'in front of the cinema' is a directional relationship with the place, while 'Hilton, Cardiff' is a topological relationship that implies hierarchy.

There is a need to establish links between the existing quantitative representation in GIS and this targeted qualitative spatial form. This is achievable by extracting a general definition of place that is grounded in the notion of general topological relationships, that is, containment, as well as proximity and directional relationships. This also needs to be supported by an abstract notion of place as a definition derived from the literature.

The general spatial relationships that are implemented quantitatively in GIS, define the spatial connections between features in a spatial database. Whereas the typical way that people describe places' locations among each other is through approximate description, and is based either on the existence of the place in reality or a projection of a perceived place on the earth's surface.

This representation of qualitative spatial expressions reveals that the 'place' location (PL) can be spatially described as singular object (SP), or as a compound place (CP) that comprises many places (Figure 5.1). For example, 'Cardiff Central Station' as a place name may be seen as a defined place location with a clear boundary (one unit), such as the main building of 'Cardiff Central Station'. Or, it may be seen as a compound place that comprises a collection of places, such as the station's platforms, parking areas, amenities and the main building all together.

This notion is evident in the literature [119], where the spatial aspect of a neighbourhood, for example, is a compound place that contains all places of interest within a boundary [108, 25].

$$PL = \{SP + CP\}$$

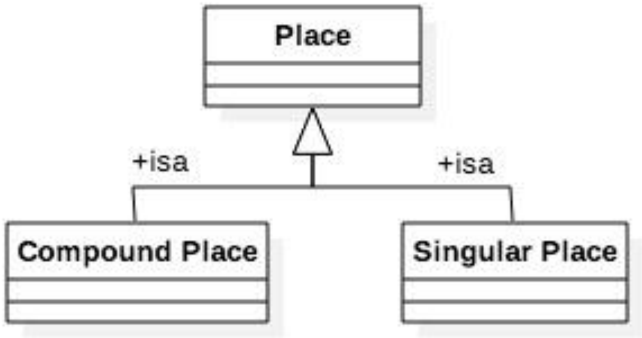


Figure 5.1 Place location can be spatially described as singular object or as a compound place that comprises many places

This singular place (i.e. one-unit) representation can also be described as a defined place (DP) with a specific boundary such as ‘Cardiff National Museum’, or as relative place (RP) defined by spatial relationships between several defined places (Figure 5.2) such ‘a site where we meet usually between the Student Union and the National Museum’. Moreover, place can be described as a combination of a compound of places, unit places, and the location of relative places. For example, a neighbourhood can be a compound place that contains a set of places, whether ‘compound places’, 'relative places' or 'singular' (i.e. existing places), and at the same time, it may have a boundary that can also be defined as a relative place according to the perception of the individual.

$$SP = \{DP, RP\}$$

Thus:

$$PL = \{DP, RP, CP\}$$

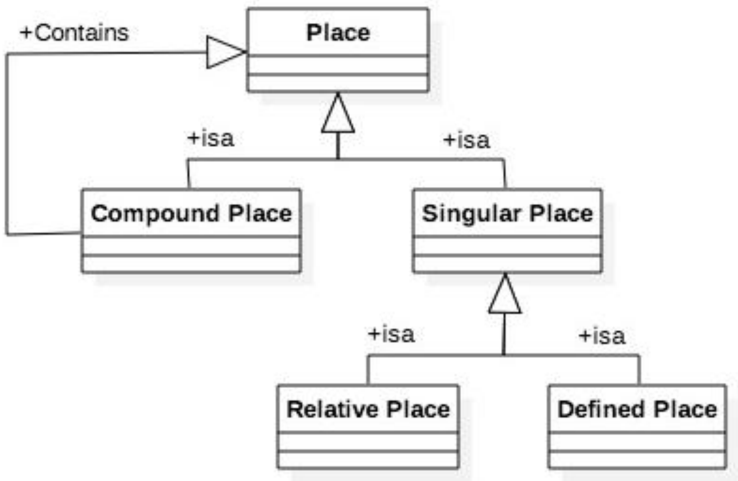


Figure 5.2 Description of PL in (Figure 5.1) is extended, where the singular place can be described as a defined place (DP) with a specific boundary or as relative place (RP)

This derivation is in harmony with the ontological analysis. First of all, general concepts such as space, time, object, event, action, and so on, are defined by top-level ontologies according to Guarino [126]. Guarino has summarised what he calls the essential conceptual tools of formal ontology. Two ontological analysis tools have been identified as being relevant, which are the 'Theory of Parthood' and the 'Theory of Integrity'. The theory of parthood is a kind of guidance used to analyse the relationship of a part to the whole, and the relationship of the part to another part within the whole [127]. On the other hand, the theory of integrity analyses how different parts are connected together to form a whole [126]. Both theories support what have been shaped by the QPM-QGIS, which is that a place can be defined as one unit (i.e. a unified whole), or a place that is defined by spatial relationships (i.e. relations between parts), as well as a compound place (i.e. parts constituting a whole).

In summary, a place can be defined spatially as follows:

- A singular place with a clear boundary in reality.
- The location of a relative place defined by spatial relationships with other singular places.
- A compound place.
- A combination of some or all of the above.

Lastly, the spatial footprint of the relative place, which is the expression that defines place based on the spatial relationships with other places, is characterised by vague boundaries. This is perhaps due to people's habit of expressing place and location qualitatively. Resolving this problem is vital in order to allow the realisation of a definition of place in GIS.

Even so, the ambiguity can probably be mitigated by spatial relationships [128], that is a more complex combination of spatial relationships in a spatial expression may add further details to the description and thus result in less vagueness. For example, 'Hilton' is disambiguated by the other 83 occurrences of this place name worldwide according to the Thesaurus of Geographic Names results' list [129] by the qualifier "in Cardiff". Moreover, if the 'Hilton' is defined by another relationship with another reference object, for example, 'Hilton, City Centre, Cardiff', this narrows the area of the footprint and decreases the vagueness.

Nonetheless, this mitigation of the ambiguity is not enough to model place in a GIS environment. While the representation of the relative place is still unsupported in current GIS, it is however something important to model. Hence, there is a need, as this work proposes, to extend GIS with a qualitative layer of representation to include the inputting of qualitative spatial expressions to allow the representation and manipulation of such data.

The next section addresses this problem by investigating and analysing some carefully selected realistic qualitative data from a mixed-methods case study, and then deriving the required prototypical qualitative expressions for the proposed QPM-QGIS.

5.4. Case Study: Studying Social Cohesion with Participatory mapping

The name of the utilised mixed-methods case study is "Reflections on the use of participatory mapping to explore social cohesion – a potential tool for Qualitative-GIS" [23]. The work has been built based on two previous studies. They conducted this study to try to understand differences between areas in social cohesion, and to investigate the processes through which social cohesion moderates the impact of deprivation on mental health.

The materials of the study, which form the basis of this analysis, comprise 881 pages of interview transcripts; 14 individual interviews, nine key stakeholder interviews and four group interviews, along with four hand-drawn maps that were sketched collaboratively by the groups during the interviews. This is in addition to the researchers' report and fourteen digitised maps stored in KLM[9] format. The KLM files comprise geo-referenced geometric representations of the boundaries that have been discussed and sketched manually by the participants through individual interviews. Then, during a later stage, the research team converted them into digital form, and stored these digitised boundaries in KLM files as part of their efforts to represent the data on a mapping system for visual analysis purposes.

During the individual or group interviews, the case study research team conducted mapping workshops. The aim was to enrich the discussions with participants to gain a full awareness of how people perceive their neighbourhoods.

The case study data has been studied and analysed using a qualitative method of analysis, that is, thematic analysis [130], particularly the identification of the patterns of description for place location.

Two strategies were followed to acquire the participants' geographical definition of their neighbourhoods: The first strategy, which was inferred from the group interviews, focuses on how the participants define place location (i.e. internal

[9] Keyhole Markup Language (KML) is an XML notation file format used to display geographic data within Internet-based in an Earth browser such as Google Earth. For more info refer to https://developers.google.com/kml/documentation/kml_tut

places within the neighbourhood). The second strategy, which was inferred from individual interviews, focuses on how the participants define the place's boundary (i.e. the neighbourhood boundary).

5.4.1. Methods of Analysis Used For the Case Study

The utilisation of the case study aimed to examine how participants in this sort of study and context define place location (i.e. place within a neighbourhood context). This has allowed for the derivation of a number of prototypical forms of qualitative spatial expressions. What is more, two main researchers who conducted the case study research have volunteered and participated in many iterations of the analysis, development and evaluation phases of this work. The following sections present the methods that were used to carry out this experiment, and this can be summarised in the following four main stages:

- Data Collection and Problem definition.
- Data analysis; extraction of spatial expressions and interpretation of spatial language for defining place location and place boundary.
- Validation of data analysis results with researchers through meetings and discussions, and through a paper prototype implementation of place location definition in a GIS.
- Redesign of place model based on the findings obtained from the continuous meetings in the previous steps.

Data Collection and Problem definition

The experiment started with an initial meeting with the social geographers research team who had carried out the case study. The meeting was conducted in order to understand the background and the nature of the study, and also to discuss the notion of qualitative GIS. The discussions included the proposal of the possibility of extending current GIS technologies to handle the notion of place definition that addresses the challenges of representation and analysis of qualitative place location. As agreed in the initial meeting, the data for the case study was obtained after satisfying the legal and ethical requirements for accessing WISERD[10] data.

Defining a Place Location (internal places)

The first strategy used for analysing the case study data (i.e. the four group interviews and their related sketches) focused on the definition of the internal places within a neighbourhood. The analysis was carried out using a combination of the text (i.e. transcripts), side by side with sketches, to fully understand the following:

- How place location is expressed?
- How these expressions have been interpreted within the manual delineation process?
- What kinds of qualitative spatial relationships correspond with these interpretations?
- What patterns can be revealed?

It is important to mention that the participants expressed the descriptions of places' locations together and side by side with the drawing exercise. This means that the expressions need to be used in conjunction with the sketches in order to gauge the correct references to places. The following quote and Figure 5.3 are example of the definition of places' locations that were expressed and sketched simultaneously.

Quote:

> "Interviewer 1: The first thing we're going to do is we're going to create a map. Now, this is a very folded up (nice version?),of a map of New Tredegar [shows them topographic map] but this not the map you are going to draw, you are going to draw your own map and we are going to try and put these places, where they are geographically, if that makes sense, so we're going to make our own map. But the first thing [to do?], obviously this map has got edges to it, but this is just a map we have printed off and it doesn't, you know these edges might mean nothing to you or they might mean something to you. So what we'd like to do is, that thinking of this as a map, and thinking of your community, where would you say these edges of the map represent? Where are the edges of your community?

---

[10] The Wales Institute of Social and Economic Research, Data & Methods (WISERD) is a collaborative venture between the Universities [138].

S: Like where does it, we end like?
Interviewer 1: Yeah, where…
S: The tops of mountains, innit really.
B: Yeah.
S: It's the two sides and then…
B: (Overlapping) On both sides
B: Brithdir,
S: Brithdir, you stop at Brithdir and then you stop…
B: Ponty
S: …at Pontlottyn.
Interviewer 2: So that would be… where would that be [pointing to edge of map]?"

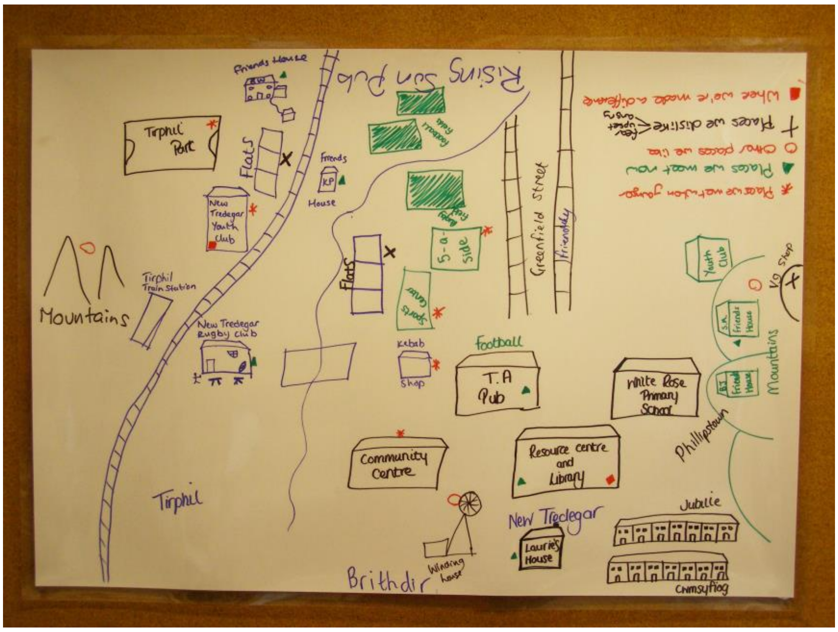


Figure 5.3 Definition of a neighbourhood as a group of places, and the edges represent the boundary of the neighbourhood

The data (i.e. the four group interviews and sketches) was qualitatively analysed by extracting all place location descriptions expressed by the participants. Then, each expression was interpreted through the analysis of the use of spatial relations in the description, and how participants within the manual delineation process have interpreted the expressions was examined. According to this interpretation, the corresponding spatial relationships that indicate similar meanings were identified. This procedure was concluded by revealing the number of prototypical qualitative spatial relationships that were repeatedly used to describe place location. Table 5.1 shows a sample of the spatial descriptions extracted, their interpretation, and the corresponding spatial relationship. Figure 5.4 shows a sample of the relevant sketch. Complete documentation of the sketches used, and the analysis of the transcripts, are provided in Appendix C.

Table 5.1: shows a sample of the spatial descriptions, interpretations and the corresponding prototypical spatial relationships.

Expression	Interpretation	Corresponding Spatial Relationship
Because we are meeting in a room that is classed different to the resource centre. Will that count?	A meeting place inside the resource centre	A place inside a place
Are you thinking about Brithdir or New Tredegar?	Using the exact place by its name to define a place	Exact place
Everywhere really, Brithdir and New Tredegar; that includes Phillipstown, Tirphil, everywhere, because it is under the umbrella of New Tredegar.	New Tredegar contains Phillipstown and Tirphil	A place contains places
he went to the local shop, and these children were on the steps and they swore and he said oh don't do that, there's no need to do that.	The children's seating area next to the shop	A place next to a place
No. At one time they used to have it in the park behind the play area.	The 'problem' area inside the park, and it is behind the play area	A place inside a place A place is located from a given direction from a place

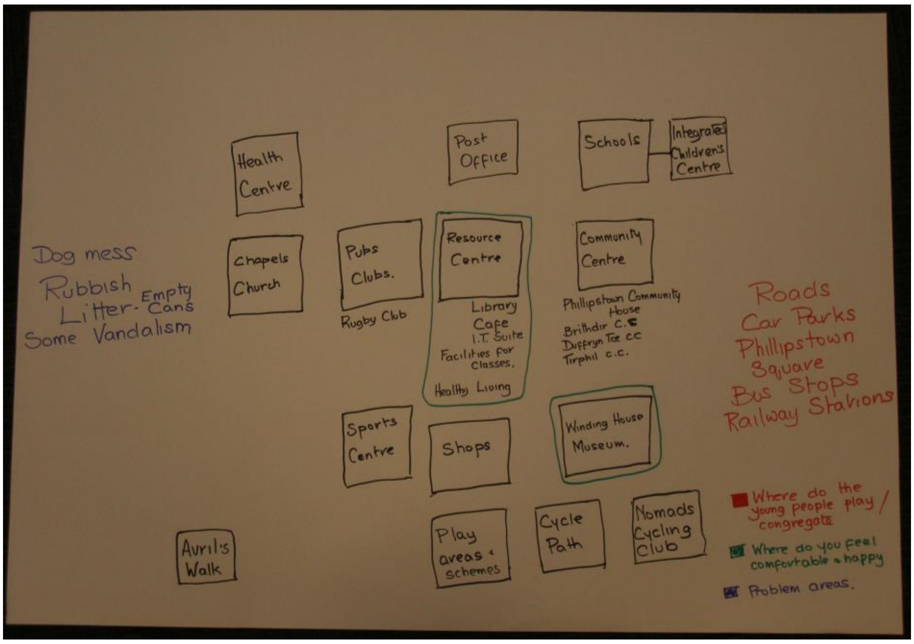


Figure 5.4 The conceptual map sketched by a group of participants to describe their neighbourhood

In the first and second group's sketching exercises, the respondents were asked to map the place in any way that they wished. The sketches were produced as conceptual maps, focusing on showing the relative importance of places to participant, from the most important at the top of hierarchy to the least important at the bottom of the hierarchy to them as shown in Figure (5.4). The third and fourth group were explicitly asked to place more focus on drawing a topographic map as presented in Figure (5.3).

A total of 248 place descriptions were extracted from these four groups' dialogues. The interpretations show that descriptions most likely come under one of the following expressions: A place contains a place/places, and this occurred 38 time, making up 15% of the total of expressions; a place inside a place, at 27%; a place between two places at 2%; a place next to a place at 18%; a place is located in a given direction from a place at 5%, and finally, a defined place (i.e. a singular place that is defined by a place name) making up 32% (see the graph below in Figure 5.5).

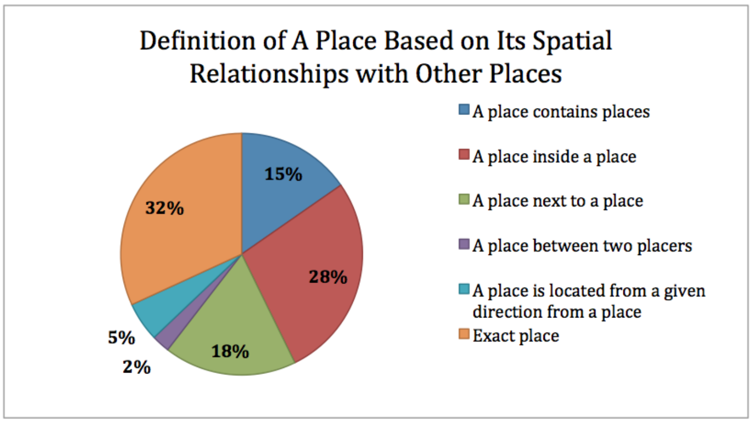


Figure 5.5 Percentage of occurrence of each spatial expression.

These descriptions can also be classified as expressions and contain 43% hierarchical spatial relationships. This percentage is compatible with the findings in the literature (e.g., [131, 132, 45]), which suggest that in the field of spatial cognition, people usually describe places in hierarchical ways. Moreover, 2% of the expressions can be considered directional relationships; which compatible with the findings of Winter, S. et al., [44]. In addition, 5% of the expressions can be categorised as descriptions that imply proximity relationships.

In spite of the above, there are other forms of expressions that indicate more nuanced descriptions, such as 'at the corner of the two streets.' However, as stated previously, this work aims to generalise the description of place in a way that captures and conveys more than one meaning of place location. The hierarchy, proximity and directional relationships are well represented quantitatively. Thus, the prototypical spatial expressions elaborated on can rely on these general qualitative spatial relationships to establish links with quantitative representation in spatial databases.

Therefore, GIS should be extended through modules that support the modelling of the following prototypical qualitative spatial expressions:

- A place inside a place, to record and represent a relative place of interest that is located inside a defined place (i.e. an exact place). For example, 'the location of the 55 club is inside the community building.'
- A place equals a place (exact place), to record and represent a relative place of interest that occupies an exact place. For example, the place of a given activity in the community hall.
- A place containing a place/places, to record and represent a relative place of interest that covers a defined place/places. For example, 'the area includes a small number of shops, a hairdressers, and a café.'
- A place next to a place, to record and represent a relative place of interest that is next to a defined place. For example, 'the hangout location is next to the sports centre.'
- A place between two places to record and represent a relative place of interest that is between two defined places. For example, 'the location of the place where we feel fear is between the shop and the bridge.'
- A place in a specific direction from a place to record and represent a relative place of interest that is in a specific direction from a defined place. For example, 'the playground is behind the school.'

The above expressions correspond closely to the conceptual model of place derived in (section 5.3.2), where a place can be defined as a singular place (i.e. one unit place), as a relative place (i.e. a place that is defined based on its spatial relationships with other places e.g. a place between two places, or a place in a given direction from a place), or as a compound place that may contain singular places and/or relative place.

In this scenario, designating only the edges of the neighbourhood crystallises the boundary. The edges are specified based on selecting a number of real existing defined landmarks or geographic features.

Defining a Place Boundary

The second strategy used for analysing the case study data (i.e. the individual interviews and digitised boundaries in KLM) focused on the definition of the place boundary. Each interview started with the delineation exercise for the boundary, before engaging in a discussion to understand the relationships between the participant, place and associated meanings. On a hard copy of a topographic base map (actual base map), each participant was asked to draw a border that contains and passes around all places that were identified by him or her as being part of their neighbourhood.

Then, at a later stage, the researchers (i.e. the case study research team) converted the sketches into digital form (i.e. KLM file format) using Google Earth. They aimed to display all mapped boundaries on a mapping system to carry out a visual comparison between the borderlines of all participants' neighbourhoods. Table 5.2 below shows a sample of the spatial expressions, which have been extracted from an individual interview, expressed while delineating the boundary. It also shows their interpretations, and is followed by the related KLM map shown in Figure 5.6.

Table 5.2: shows a sample of the spatial descriptions and their interpretations.

Expression	Interpretation of spatial relationship[11]
I used to live in ***Tredegar*** *years ago*	Part of his neighbourhood in past

[11] Interpretation was done manually by the author and the expert involved in the case study.

*Oh, very rarely I go up **Phillipstown** to be honest*	Phillipstown is not part of (the definition) his neighborhood
*it's just around, it's, **the village area** really*	The village area is part of his neighbourhood
*INT: so there's **Commercial Street** and **Greenfield Street**.* *RES: Yeah, Green . . . , that's all over the village over there.*	*The Commercial Street and Greenfield Street* are part of his neighborhood, and they are part of the village
*would you include **Fothergills Road** for instance as part of . . .* *RES: No it's just . . .*	Fothergills Road is not part of his neighbourhood.
*INT: Or perhaps would it start **in Tredegar**, would it start round here? **The sports hall**, round that area, would that include that area?* *RES: Yeah, I would say, I would say just around there you know.*	Tredegar is part of his neighbourhood The sports hall is part of (the definition) his neighbourhood
*INT: Just put a line round and include **your street (Church Terrace)** presumably.* *RES: Yeah.*	Church Terrace is part of his neighborhood
INT: And your street is here, and over the river, on the other side of the river too, would you consider? *RES: Not really, you know, cos I'm from **Tirphil**-originally you see so . . .*	Tirphil is not included as part of his neighbourhood
*INT: Yeah. And would it include the, the **White Resource Centre**?* *RES: Oh yes, yeah.*	White Resource Centre is part of his neighbourhood
*RES: Yeah, and **Elliotstown**, we go up around there.*	Elliotstown is part of his neighbourhood

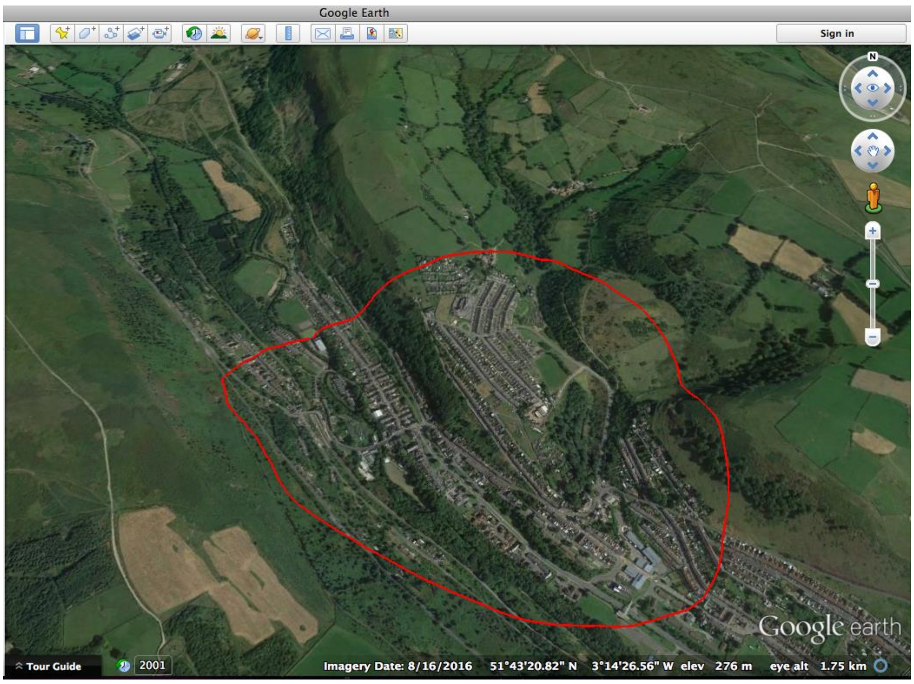


Figure 5.6 The delineated boundary, which was demarcated manually by the participant, has been converted into this format (digitised borderline in KLM format) by the research team

The individual interview approach shows the procedures that can be followed in delineating a neighbourhood's boundary. A place, which is the boundary of a neighbourhood, can be defined as a singular place (i.e. borderline as in Figure 5.6), or as a compound place that may contain singular places and/or places that are defined based on spatial relationships with other places (e.g., as presented in Figure 5.3). Similarly, this definition is compatible with the QPM-QGIS developed.

Therefore, the GIS should be extended with modules that support the representation of the boundary through any of the following approaches:

- Free drawing to enable the user of the system to freely delineate the boundary as a region or more than one region.
- Enabling the edges of the neighbourhood area to be specified by picking up any defined places from a base map layer, and defining them as the edges of the neighbourhood.
- Allowing automatic demarcation of the boundary around predefined interior places.

Paper Prototype Implementation

A primitive and low-fidelity design for a Qualitative Model of Place for Qualitative GIS (QPM-QGIS) prototype was developed. The objective was to approximate the idea of a concrete solution for the user by showing rough user interfaces. These interfaces involve some sketches to simulate the proposed solution's appearance, and how it will operate (see Figure 5.7). This primitive design is for the purpose of obtaining users' feedback on the findings, and also to gain recommendations for further development

However, for further understanding, another version of the low-fidelity prototype was provided to the user. The aim was to provide detailed information on the processes of defining place as a concept and to mimic GUI on GIS to ensure that the idea has been absorbed (see Figure 5.8).

The feedback clearly indicates that there is something promising and that it is worth following up, however, there are some additional factors to think about, such as who is this for, and who is the audience. This also relates to other issues in that there are many ways of carrying out social research and framing research questions (e.g. asking different questions about place as a social construct).

The recommendation from the feedback is that the solution should not deal with too specific a set of issues. It is also recommended to think about usability and audience: Who is going to be using the model? How much knowledge will they have of GIS? Furthermore, there is a lot of work to be done in relation to preparing the data and entering it into the GIS environment, and qualitative researchers might not have these skills.

The final model was redesigned and developed according to the recommendations agreed in the first evaluation, and then the application of the model was implemented as presented next in (Chapter 6).

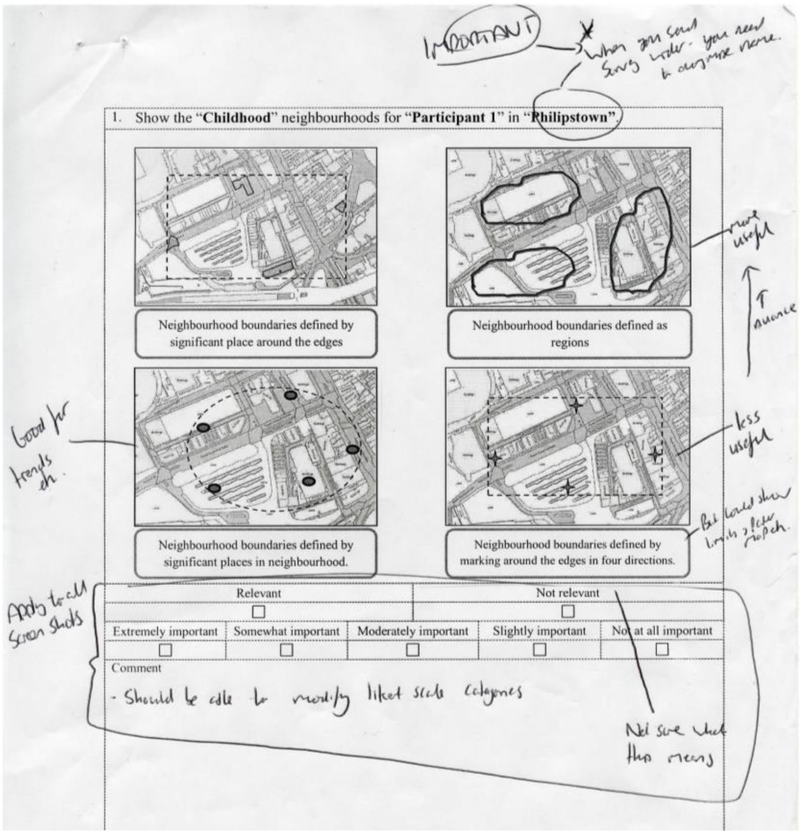


Figure 5.7 A copy of the low fidelity prototype version 1 that shows methods to define neighborhood's boundary. The hand writing is a comment from the user (i.e. social geographer expert)

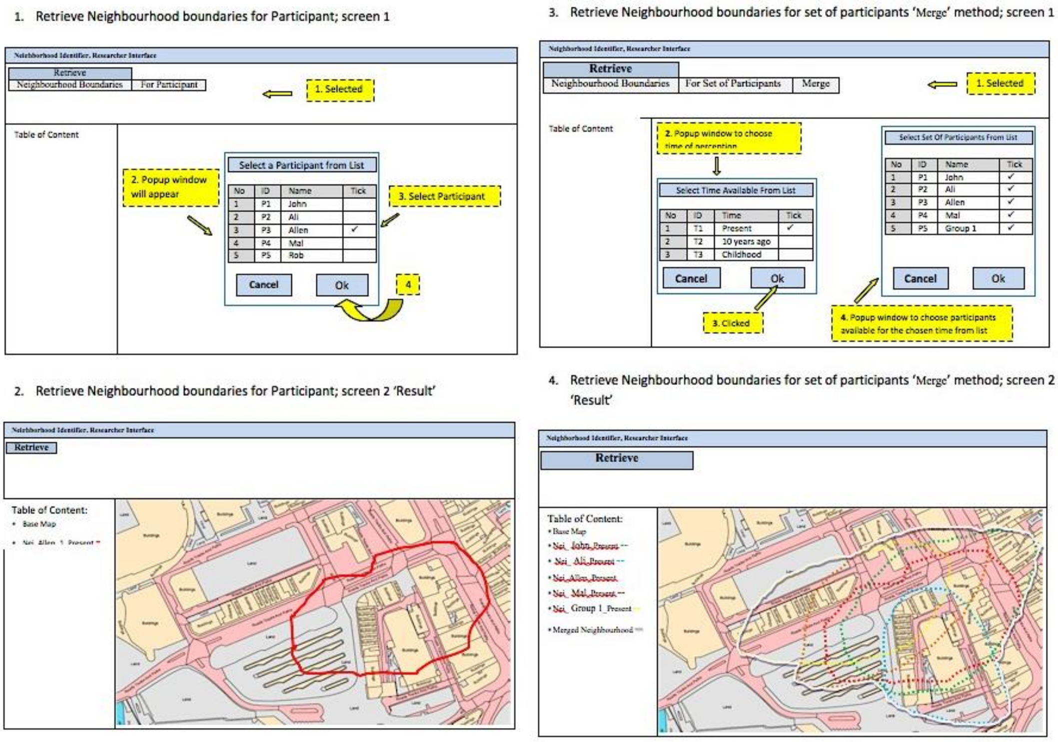


Figure 5.8 A screenshot of the low fidelity prototype version 2 that shows some manipulation operations that can be carried out for data retrieval.

5.5. Conceptual Model of Place Revisited

In section (5.3.1) above, the conceptual model of place as a social and an ontological construct revealed that the personal notion of place PN (H) describes an individual perception of place location (PL) and the associated qualitative characteristics, that is, significances (SG) at a particular time point (TP). Section (5.3.2) has introduced the notion that place location can be described as singular object (SP) or as a compound object (CP). The singular place can also be described as a defined place (DP) or as a relative place (RP). The formula below summarises this derivation:

As: PN (H) = {PL, SG, TP}

&

As: PL = {SP, CP, RP}

Therefore: PN (H) = {{SP, CP, RP}, SG, TP}

Section (5.4) identified the prototypical spatial expressions that are required to describe qualitative place location in GIS. These expressions can be used to describe a relative place location (RP). One expression (i.e. 'a place equals a place') can also be used to describe a singular place (SP), because the description is an exact replication of the singular place. Thus, the qualitative definition of place location in GIS should be extended to include these prototypical spatial expressions. Therefore, the proposed QPM-QGIS can be summarised in the conceptual diagram presented in (Figure 5.9)

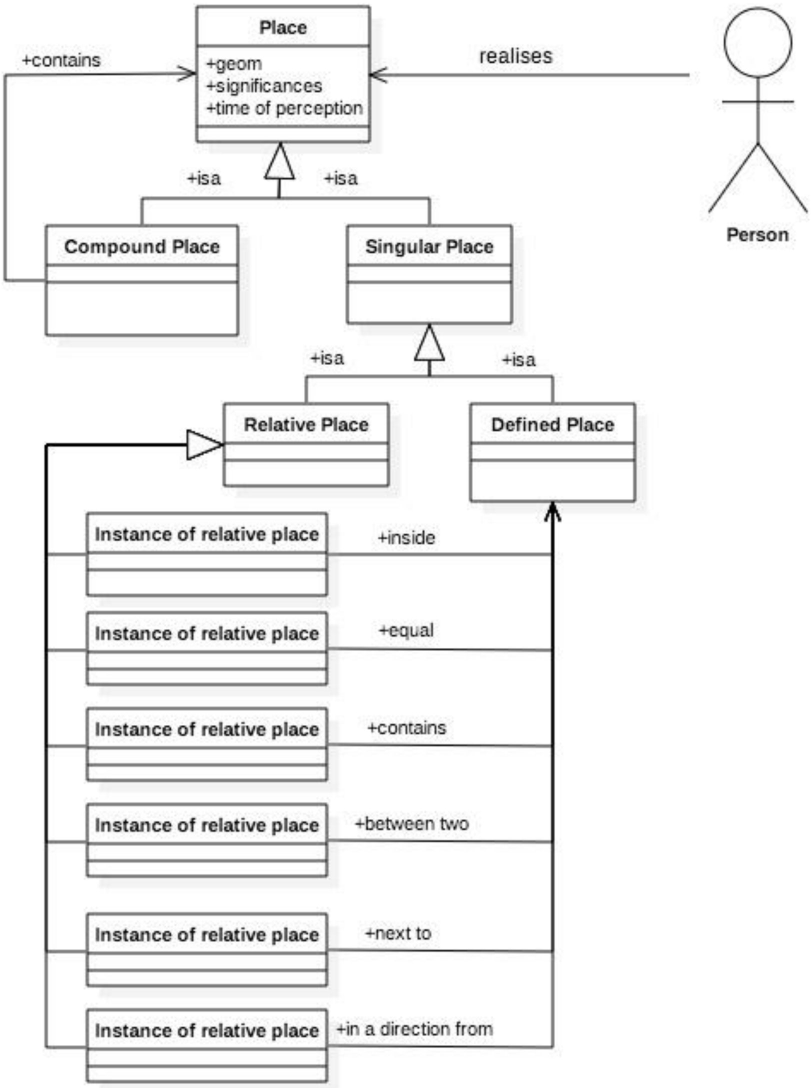


Figure 5.9 Conceptual QPM-QGIS diagram

Retrieval and manipulation operations can be defined on PN to allow for the projection of its defining attributes as well as for the application of different types of spatial projection and joins as defined in a GIS. Some examples of such operations include the following:

- Merging different PNs.

- Generating a common boundary for different PNs.
- Finding the intersection between different PNs.

The application of the developed model, along with complete and realistic scenarios for defining personal place within GIS, as well as the range of manipulation and data selection and retrieval operations possible, will be demonstrated in the next chapter as part of illustrating the utility of the model.

5.6. Summary

A qualitative place model for GIS was proposed based on a combined approach of literature review and an investigation of a realistic case study. The development passed through three phases: The first phase focussed on conceptualising a general definition of the notion of place, that is, place is an expressive spot that combines an ontological construct and a social construct. The second phase identified the constituents of place definition (i.e. human actor, time of perception, significances and spatial aspects) and proposed their homogenous treatment in a GIS. This thesis focuses on modelling qualitative place location, therefore the third phase focused on the definition of the spatial component of place on two levels: 1) an abstract level, which describes how a place can be modelled from an ontological perspective (i.e. defining place as a singular entity, as a relative place and as a compound place). 2) An applied level, which is the formulation of prototypical qualitative spatial expressions that convey qualitative place location in a GIS environment. This step is essential in order to expand GIS capabilities with the ability to deal with qualitative form of spatial data. The diversity of spatial expressions, previously introduced in (Sec 2.2.1), shifted the focus towards identifying a manageable number of expressions, and this was achieved by the examination of the qualitative data from the case study. It is important to mention that modelling other aspects of the place notion (i.e. human actor, time of perception and significances) need to be studied further as suggested in the future work section.

Chapter 6

Implementation

6.1. Introduction

Chapter Five focused on the derivation process for the model, as well as specifying the requirements for its realisation. This chapter demonstrates the application of the model using a practical example. This includes a discussion of the implementation methodology and an overview of the prototype system's structure and database design, followed by an explanation of the modules included for interpreting and delineating spatial expressions that describe place location. Examples are used throughout the chapter to demonstrate the implemented system's components for data input and retrieval, and manipulation operations.

6.2. Place location within a neighbourhood context

As emerged in the analysis of the group interviews as well as the individual interviews (section 5.5), the definition of the geographic aspect of place within a neighbourhood context is expressed according to two levels of perception:

- Defining the boundary of a neighbourhood.
- Defining the interior places of interest in the neighbourhood.

Thus, a qualitative place model for GIS should support the representation of the four main components, in particular, the definition of geographic aspects, as proposed, in a manner that mimics people's way for expressing place location.

The first spatial component, which is the boundary, has been defined by the participants either as a region that surrounds all internal places (i.e. a singular place), or as distributed edges in many directions that frame the scene (i.e. a compound place). Demarcation of the border - the regional demarcation - can be done in two ways: Either by drawing an empty polygon that covers the neighbourhood space, or by taking into account the internal places first and then drawing a border that directly passes behind these places and surrounds them. Consequently, the proposed prototype system should support the representation of the boundary in GIS through any of the following approaches:

- Enabling one region or more to be delineated freely.
- Enabling edges of the neighbourhood area to be specified by copying any defined place from a base map, and describing it as the edge of the neighbourhood.
- Allowing automatically demarcating of the boundary around predefined interior places that have been stored in an independent layer.

As also revealed in the analysis stage, the second component- interior places- can be identified in three ways:

- As a perceived place that is represented by a defined place (i.e. an existing place). In reality this is a specified footprint that can be selected from a base map, and thus can be represented in conventional spatial database as point, line or polygon, such as a building or street.
- As a relative place that can only be defined based on its spatial relationships with other defined places (existing places), such as the place for hanging out in the expression: “the hangout place is behind the sports centre”. In this situation, three procedures are required to identify the location on a map:
    - Locating the reference object (RO).
    - Interpreting spatial relationships (SR), which are contained in natural language encoded using spatial prepositions, between the located object (LO) and RO.
    - Finally, defining the footprint of the perceived place (i.e. LO). The ambiguity of the footprint boundary is addressed by allowing the configuration of the measurement as the user sees fit. However, in this

demonstration of the system prototype, it has been calculated based on one possible method that uses the average distance between buildings as a base for determining the footprint's buffer distance

- As a compound place that can be either constituted by an amalgamation of relative places and/or defined places.

6.3. Implementation

This section is concerned with the implementation of the model into a GIS prototype and its realization using a concrete example. The subsequent sections provide an overview of the implementation methodology; a brief about the prototype's system design, including the system's architecture, spatial database design and the method implemented to quantifying qualitative location of place, and finally, the application of the model through constructing neighbourhoods using the especially designed interfaces of the prototype. It is important to mention that the implemented system is a proof of concept and as such is not concerned with optimal representation of spatial relationships. In addition the system is only tested with sample data sets and issues of scalability of implementation is outside the scope of the current study.

6.3.1. Implementation methodology

System implementation is the demonstration of the feasibility of the proposed model. The desired solution was found after passing through several phases of evaluation and making gradual improvements to the initial prototype as detailed in (section 5.4). The final model was redesigned and developed according to the recommendations agreed in the first evaluation, and then the application of the model was implemented.

To implement the QPM-QGIS, a series of tasks needed to be undertaken. The first task was to setup the GIS interface to organise the data, to aid representation and link the main components of the personal place definition (i.e. time of perception, significances and spatial footprints). The second task was to allow the inputting and interpreting of qualitative spatial expressions, and ensure the quantitative capabilities were easily available. Finally, the user interfaces were implemented to provide the user with the ability to construct the place with all its constituents, while also making this easily accessible.

6.3.2. Implementation Overview

The implementation concentrated on facilitating the use of the current GIS as a means for users who are interested in representing neighbourhood and interrogating people's perceptions of places' data using a GIS environment. The prototype system was developed as an extension of conventional GIS to support constructing neighbourhood as a quantitative and qualitative structure. This extension tackles the spatial aspects and other associated characteristics.

The first task in the system's implementation is data organising, representing neighbourhood components and establishing links between these components. This was accomplished through enabling the creation of a folder unit in the table of contents (TOC), and assigning the respondent's name to it. This unit is used to hold all perceptions of a respondent as unique profiles, that is, the interpretation of the respondent's perceptions. Each profile comprises the four components of 'neighbourhood'; representation of spatial aspects (i.e. geometric representation of place in spatial layer), and the other characteristics, which have all been attributed to place location (i.e. time of perception and significances).

The second task is representing the spatial aspect of the neighbourhood. This was carried out through a layer of representation operating on top of the topologic data structure[12] of the GIS. This layer assists in establishing links between the qualitative spatial expressions and existing GIS quantitative representations. The layer is a means of allowing qualitative spatial expressions to be input to define a place's locations. Then the system interprets these expressions according to the qualitative spatial relationships between places, which are implicitly articulated in

[12] It is a mathematical approach used in GIS to define spatial relationships between features based on the principles of adjacency and connectivity.
http://planet.botany.uwc.ac.za/nisl/GIS/GIS_primer/page_22.htm

these expressions through the presence of some spatial prepositions or verbs (e.g., ‘next to’ or ‘between’).

The user interfaces are the last task of the implementation and last constituent of the structure. These interfaces play a fundamental role in the system operations by forming an intermediate means between the user of the system and other modules in the background of the system. It enables the user to setup the GIS environment for organising data; inputting data (i.e. spatial data e.g. qualitative expressions and also the associated non-spatial data); retrieval and data manipulations, and also to display the outcomes back to the user (see sequence diagram in Figure 6.1).

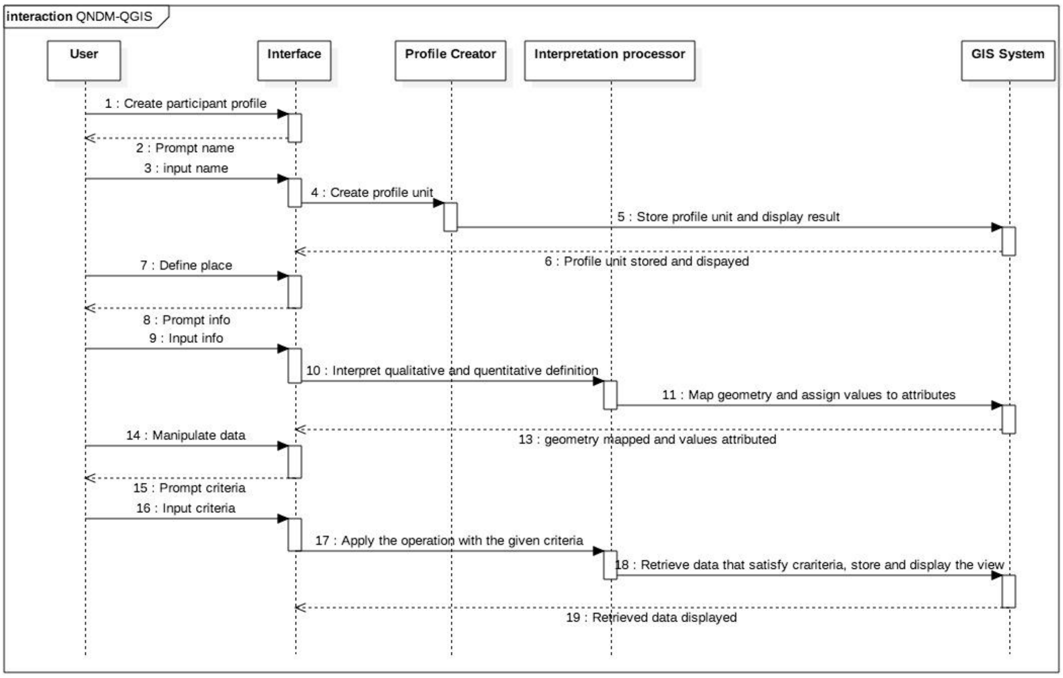


Figure 6.1 The sequence of process to construct neighbourhood in GIS

To implement the three tasks mentioned above, four plug-ins[13] were developed using Python[14] for Quantum GIS. Each plug-in has user interface/interfaces and also modules in the background to perform particular functions. The first plug-in is for setting up the environment to organise the data and link components together. The two other plug-ins are for defining the spatial aspects of neighbourhood (i.e.

[13] A plugin is an additional software component that is installed onto an existing computer program to allow performing additional features. More information is available at: http://www.computerhope.com/jargon/p/plugin.htm

[14] Python is a high-level programming language. More information is available at: https://www.python.org/doc/essays/blurb/

boundary and interior places) and associated characteristics, and the last one is for facilitating the retrieval and manipulation of the modelled data.

As graphical user interfaces (GUI), the user interfaces were built using (Qt Designer) widgets such as command buttons, text boxes and option buttons. The following tools were utilised in the prototype's implementation:

Quantum GIS: is a freely available cross-platform desktop geographic information system (GIS) application that allows data viewing, editing and analysis [133].

Qt Designer: is the Qt tool for designing and building graphical user interfaces [134].

PyQt: is the Python wrapper for the Qt library, responsible for rendering the GUI and interacting with it. The interface layout is described via *.ui files created using Qt Designer. The interactions between GUI components and event handlers were implemented in Python using PyQt4[15] bindings.

PyQGIS: is the QGIS Python API, which allows the plugins to interact with the projects and layers in Quantum GIS. It also provides some utilities, which the plugins rely on, for example computing the centroid of polygons or its buffer zones [135].

6.3.3. System Architecture and Database Design

System design is the process involving the definition of the architecture, components, modules and interfaces for a system to satisfy specified requirements. This section provides the design of different components for the proposed Qualitative GIS system. This involves the system architecture and spatial database design where the spatial and non-spatial attributes are stored.

System Architecture

The nature of the data representation and the mechanism for handling data in GIS, as sophisticated software, is a special case. The spatial databases (e.g. shapefile or geo-database) store the quantitative spatial attributes (i.e. geometry) and the

[15] PyQt4 Python bindings for the Qt cross platform GUI toolkit. More information is available at: https://pypi.python.org/pypi/PyQt4

associated non-quantitative spatial attributes (e.g., place name). Moreover, the project file (e.g., .qgs file in Quantum GIS or .mxd in ArcGIS package) keeps other data such as the user's configuration information for the interface (e.g. layers' colour or order of the layers…etc.). In this implementation, the information that is necessary to materialise the neighbourhood concept in front of the user is set up.

Accordingly, the design was implemented to satisfy the required **interfaces** and **modules** needed for extending GIS, with plug-ins used to support place component representation and also data manipulation.

The Qualitative GIS prototype system consists of a set of modules (see Figure 6.2). A graphical user interface (GUI) enables the user to create a participant folder and assign its name. The relevant module receives the request from the user interface, and creates the profile in the TOC under the chosen name. Another GUI facilitates the delineation of the boundaries and inputting values of the associated non-spatial attributes. A further GUI assists with delineating interior places within the neighbourhood by allowing the input of qualitative spatial expressions that describe a place's location according to qualitative spatial relationships with other places in the scene.

The relevant modules for depicting the boundary and interior places of the neighbourhood are responsible for processing the descriptions received from the user interfaces, and executing the appropriate spatial interpretations according to the description type. The modules also store the generated spatial layer in a spatial database, and display the output on the system interface. In addition, the modules assign the layers generated to the relevant participant's folder in the TOC.

Furthermore, another GUI facilitates the qualitative manipulation of the processed information by allowing the retrieval of the generated layers, or part of them, based on specific attribute/attributes values. It also enables the user to select some geo-processing analysis (e.g. union and intersect). The relevant modules are responsible for processing the request from the user interface and retrieving the desired information.

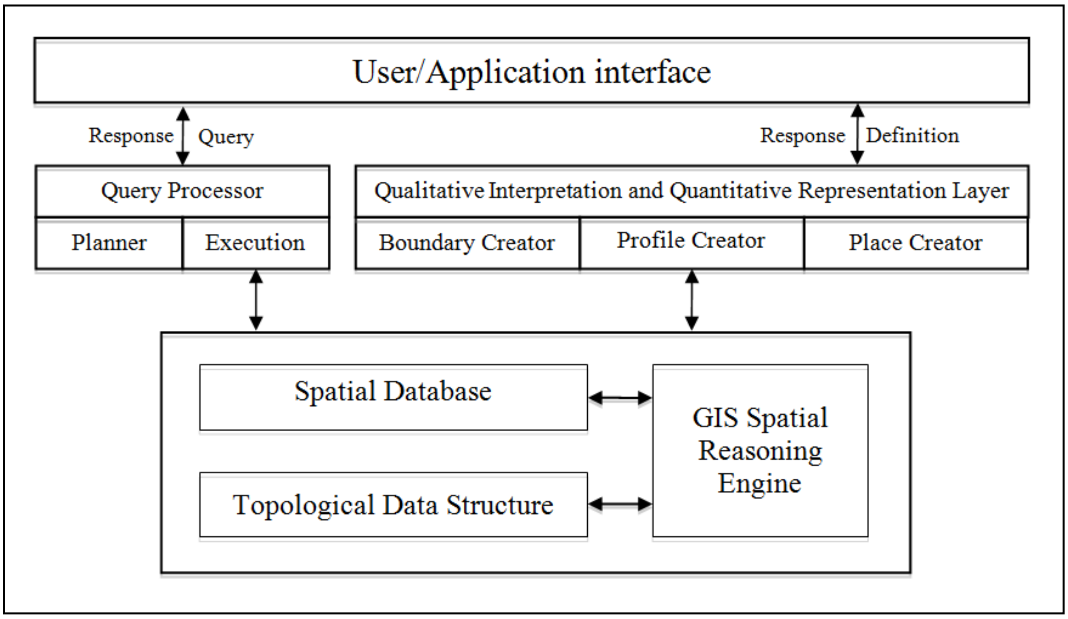


Figure 6.2 System Architecture

Database Design

As stated above, in many GIS packages, spatial attributes and non-spatial attributes are stored on a spatial database, and some other information is kept in the user interface and stored as a project file on the system. The data that needs to be stored in the spatial database includes the spatial and non-spatial information for the boundary as well as the interior places. For each entity, a different table schema has been designed. The other entities (i.e. personal element and unique profiles of perceptions of neighbourhood), are stored in the project file.

The design of the boundary data table is shown in Figure 6.3. This table contains ID, as the primary key; the name, which is the name of the area designated by the participant; belong_to, which is a reference to the appropriate profile; type, which is the type of neighbourhood; period, which is the period of perception; and finally geom, which is the geometric polygon representation of the boundary.

The schema of the interior place table is shown in Figure 6.4. This shows the name of the place designated by the participant; the period, which is the period of perception; time of day (i.e. the time of day the perception occurred); significance of the place to the participant; user (i.e. the one who utilises the place); and finally, geom, which is the geometric polygon representation of the place. The schema of the profile table is shown in Figure 6.5. This table comprises ID as the primary key and the name of the participant. Figure 6.6 shows the Entity Relational (ER) design of the spatial database for linking neighbourhood components.

Place boundary		
PK	ID	int
	name	string
	Ptfle_ID	int
	type	string
	period	string
	belong_to	int
	geom	gometry

Figure 6.3: Database table design for the place boundary data

Place location		
PK	ID	in
	name	string
	Bondry_ID	int
	Ptfle_ID	int
	time	string
	significance	string
	user	string
	period	string
	geom	gometry

Figure 6.4: Database table design for the perceived place data

Profile		
PK	ID___________	int
	Partcpt_name	string

Figure 6.5: Database table design for the profile data

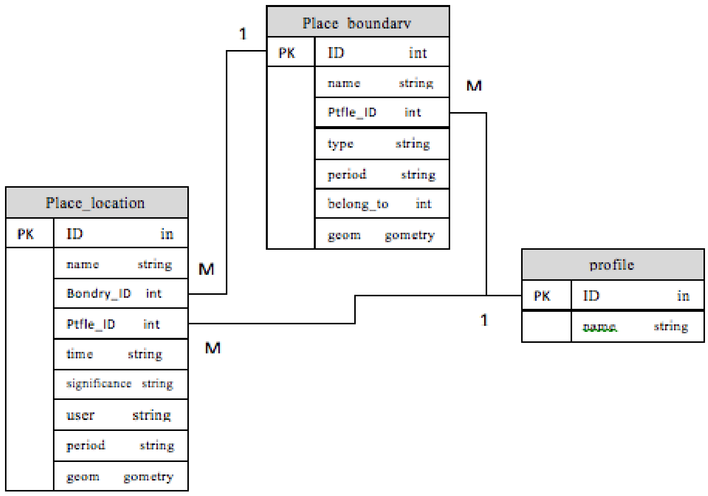


Figure 6.6: Database table design for linking neighbourhood components

6.3.4. Quantifying the location of Qualitative Place

Prior to the application of the model in GIS, this section deals with the quantitative modelling of relative place that is characterised by an ambiguous spatial footprint (i.e. a place that is defined based on its spatial relationships with other places). This can be done in many ways, especially as many efforts in the literature have been made concerning the computational modelling of interpretations of vague spatial footprints. It is important to emphasise that the exact size of the footprint is a research question that is outside the scope of this work.

In this work, a buffered zone for automatically delineating the different types of spatial expressions' footprints has been utilised. In summary, an experiment has been conducted to calculate the average distances between places in a built up environment (i.e. an Ordinance Survey (OS MasterMap) dataset containing 986 buildings (polygons)). This setup largely simulates the spaces between places in a neighbourhood environment in a systematic way. The aim of this experiment was to specify a constant buffer distance for automatically delineating the expressions' footprints from the border of the ROs (see Figure 6.7). This guarantees that the delineation, retrieval and manipulation of these places will be performed in a systematic and constant manner. A further explanation of the experiment is provided in Appendix D.

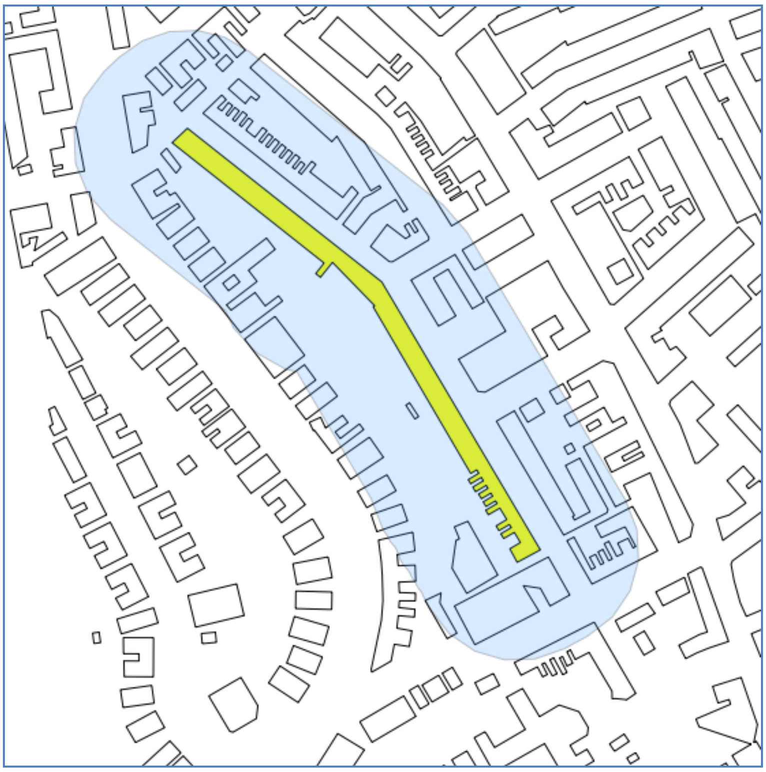


Figure 6.7 The yellow colour represents the RO, and the shaded section represents the buffer footprint

The experiment provides an idea of the average distance between objects in an urban setting, which is useful for sketching neighbourhood components, as required for the research. Descriptions of how this buffer zone has been constructed for the different expressions are presented in the following section as part of the model's application.

It is important to emphasise that the implemented system allows the size of the buffer to be altered as the user sees fit. However, identifying the distance used is necessary to maintain a fixed measurement for the delineation of footprints, and to guarantee that the delineation, retrieval and manipulation are performed in a systematic and constant manner.

6.4. Application

This section demonstrates the application of the model using a scenario to construct a neighbourhood using the prototype. This application is presented as follows: it starts with preparing the GIS environment to represent the neighbourhood components. Then defining the spatial aspects of the neighbourhood, whether initially describing boundary or defining interior places. This definition includes associating the significances and time of perception. This is illustrated using examples from the methods of data retrieval and manipulations.

6.4.1. GIS environment preparation

The first phase in system implementation is data organisation and linking. This is done by enabling the user to create folder units in the table of contents (TOC) in the GIS's main interface under the respondents' names. The procedure is required to prepare the GIS environment for the subsequent procedures to link each unique perception's elements together.

In this phase, the first component of the model is materialised, that is, the representation of the personal element in a GIS setting. Each unit contains all perceptions expressed by a respondent, whether this respondent is an individual expressing his/her perceptions, or a group of individuals expressing their common perceptions. This is implemented through a pop-up window (see Figure 6.8) that allows the user of the system to input the folder's name (i.e. the respondent's name) and it prepares for the subsequent procedures in the background. Figure 6.9 demonstrates the system's behaviour when the user enters the name and clicks o.k.

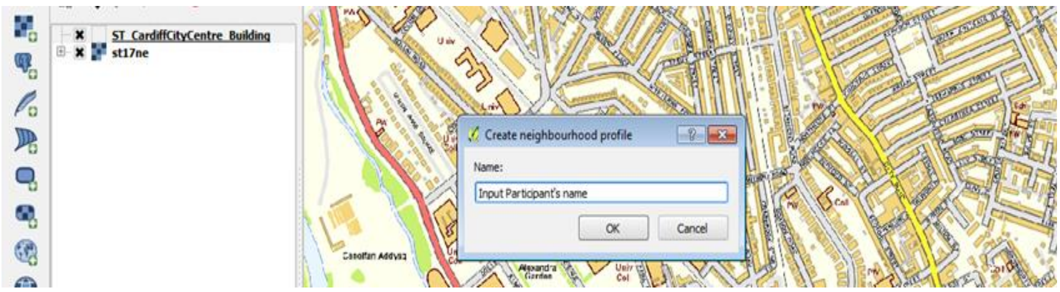


Figure 6.8 The popup window for creating the organisational unit

System behaviour:

Figure 6.9 The system's response; the unit is created, and the name assigned and displayed in the TOC

6.4.2. Spatial Description

The second phase in the system's implementation is defining the spatial aspects of neighbourhood and attaching other qualitative characteristics. Describing either a place boundary (i.e. the boundary of a neighbourhood) first or defining a place location (i.e. interior places) forms the description. Therefore, the user has the option of leaving the definition of the boundary to a later stage until defining the internal places.

As the work focuses on spatially modelling the notion of 'place' in GIS, this prototype does not record all possible qualitative characteristics of the neighbourhood. It demonstrates the applicability of the model and its capability of recording and associating qualitative characteristics of place to its spatial constituents in a GIS environment.

a) Place Boundary Definition

A definition of the neighbourhood boundary is formed by utilising a specially designed GUI (see Figure 6.10) that allows the user to delineate neighbourhoods' boundaries and to record the relevant qualitative characteristics. The qualitative characteristics of the boundary that were implemented are: 1) 'Belongs to', which is an attribute used to attach and include the envisaged boundary shapefile[16] under the associated participant's profile. 2) 'Neighbourhood type', which is an

[16] Shapefile: is a vector data file to store geometries and attributes of a geographic feature, and contains one feature class (i.e. polygon, line or points). *Definition - Esri support GIS dictionary*; available at: http://support.esri.com/other-resources/gis-dictionary/term/shapefile

attribute that comprises the values of neighbourhood types. These types were identified based on the literature review as 'my neighbourhood' in general, 'home' neighbourhood, 'work' or 'locality'. 3) 'Perception time', which is an attribute that represents the time dimension. The values of the implemented list comprise present, past, childhood or blank. However, these lists are modifiable and can be adapted as the user of the system sees fit.

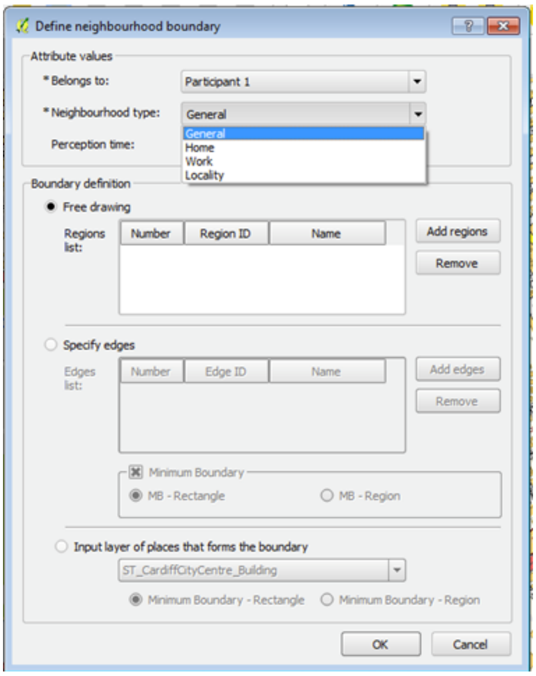


Figure 6.10 Place boundary definition interface

Two lines are available for defining the boundary; either delineating of the boundary by the user, and this can be done using two methods, or the user can ask the system to automatically delineate a borderline (i.e. polygon feature class using convex-hull method[17]) around a predefined spatial layer that holds group of features (e.g., interior places). Consequently, the system supports the spatial description of the boundary using three different methods as follows:

- 'Free drawing' method: to enable the user to freely delineate the boundary as a region or more than one region. After accomplishing the procedure, the system responds and generates a shapefile containing all the regions that have been

[17] Convex-hull is the smallest convex polygon that envelops a group of features such as points. *Definition - Esri support GIS dictionary*; available at: http://support.esri.com/other-resources/gis-dictionary/term/convex%20hull

defined by the user, and then adds this shapefile to the TOC and displays the generated features on the map (see Figure 6.11).

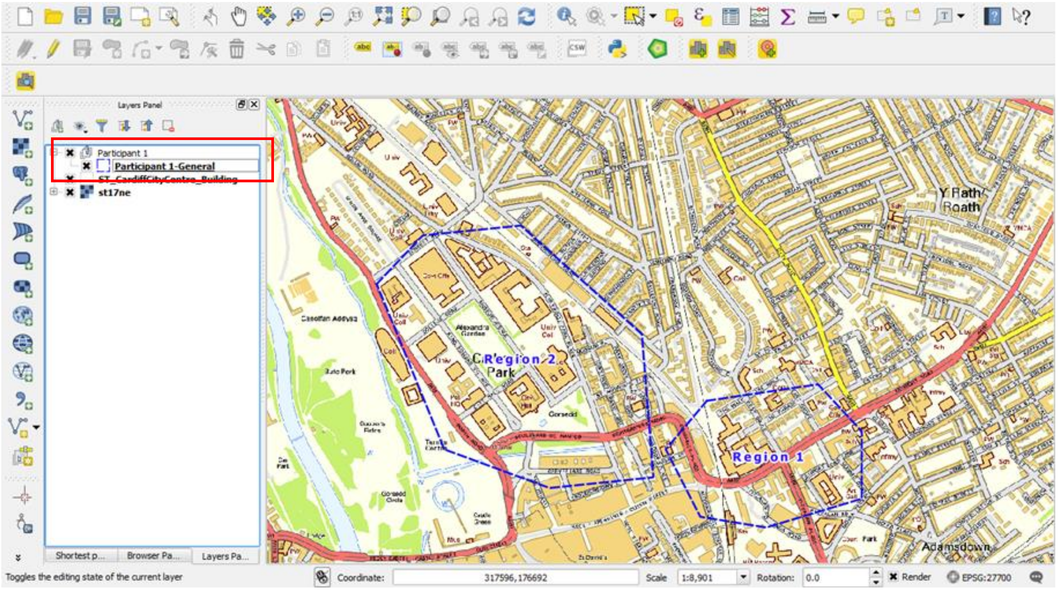


Figure 6.11 The system's response after running the plug-in when using the 'Free drawing' method

- 'Specify edges' method: the system enables the user to specify the edges of the neighbourhood by picking up and copying existing places, as desired, from a base map (see Fig 6.12). Then, the system responds and generates a shapefile containing these edges; adds the shapefile to the TOC, and displays the generated features on the map (see Fig 6.13). The system also offers an additional choice of automatically generating a minimum boundary (MB) that surrounds these edges (see Fig 6.14). Two options are available, that is, MB - Region or MB – Rectangle.

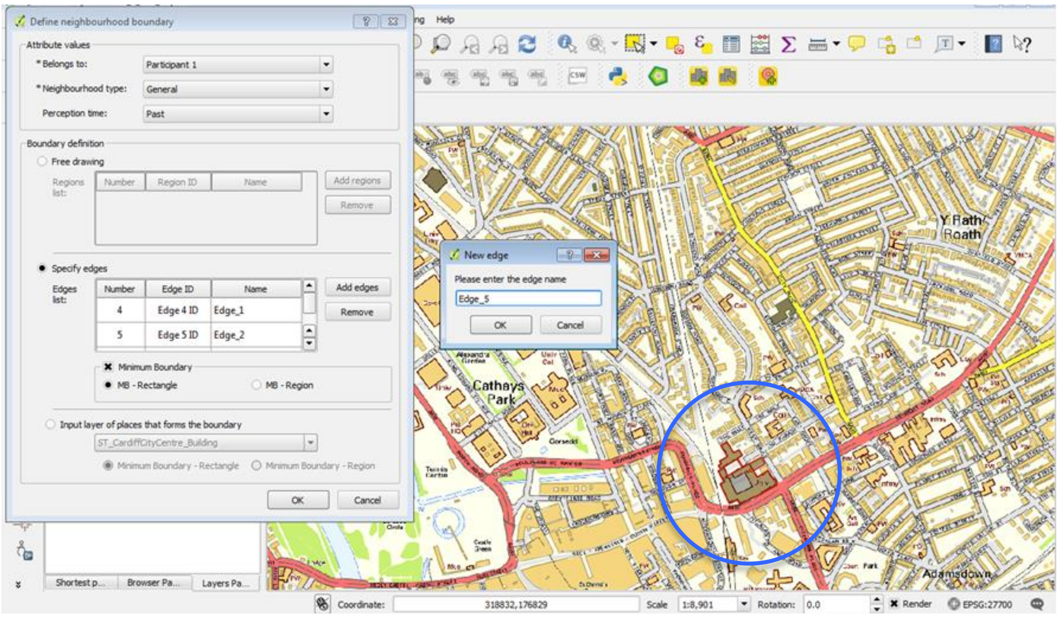


Figure 6.12 a The user specified an edge by copying existing place, and then rename it.

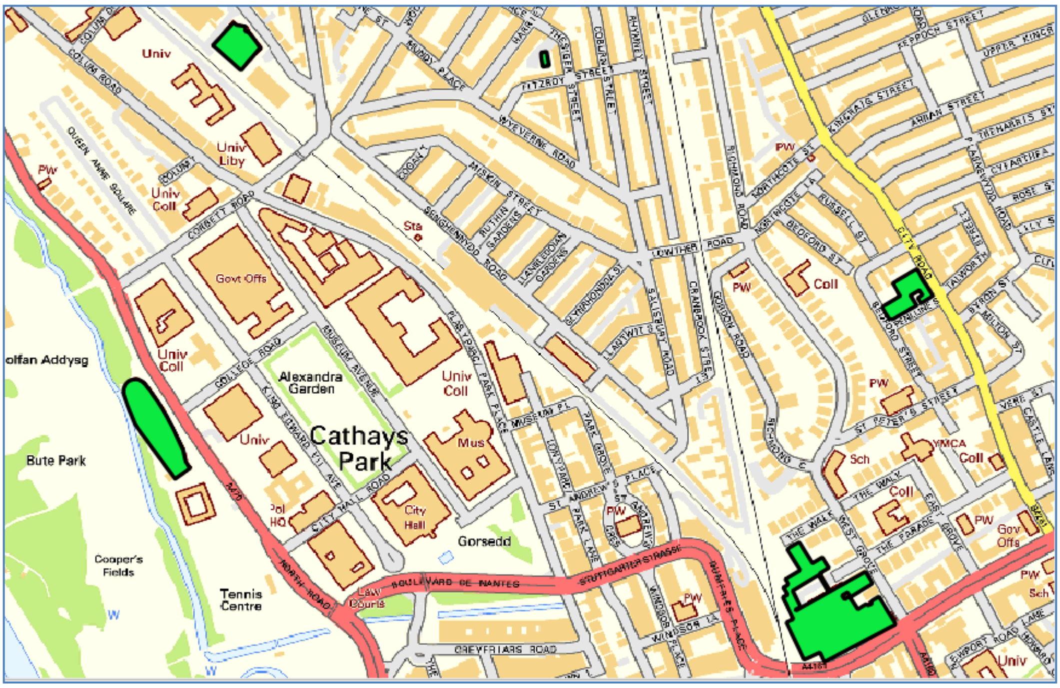


Figure 6.13 b: The system's response when using the 'Specify edges' method without selecting the 'Minimum Boundary' option; the green objects (places) represent the edges

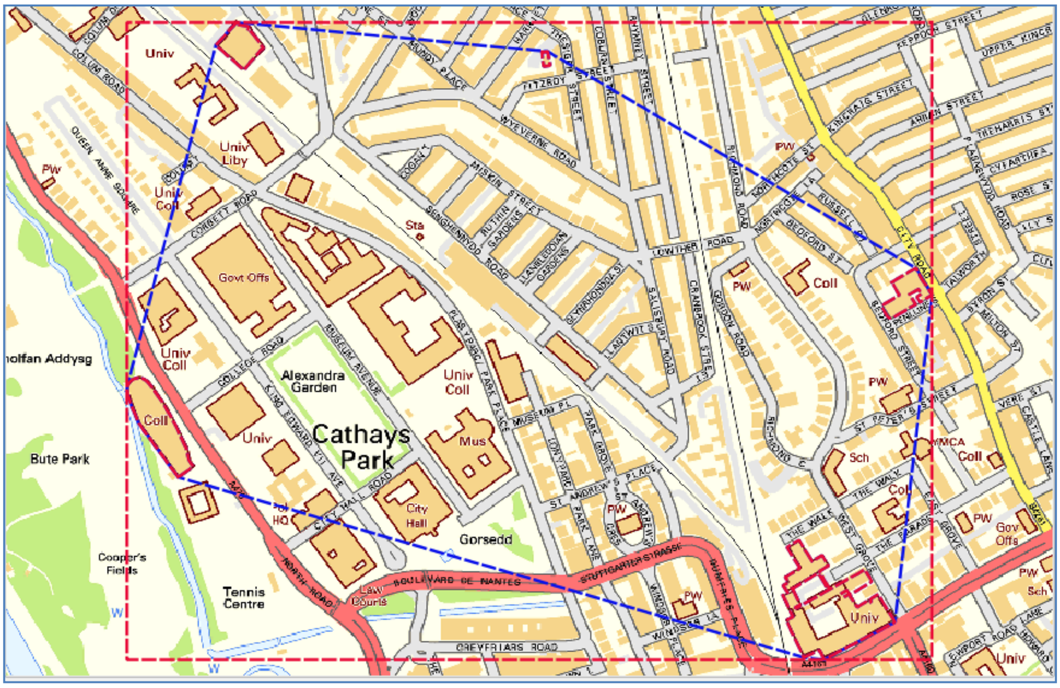


Figure 6.14 c: The system's response when using the 'Specify edges' method, and selecting the 'Minimum Boundary' checkbox; in one scenario the red dotted polygon represents the MB-Rectangle, whereas the blue dotted polygon represents the MB-Region for the same edges but in the other scenario

- 'Input layer of places that form the boundary' method: The system supports the automatic delineation of the boundary by enabling the user to select a layer from the TOC. This layer is supposed to contain predefined interior places. The system reads the selected layer's features and, in a new shapefile, draws a boundary that surrounds these features (see Fig 6.15 and Figure 6.16). Two options are also available to complete the generating of the boundary (MB), either Minimum Boundary - Region or Minimum Boundary – Rectangle.

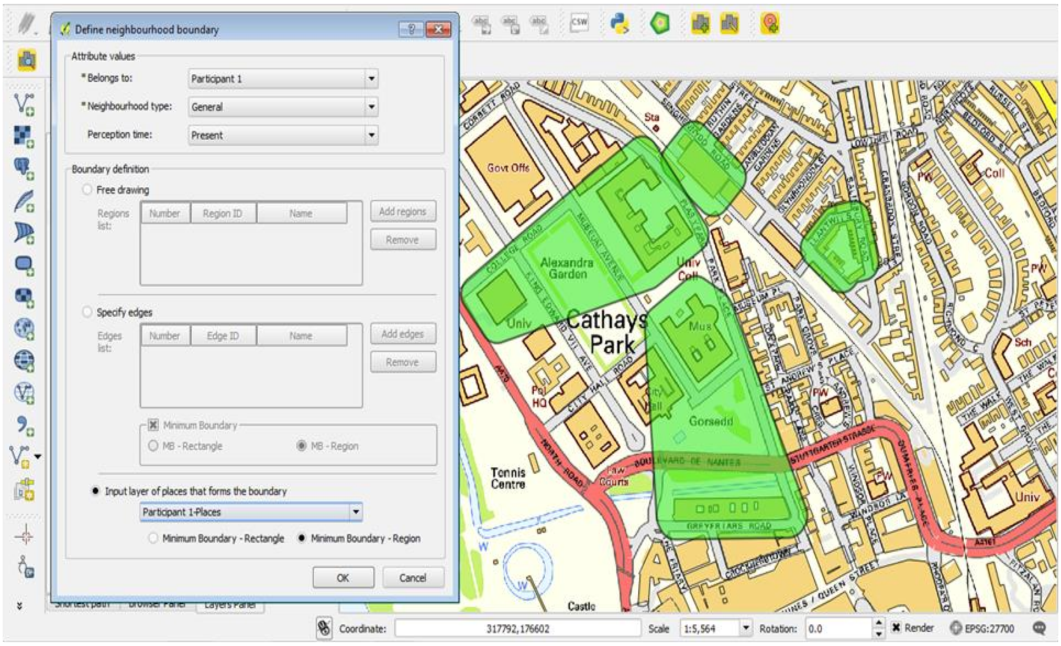


Figure 6.15 Layers retrieval

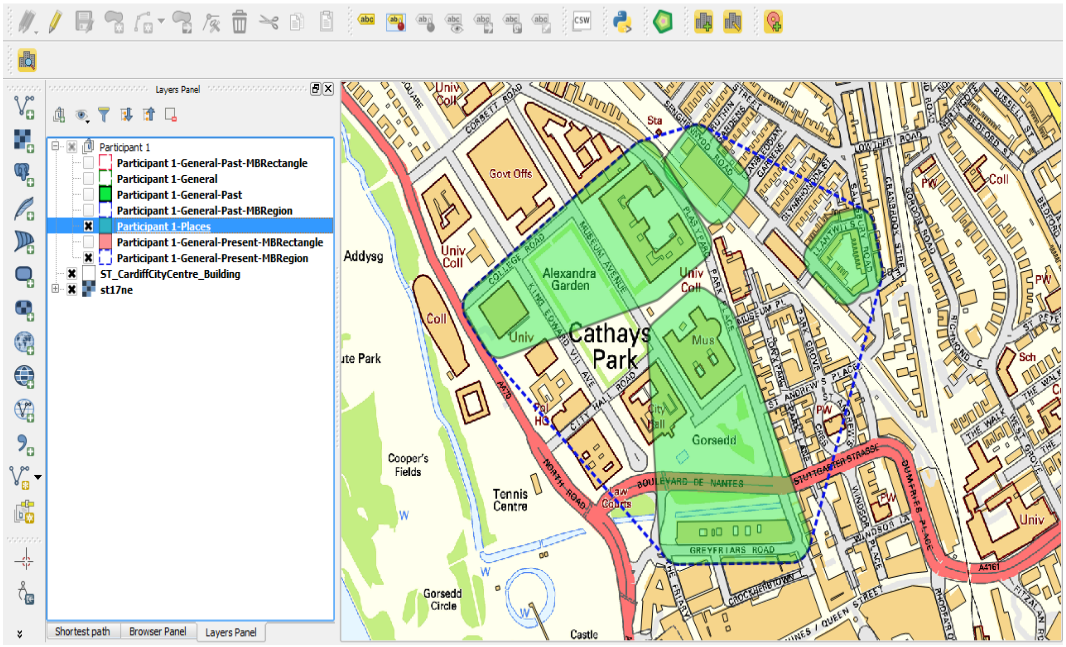


Figure 6.16 The system's response when selecting the 'Minimum Boundary-Region' option; the blue dotted polygon represents the output of the system, that is, the boundary in a new layer.

It is important to mention that, in all of the above scenarios for the boundary's definition, the default shapefile name that is going to be generated will include the attribute values specified by the user following the pattern:

AttributeName[AttributeValue1(,AttributeValue2,AttributeValue3,...)]

For example (see TOC part in Figure 6.16):

[Profile]- [Participant 1]-NeighbourhoodType [General]-PerciptionTime[Past]-BoundaryDefinition[MBRegion]

Displaying the names in the TOC in this format will remove ambiguity and make it easier for the user to differentiate between the layers. This is designed in order to facilitate the retrieval process for the layers when manipulating the data, as will be demonstrated later on in the 'Manipulation neighbourhood data' plug-in section.

b) Place Location Definition

This commences by utilising a specially designed GUI (see Fig 6.17) that allows the user to define each place location (i.e. interior place of interest) within the neighbourhood, and to record the relevant qualitative characteristics of this place.

The qualitative characteristics of the place location that were implemented are: 'Place name' attribute, which is required to designate a name to the perceived place. 'Period of perception', which is an attribute for recording the time dimension. 'Time of the day' attribute, which is an optional attribute used to record the time dimension as well, but in more elaborate way. 'Place significance', which is an optional attribute for imbuing perceived place with qualitative meanings (e.g. feelings evoked by the place, usage or activities that took place). 'Place users', which is an optional attribute for defining the type of people who utilise this place. Regardless of the 'Place name' attribute, all other values for the other attributes can be modified and adapted as the user sees fit.

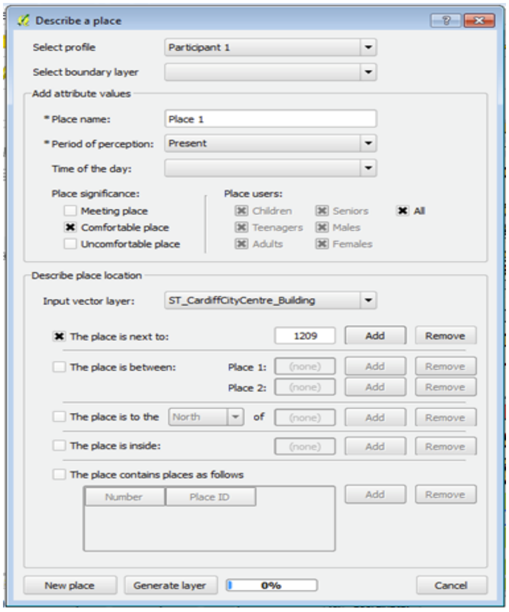


Figure 6.17: The GUI for defining interior places

In the non-traditional method that is used in the GIS environment, the system offers an alternative approach, which is built on top of the GIS, to define place location. The analysis phase in the previous chapter (section 5.1) identified the prototypical qualitative expressions that describe place location, while the experiment that was conducted in (section 6.3.4) above specified a stable buffer distance for delineating the footprints.

The GUI facilitates the spatial description of a place's location by enabling the inputting of the prototypical qualitative spatial expressions. The five formulas used to convey these qualitative descriptions of place location are as follows:

I. A place next to a place

The expression is used to record and represent the relative place of interest that is located next to a place (i.e. reference object (RO)). For example, “the hangout location is next to the sports centre”. In this scenario, the hangout location, which is the located place (LO), is defined based on its spatial relationship with a defined place RO, that is, the sports centre. The GUI designed (Fig 6.17) allows the defining of the expression by allowing the user to select the RO from the base map. Then the system captures the footprint of the RO, before applying an algorithm to draw a buffer zone from its border using the fixed distance identified (see Fig 6.18).

Figure 6.18 The yellow object represents an existing place (defined place) that is selected by the user from the base map, and the shaded buffer represents the location of the relative place's footprint- the 'next to' area

II. A place between two places

This expression is used to record and represent a relative place of interest that is between two places, whether these places are defined (DP) or relative (RP); for example, "a site where we meet usually between the Student Union and the National Museum." The prototypical 'between' location is located at the midpoint between two objects, and then gradually drops off towards the two ROs [43]. The solution represents the 'between' footprint as the whole area covering the footprints of the two ROs, with the buffer zones around them and the area in between altogether (see Figures 6.19, 6.20 and 6.21). The designed GUI (Figure 6.17) allows the definition of the expression by allowing the user to select the two ROs from the base map. Then the system captures their footprints before applying an algorithm to draw a buffer zone from the border of the ROs and drawing a polygon that surrounds the two ROs and the area in between (i.e. convex-hull method).

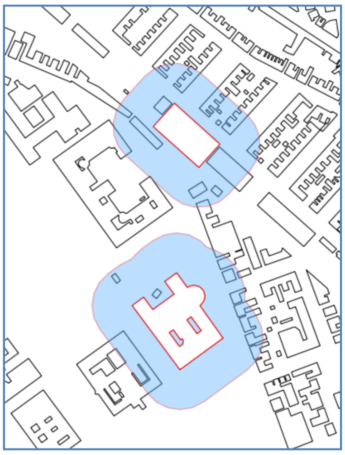


Figure 6.19 The white objects represent the places that have been selected by the user; the shaded cyan areas represent the buffers that the system calculated

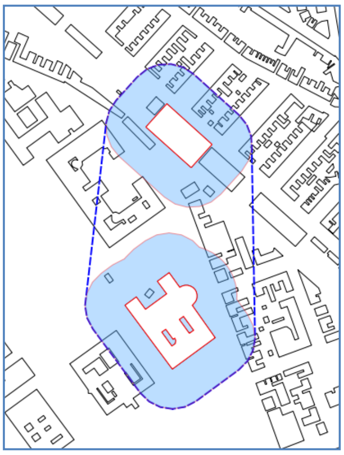


Figure 6.20 A polygon (blue dashed closed line) covering the two buffers that have been calculated in (a)

Figure 6.21 The green shaded area represents the 'between' footprint, which is the location that is required to be plotted

III. A place in a specific direction from a place

This expression records and represents a relative place of interest that is located in a specific direction from a defined place. For example, 'the smoking area is to the north of the Students Union'. The solution defines the location of the smoking area, which is the relative place (i.e. LO), by representing a buffer zone footprint that is located north of the RO. The designed GUI (Figure 6.17) allows the defining of the expression by allowing the user to select the RO from the base map, and also select the appropriate direction. Here, the system captures the footprint of the RO and applies an algorithm to first identify the centroid of the RO. It draws a line that crosses this centroid and divides the RO into two parts (e.g., north and south), and then draws a buffer zone from the border of the RO around the north part (see Figure 6.22). Ideally, it is supposed that all directional frames of reference (i.e. absolute, intrinsic and relative frame of reference) are implemented and can be selected as the user sees fit. However, as this implementation aims to demonstrate the applicability of the model, and prove the concept, the absolute frame of reference is implemented in this prototype.

Figure 6.22 The shaded cyan area around the yellow building represents the relative place (i.e. north area of the Students' Union building)

IV. A place inside a place

This expression is used to record and represent a relative place of interest that is located inside a place. For example, ‘the Lounge is situated on the third floor of the Students Union’. Similarly, the expression ‘***A place equals a place’*** is used to record and represent a relative place of interest that is at defined place. For example, ‘Cardiff's Winter Wonderland is situated on City Hall’s Lawn’. To represent both forms, an algorithm has been developed that defines the perceived place of interest by duplicating the actual footprint of the RO itself, and allowing the user to attach the associated properties to the copied object (see Figures 6.23 and 6.24).

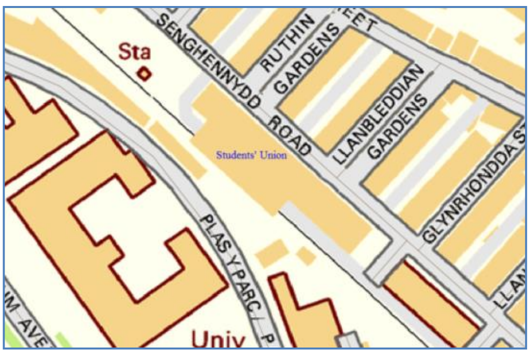


Figure 6.23 a: The RO (Students Union) on the Map

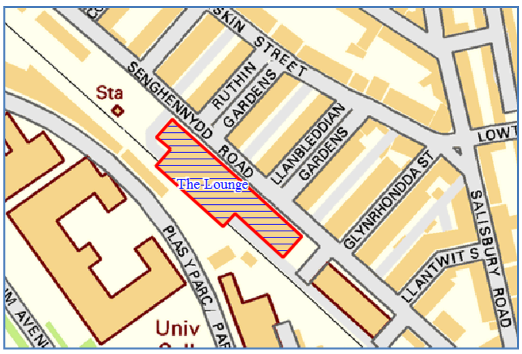


Figure 6.24 b: The projected place, which is located inside a place or occupies the whole place

V. A place contains a place/places

This expression is used to record and represent a perceived place of interest, which might be described as a defined place or as a compound place, covering a defined or relative place or group of places. For example, 'the area includes a small area of shops, a hairdressers, and a café.' To represent this small area (i.e. the perceived place of interest), which is at the same time a ***compound place***, the GUI allows the user to select the ROs (i.e. shops, hairdressers and the café) from the base map, and then the system generates buffer zones from the border of each RO. Next, it generates a polygon (i.e. convex-hull method) that contains and directly surrounds these new footprints to represent the border of the LO (i.e. in this example the small area) (see Figures 6.25 and 6.26).

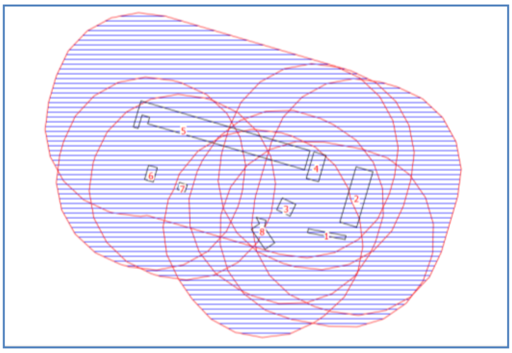


Figure 6.25 The ROs and buffer zones plotted around each one of them with the specified distance

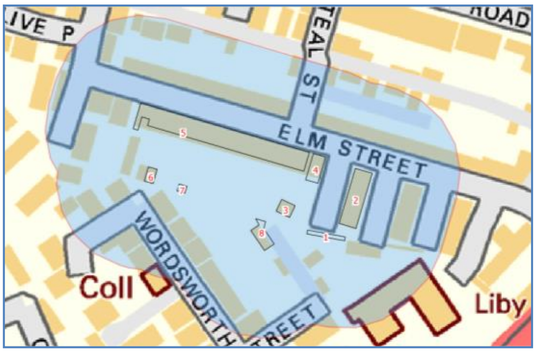


Figure 6.26 The shaded area shows a line boundary that represents the border of the area

Furthermore, perceived place location can be defined using only one expression, or can be described using multiple expressions. By completing the description of the perceived interior places, a shapefile will be generated to store all the geometrical representations of these places and their associated attributes.

Similar to the default shapefile name of the place boundary, the default name of the shapefile that is generated for describing the places' locations layer will include the attributes' names, as specified by the user, following the pattern

[Profile] - [Participant 1] - BoundaryLayer (if applicable) [General]-Places.

This makes it easier for the user to differentiate between layers, and facilitates the retrieval process of the layers when manipulating the data.

6.4.3. Manipulation operations

The capacity shown by the prototype to formulate the spatial aspects, as well as their associated characteristics, enabled the application of the GIS analysis capabilities over this fabric. The following operations have been implemented

- Selecting the desired profiles (layers) from a user's folder(s).
- Filtering the outputs of the selected layers on specific values of one or more attributes.
- Retrieving the data (and producing maps) based on specific criteria.
- Merging different neighbourhood profiles.
- Generating a common boundary for different neighbourhood profiles.
- Finding the intersection between different neighbourhood profiles.

The application of the developed system with complete and realistic scenarios for defining neighbourhood in the GIS as well as the range of manipulation and data selection and retrieval operation possible are demonstrated in chapter Seven next as part of illustrating the utility of the model.

6.5. Summary

The realisation of the model in a GIS was implemented using a concrete example, that is, the representation of 'neighbourhood' place concept. The ontological construct (spatial aspects, whether qualitative or quantitative forms) and a sense of place (i.e. time of perception and significance in relation to individuals) were all materialised as a single homogeneous component. In addition, the work has also focused on extending the GIS to allow the inputting of qualitative expressions of place location. Hence, two main aims were achieved: modelling all of the constituents of the place concept in GIS, and also automating the conversion of qualitative form of spatial location expression into a quantitative representation of place location.

This step aimed to test the feasibility of the model, and to facilitate the use of current GIS by non-expert users. The work has been designed to be a proof of concept, thus the individual processes that have been followed are not likely to be optimal but deemed sufficient for proof of concept. The system can be extended further by using more accurate representations of spatial relationships and by evaluating different methods for delineating the footprints of place boundaries.

Chapter 7

Evaluation - QPM-QGIS

7.1. Introduction

Chapter Six sets out how the QPM-QGIS was implemented and used for mapping neighbourhoods. This chapter will evaluate the QPM-QGIS by firstly demonstrating its effectiveness as a tool for modelling and manipulating place concepts in a GIS; secondly, by assessing the quality of the interpretation of the spatial expressions used to define the location of the neighbourhood, and finally, through a user-based evaluation of the quality of the implemented system.

In the first stage, a demonstration of the different types of operations that can be carried out on the neighbourhood profiles is presented. Next, a user-based evaluation that was carried out in two stages is described: firstly, to compare the researcher's own spatial interpretation (an expert from the research team who conducted the case study described in section 5.4) of neighbourhood extents against those derived automatically from the system, and secondly, by interviewing the expert to gauge his views on the utility of the proposed representation and the implementation of the framework.

7.2. Evaluation methodology:

The purpose of the evaluation phase is to validate and verify the effectiveness and utility of QPM-QGIS. A continuous evaluation process was implemented throughout the design and development phases. This chapter presents the final evaluation round that was carried out collaboratively with an expert from the case study research team. In addition, the effectiveness of the QPM-QGIS in representing and manipulating neighbourhood using real data is demonstrated.

In this context, the QPM-QGIS applications have been evaluated by demonstrating its ability to represent all components of a neighbourhood, that is, individualised spatial aspects, perceptions of time, as well as the associated significances. Moreover, the manipulations of these components for exploring the modelled data more fully, and inferring new information, have also been qualitatively measured.

Another objective of the evaluation has also been met, as for four different individual interviews all spatial expressions that describe the boundary of the neighbourhoods were extracted and then transformed into maps using a QPM-QGIS prototype. Subsequently, the resultant maps produced by the prototype were compared with the maps that had been digitised manually by the research team for the same neighbourhoods. The comparisons were achieved by calculating the extent of the spatial compatibility and the amount of difference between the two sets.

Finally, the social geography expert expressed his explicit subjective judgment of the feasibility of the QPM-QGIS and its application.

The next section is concerned with evaluating the outputs of the model's application when executing the manipulation operations. This will be done by showing the system’s capability of revealing a variety of views (profiles) and generating valuable new information. The diversity of the profiles can be quantified using the number of unique scenarios that are generated from the manipulation operations. Also, the outcomes’ quality can be evaluated through the value of the knowledge that is attained.

7.3. Effectiveness of the QPM-QGIS

This section demonstrates the application of the system developed using realistic scenarios for defining neighbourhood using GIS, as well as the range of manipulation operations possible. The main operations that can be performed are: aggregating the data into one profile (layer), splitting a profile into parts, and filtering the outputs based on specific criteria.

The manipulation operations enable, for example, the generation of a common boundary for a group of participants or for all participants. This may be appropriate if the user wants to split the modelled data into boundary-based stacks based on the respondents' type; for example, to generate a common boundary according to the perceptions of all teenage respondents, and a common boundary for all adult perceptions, in the present time. Measuring the intersection between the two groups can give an initial indication of the presence or absence of communication between the two groups. This is apart from the nature of this communication, or to what degree it exists. Another example is to explore the difference between a common boundary for teenagers in the present and a common boundary for teenagers in the past, both for uncomfortable places; this is possibly a way of discovering the changes that occur and methods for tracking the causes of the change. Moreover, this might be suitable for obtaining a public boundary for the complete neighbourhood, which is generated based on the definition of the residents themselves, instead of using existing boundaries such as administrative boundaries. Accordingly, the following manipulation operations have been implemented, and are set out with their relative examples below:

- Selecting the desired profiles (layers) from a user's folder(s).
- Filtering the outputs of selected layers on specific values of one or more attributes.
- Retrieving the data (and producing maps) based on specific criteria.
- Merging different neighbourhood profiles.
- Generating a common boundary for different neighbourhood profiles.
- Finding the intersection between different neighbourhood profiles.

Figure 7.1 shows the main GUI for manipulating the neighbourhood objects in the GIS.

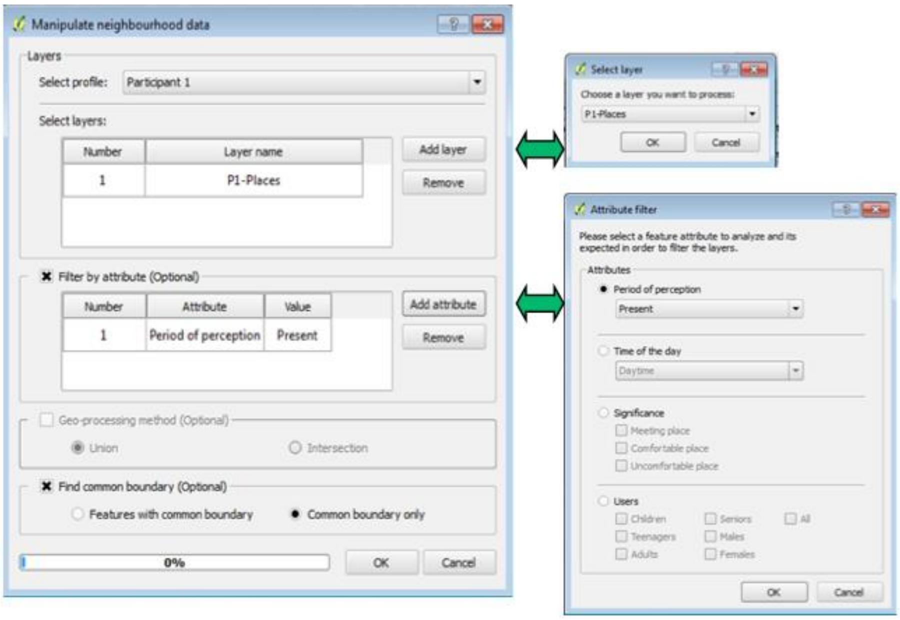


Figure 7.1: The main GUI and its pop-up windows for manipulating neighbourhoods

7.3.1. Creating Neighbourhood Profiles

In this context, two different neighbourhood perceptions have been mapped and represented using the QPM-QGIS prototype as follows: All places' locations (PL) within the two neighbourhoods in the present and the past were identified. Attributes that are associated with the PL(s) (i.e. internal places), such as time of perception and significance, were also specified, stored and linked. Then, the place boundary (PB), that is, the boundaries of the two neighbourhoods, was automatically generated by the system (see Fig 7.2 and 7.3), and the associated attributes, such as neighbourhood type and time of perception, were also specified, stored and linked. In such a case, the names of places are assumed to be unique to individual participants. Tables 7.1 and 7.2 explain the values of the internal places' attributes for both neighbourhoods in the present and past time. The temporal qualifiers are simplistic (e.g. the reference to the past may vary from one to another), or the time range may be different according to specific research requirements. The null value means an undefined value.

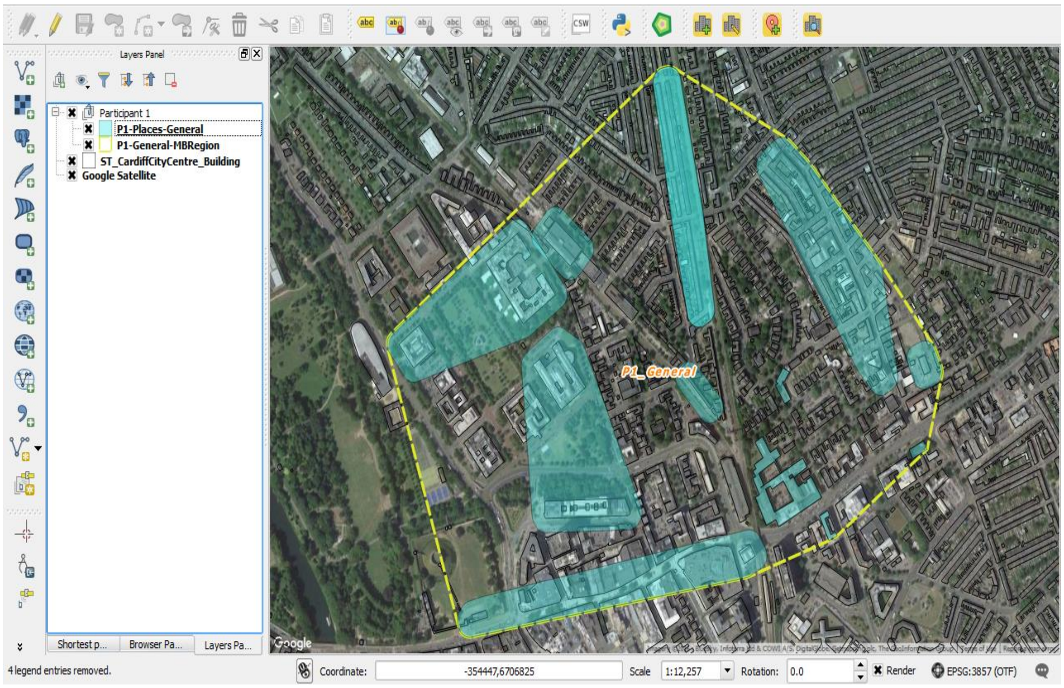


Figure 7.2: Perceptions of a neighbourhood's boundary by a given participant (Pt_1). The TOC section shows a folder unit under the participant's name containing the associated profiles. In the map view section, internal places of interest and the boundary are demarcated.

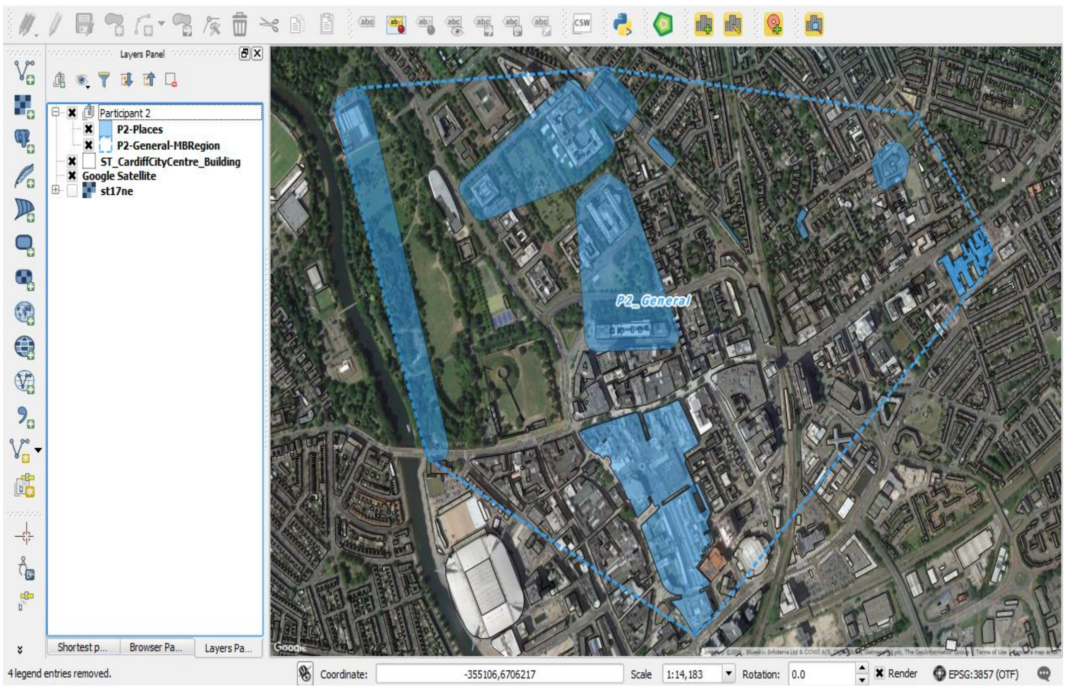


Figure 7.3 An instance of a neighbourhood's perception for Participant 2 (Pt_2)

Table 7.1: The values of the attributes that are associated with the PL (s) of Pt1's neighbourhood.

place_name	period	time_of_day	significance	users
Cafe	Present	Daytime	Meeting and comfortable	All
Relaxation area	Present	Daytime	Meeting and comfortable	All
Shopping area	Present	Daytime	Meeting and comfortable	All
Walking area	Present	Daytime	Meeting and comfortable	All
Place 1	Present	Evening	Uncomfortable	Teens, adults
Residence	Present	Null	Meeting and comfortable	Adults
School of Computer Science	Present	Null	Meeting and comfortable	Adults, seniors
Student Union	Present	Null	Meeting and comfortable	Adults
Home	Past	Null	Comfortable	Null
Play area	Past	Daytime	Meeting and comfortable	All
Shops	Past	Daytime	Meeting and comfortable	All
School	Past	Null	Meeting and comfortable	All

Table 7.2: The values of the attributes that are associated with the PL (s) of Pt_2's neighbourhood.

Shopping area	Present	Daytime	Meeting and comfortable	All
Mathematics School	Present	Daytime	Meeting and comfortable	All
Place x	Present	Evening	Uncomfortable	Teens, adults
Student Union	Present	Null	Meeting and comfortable	Adults, seniors
Relaxation area	Present	Daytime	Meeting and comfortable	All
GP	Present	Null	Null	All
Residence	Present	Null	Meeting and comfortable	Adults
Walking area	Present	Daytime	Meeting and comfortable	All
GP	Past	Null	Null	All
Play area	Past	Null	Meeting and comfortable	All
Residence	Past	Null	Comfortable	Null
School	Past	Null	Meeting and comfortable	Children, Teens

7.3.2. Filter and Selection Operations

Data from a user's profile can be extracted by specifying the constraints on any of the stored attributes. For example, the data can be filtered to retrieve the places' locations (PL), as in the profile of Participant 1, where the time of perception = "present". This can be summarised as follows:

Extract Pt1 (PL) where {PL.period = 'present'}

Result:

Figure 7.4 The place locations in the profile of Participant 1 in the "present" time

Discussion:

The resultant map (profile) shows the system's ability to partition the information by extracting the neighbourhood data for the present time only. This might be useful in practice, for example to differentiate between places that are utilised in the present and places utilised in the past, and also for the preparation of data for further investigation, as planned in this scenario.

7.3.3. Boundary Generation

The boundary for a profile(s) or for a selection of neighbourhood profiles can be automatically generated by the system. For example, a boundary can be generated for the already filtered profile in a previous operation (i.e. the profile of Pt_1, where the time of perception = "present"). Prior to the generation, the retrieved information can also be re-filtered based on other attributes values such as 'Time of day'. This can be formulated as follows:

Find Pt_1 (PL.boundary) where {period = 'present'}

Result:

Figure 7.4 The boundary that surrounds internal places of Participant 1 in present time

Discussion:

The capacity of the system to generate boundaries around neighbourhood profiles is useful for the purpose of: a) visually delineating the borders of the neighbourhood in question, b) comparing the spatial extent of different neighbourhoods, and c) facilitating operations on multiple neighbourhoods, such as overlapping, merging and intersecting different neighbourhood profiles.

7.3.4. Merging Neighbourhood Profiles

Spatial features from multiple sources (profiles) and of the same geometry type (e.g. polygon and polyline features) can be merged into a new, single output dataset [136]. In QGIS, a polygon feature class, for example, can only be merged with another polygon feature class, but it cannot be combined with a line feature class.

This operation may be useful for merging the perceptions of a neighbourhood according to different participants (individuals) to obtain a collective view of neighbourhood. This involves merging stored or derived internal places, or neighbourhood boundaries from two different profiles or more, whether these profiles belong to one participant or a group of participants. Prior to the merge, the retrieved data can be filtered based on the specific value/values of associated attributes.

For example, a new view of the data can be obtained by merging internal places (i.e. PL), in present time, for the neighbourhood of Pt_1 (profile 1) and the internal places of the neighbourhood of Pt_2 (profile 2). This can be formulated as follows:

Find Pt_1 (PL) U Pt_2 (PL) where {period = 'present'}

The result of the operation is shown in Figure 7.6. Similarly, for merging boundaries, a new profile of the data can also be generated by merging the boundaries of the neighbourhood of Pt_1 with the boundaries of the neighbourhood of Pt_2 in present time. The operation can be formulated as follows:

Find Pt_1 (PL.boundary) U Pt_2 (PL.boundary) where {period = 'present'}

Results:

Figure 7.5 Places' locations for Participants 1 and 2 in present time were combined and stored in a new profile (layer)

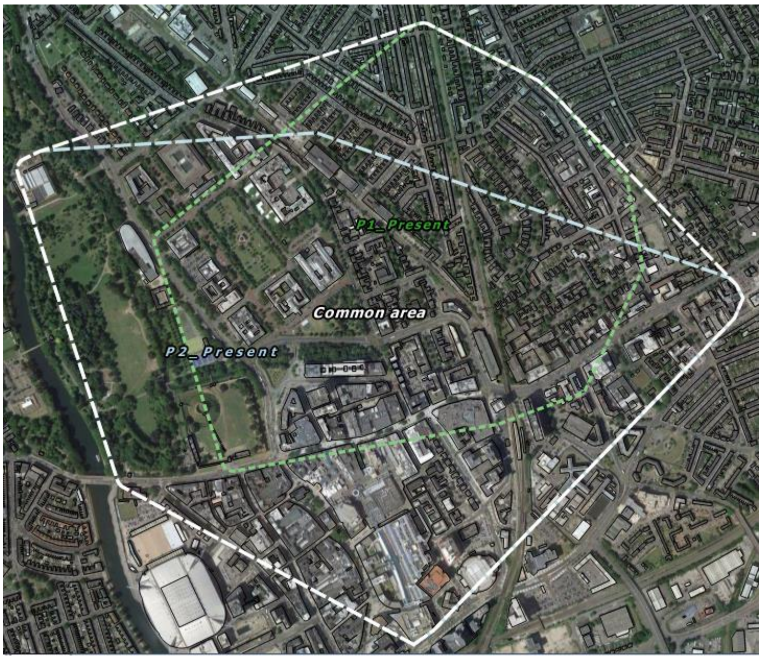


Figure 7.6 The boundaries of the neighbourhoods of Participants 1 and 2 in present time were combined and stored in one new profile (layer). The white dotted border represents the merged boundaries

Discussion:

This operation has the potential for the user to, for example, carry out comparison exercises between the diversity of stored or derived profiles by splitting the data into bundles (i.e. boundary-based or place-based stacks, based on specific criteria); the system can facilitate such operations efficiently.

7.3.5. Intersecting neighbourhood profiles

This operation involves finding the shared locations between stored or derived internal places or boundaries for two different profiles or more. Prior to the retrieval, the data can be filtered based on the value/values of the associated attributes. For example, a new interpretation of the data can be deduced by finding the intersection between internal places, or the boundaries of the neighbourhood of Pt_1 and the neighbourhood of Pt_2 in present time. The operation can be formulated as follows:

Find Pt_1 (PL.boundary) ∩ Pt_2 (PL.boundary) where {period = 'present'}

Results:

Figure 7.7 The intersection location between the two boundaries (profiles)

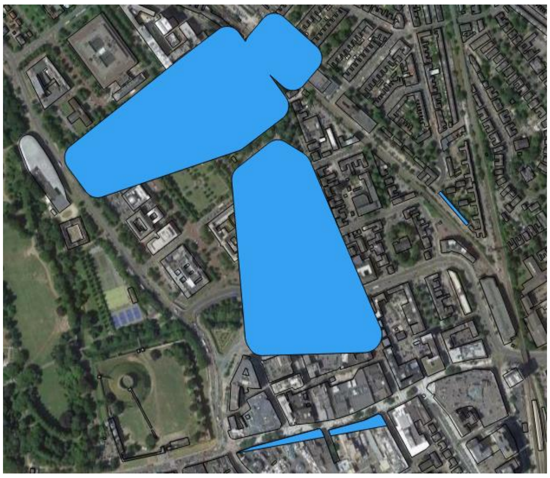


Figure 7.8 The shared location between the internal places of the two neighbourhoods (profiles)

Figure 7.9 The shared internal places within the intersection area of the boundaries

Discussion:

The results show the system's ability to extract the intersection, whether between boundaries or internal places' profiles. For boundaries, the system calculates the intersections (i.e. shared areas) between the retrieved boundaries of the two profiles, before generating a new profile containing a polygon that represents the intersection area (see Figure 7.8). For internal places, the system retrieves the shared internal places only (see Figure 7.9). Finding the shared internal places between neighbourhoods has two main benefits: it allows the precision of the location to be increased by zooming into the places of interest directly, instead of one relatively larger area; that is, the intersection area between boundaries. In addition, it prepares the associated attributes of these places for further manipulation using another operator, as demonstrated in the next operation.

7.3.6. Compound Operations

Executing more than one operation on profiles is a possible method for achieving a deeper exploration of the data. As stated in the previous example, applying the 'Intersect Neighbourhood Profiles' operator has resulted in the extraction of the PL(s) (i.e. shared internal places) between the two given neighbourhoods. This result paves the way for the execution of the 'Filter and Selection' operator, again to derive a new vision of the data by interrogating the values of the attributes. For example, the values of the significant attributes may be comfortable areas and uncomfortable areas (see Figure 7.11). Thus, this profile can be fragmented into more elaborate information to produce new profiles based on these given values (see Figure 7.12 and Figure 7.13). This can be summarised as follows:

Find Pt_1 (PL) ∩ Pt_2 (PL) where {period = 'present' and significance = 'comfortable'}

Or

Find Pt_1 (PL) ∩ Pt_2 (PL) where {period = 'present' and significance = 'uncomfortable'}

Results:

Figure 7.10 The internal places that satisfy the conditions were extracted

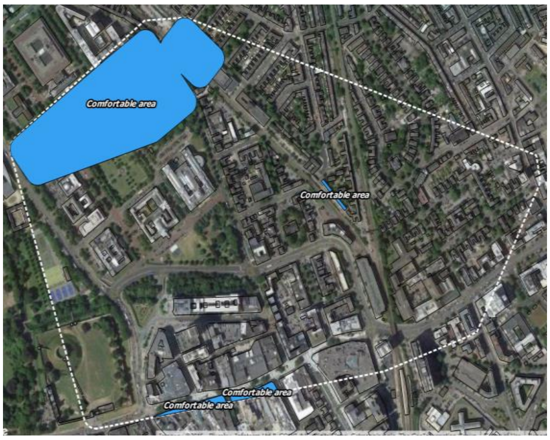


Figure 7.11 The comfortable shared internal places (profile)

Figure 7.12 The uncomfortable shared internal places (profile)

Discussion

The results show the controllability that is granted to the user to explore the data more fully by applying compound operations. This flexibility permits the preparation of the profiles for further investigation in an iterative way, as well as the interrogation of data from many aspects.

In the above example, the area that covers the intersection of the resultant area from the boundaries' intersection method (Figure 7.8) is relatively large compared to the area that is occupied by the shared places (Figure 7.11). Hence, it might be useful to obtain one polygon to represent shared PL(s), instead of scattered objects, for comparison processes. In this case, the user has the ability to run the 'Intersection' operator again and generate a boundary over the shared places profile to obtain a more precise view (see Fig 7.14).

Figure 7.13 The blue dotted line shows the new boundary surrounding the shared places, while the white dotted represents the boundary generated in the previous step

7.3.7. Summary

The system has added the ability to generate a definition of the place concept in a GIS and the treatment of this concept has been implemented in the GIS in a homogeneous fashion for the treatment of layers and regions and non-spatial attributes. Thus, all the operations that can be done on layers and regions, as well as their non-spatial attributes and manipulation, are supported

The system offers a high degree of flexibility and diversity in the definition of neighbourhood profiles, where an individual can be associated with many profiles, which may overlap partially or totally in space. The profiles are distinguished by the different attributes, which are for a boundary's profile: time of perception and type of neighbourhood; and for an internal place's profile: period of perception, time of day, significance, and user of the place.

7.4. Evaluating the Quality of the QPM-QGIS

The implementation of the QPM-QGIS assumes specific interpretations of the spatial expressions, as described in Chapter Six. Here, an attempt is made to evaluate the proposed QPM-QGIS and its specific realisation in the implemented system. A user-based evaluation has been carried out in two stages: firstly, to compare the expert's own spatial interpretation of neighbourhood extents against those derived automatically from the system; and secondly, through interviewing the expert from the research team to gauge his views on the utility of the proposed representation and implementation framework.

7.4.1. Evaluating the Interpretation of Neighbourhood Spatial Extent

The case study data introduced in Chapter Five (sec, 5.3.3) has been used to derive four individual interpretations of neighbourhoods from the interviews. The spatial expressions from the four scenarios were extracted in collaboration with the expert. These were then used in two ways: 1) to automatically create the spatial neighbourhood profiles in the system, and 2) by the expert to sketch the boundaries manually on Google Earth. The resulting spatial representations of the neighbourhood regions were then compared.

I. Methodology

From the four different individual interviews, all place names or spatial descriptions specifically mentioned by the participants with regard to their neighbourhoods' boundaries were extracted. The expressions were then coded as follows:

- Place name or description of location, as mentioned and included by the participant as part of the neighborhood.
- Place name or description of location, as mentioned and excluded from the neighborhood by the participant.

Next, the expressions were then represented in the system. All places included within the boundary were plotted, and a boundary was generated for the neighbourhood.

On the other hand, the expert's interpretation of the spatial extent of the neighbourhood, digitised as Google Earth maps and stored as KLM files[18] as line features, were loaded into the GIS and stored as shapefiles. The process included modifying the Coordinates Reference System[19] (CRS) to be compatible with other data, as well as converting the line representations to polygons for comparison purposes with other data. Subsequently, the resultant maps produced by the prototype were compared against the KLM maps for each one of the four neighbourhoods, and the results are presented below.

II. Results

The following scenarios comprise quotes from the interviews showing the discussions between the case study research team and the participants about

---

[18] Keyhole Markup Language (KML) is an XML notation file format used to display geographic data within Internet-based in an Earth browser such as Google Earth. For more information refer to https://developers.google.com/kml/documentation/kml_tut

[19] Coordinate reference system is a set of numbers, called coordinates, used to locate every place on the earth. For more info refer to http://docs.qgis.org/2.0/en/docs/gentle_gis_introduction/coordinate_reference_systems.html

drawing the boundaries (see Table 7.4). The digital maps (i.e. KLM files) for the boundaries, and the boundaries for the same neighbourhoods that have been generated by the system, are also demonstrated, followed by a discussion. The researcher was involved in the process of identifying the spatial expressions and references to places and in filtering non-relevant references to places. The excluded place names are shown as "deleted" texts in the transcripts below.

Scenario 1:

Table 7.3 Reference to places in the interview transcript and the researcher's interpretation of the spatial expressions

EXPRESSION	INTERPRETATION
I used to live in Tredegar years ago	Part of his neighbourhood in the past
Oh, very rarely I go up ~~***Phillipstown***~~ *to be honest*	Phillipstown is not part of (the definition of) his neighbourhood
it's just around, it's, the village area really	The village area is part of his neighbourhood
INT: so there's Commercial Street and Greenfield Street. *RES: Yeah, Green . . . , that's all over the village over there.*	*Commercial Street and Greenfield Street* are part of his neighbourhood, and they are part of the village
would you include ~~***Fothergills Road***~~ *for instance as part of . . .* *RES: No it's just . . .*	Fothergills Road is not part of his neighbourhood
INT: Or perhaps would it start in Tredegar, would it start round here? The sports hall, round that area, would that include that area? *RES: Yeah, I would say, I would say just around there you know.*	Tredegar is part of his neighbourhood
	The sports hall is part of (the definition of) his neighbourhood
INT: Just put a line round and include your street (Church Terrace) presumably. *RES: Yeah.*	Church Terrace is part of his neighbourhood
INT: And your street is here, and over the river, on the other side of the river too, would you consider? *RES: Not really, you know, cos I'm from* ~~***Tirphil***~~ *originally you see so . . .*	Tirphil is not included as part of his neighbourhood
INT: Yeah. And would it include the, the White Resource Centre? *RES: Oh yes, yeah.*	White Resource Centre is part of his neighbourhood
RES: Yeah, and Elliotstown, we go up around there.	Elliotstown is part of his neighbourhood

Application:

Figure 7.14 Plot of the spatial expressions referring to places in the neighbourhood as defined in scenario 1

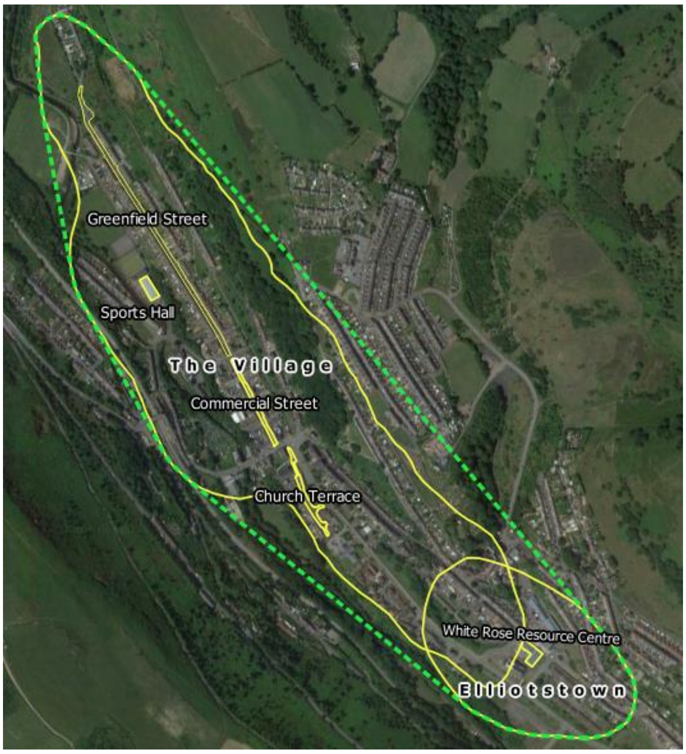


Figure 7.15 Neighbourhood boundary generated by the system for scenario 1

Figure 7.16 Boundary drawn independently by the researcher for scenario 1; shown as the solid red line, overlaid on top of the boundary and place representation generated by the system

Figure 7.17 The shaded area of intersection between the two boundaries in Figure 7.17

Stats:

Table 7.4 Comparison of the neighbourhood measurements for scenario 1

Description	Area (m^2)
Manually-created area	1017679.109
System-generated area	621451.8022
Intersection area	464275.7895

Discussion:

The area of the intersection covers 45.62% of the manually created map. There is a notable difference between the system output and the drawn map; however, this difference can be explained. While the places within and outside the boundary of the neighbourhood were identified, some of these excluded places were added onto the map's representation. For example, 'Phillipstown' and 'the other side of the river', which is 'Tirphil' were clearly excluded from being part of the neighbourhood. However, those excluded places, presented on the map (see Figure 7.19) as solid orange polygons, were still used in mapping the neighbourhood boundary.

On the other hand, the intersection area covers 74.7% of the system-generated boundary, which means that roughly 25% of the places that should have been considered as part of the neighbourhood have been neglected by the respondent's boundary.

The results were validated by the researcher who agreed there are errors in the manual interpretation of the boundary. The example demonstrates how the system can be useful in reducing the chance of interpretation error when mapping the neighbourhoods and their boundaries.

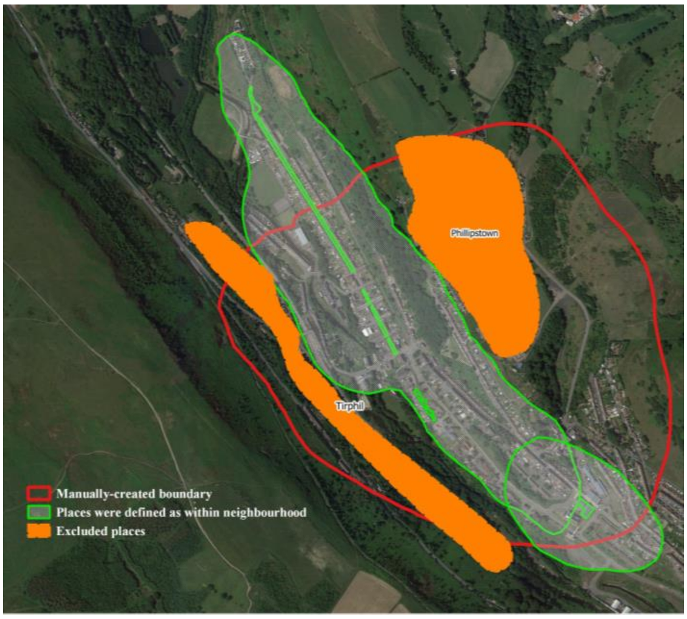


Figure 7.18 The places that should be excluded in orange colour, were still used in mapping the neighbourhood

Scenario 2:

Table 7.5 Reference to places in the interview transcript and the researcher's interpretation of the spatial expressions

Expression	Interpretation
INT: We're asking people what they consider to be their neighbourhood, to draw a ring round the map of New Tredegar, around where you feel your community is. Is it mainly in the whole of New Tredegar or it maybe just the few streets around you. It's up to you, so where we are, where schools are, there's your street there. Would you be able to do? *RES: Well I would say the whole because it contains Phillipstown New Tredegar…*	*Phillipstown and New Tredegar are part of his neighbourhood*
INT: Did you, what about Brithdir, would you include Brithdir? *RES: No, I wouldn't include ~~**Brithdir**~~ no because obviously I don't go there.*	*Brithdir is not part of (the definition) his neighbourhood*
RES: It's more, you know, you've got family and friends in Fothergills Road, Derlwyn Street, ahm Railway Terrace, School Street, Colliers Row, Station Row, you've got all people like er Penryhn er Fernhill, all that.	*Fothergills Road, Derlwyn Street, Railway Terrace, School Street, Colliers Row, Station Row, and Penryhn er Fernhill are all part of his neighbourhood*

Application:

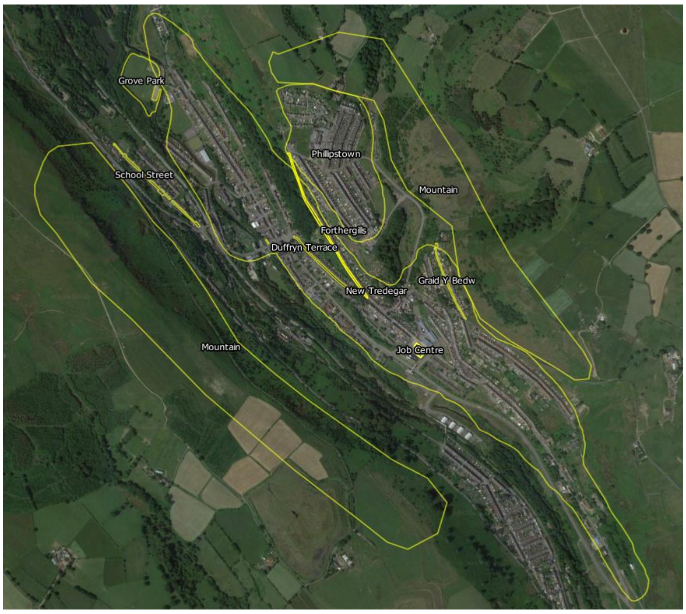


Figure 7.19 Plot of the spatial expressions referring to places in the neighbourhood as defined in scenario 2

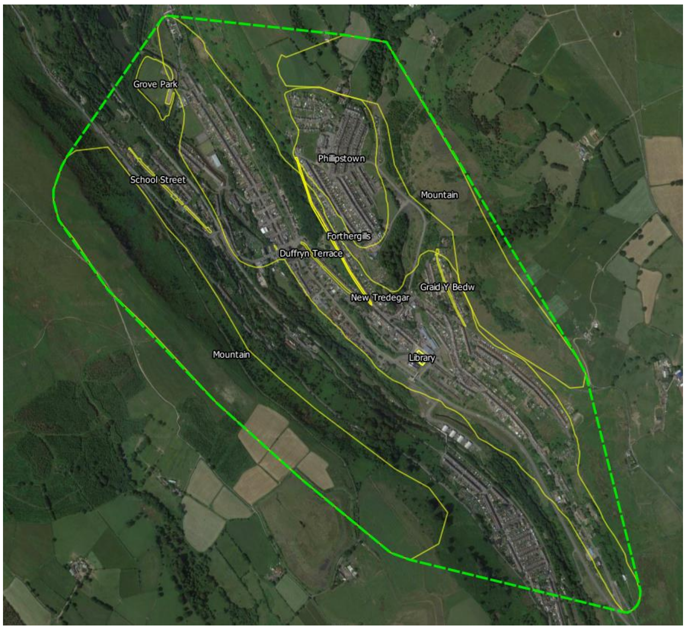


Figure 7.20 Neighbourhood boundary generated by the system for scenario 2

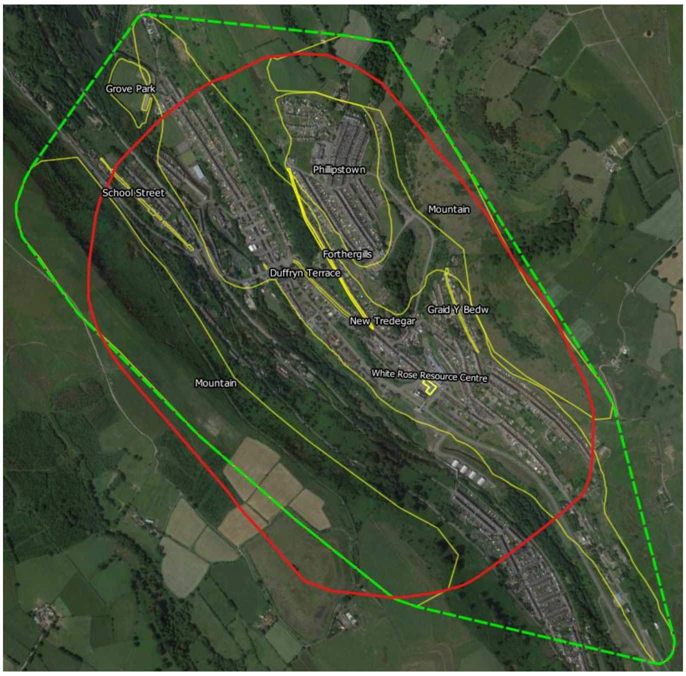


Figure 7.21 Boundary drawn independently by the researcher for scenario 2; shown as the solid red line, overlaid on top of the boundary, and place representation generated by the system

Figure 7.22 The shaded area of intersection between the two boundaries in Figure 7.22

Stats:

Table 7.6 Comparison of the neighbourhood measurements for scenario 2

Description	Area (m^2)
Manually-created area	2172936.551
System-generated area	2790545.144
Intersection area	2078179.925

Discussion:

The intersection area covers 95.64% of the manually created map, indicating considerable consistency between the system output and the drawn map. On the other hand, the drawn boundary covers 74.47% of the map generated by the system, which means that roughly a quarter of places that should have been considered part of the neighbourhood have been ignored on the manually created map.

Scenario 3:

Table 7.7 Reference to places in the interview transcript and the researcher's interpretation of the spatial expressions

EXPRESSION	INTERPRETATION
INT: Yeah, it's still working. OK, could I, could we just nip over to the table for us, I just want to ask you to do something, er, I've got a map here of ***~~New Tredegar~~*** *and, er, right, you can see this is where we are now here, or the bottom of the . . .* *RES: Yeah, by down here.* *INT: Yeah.* *RES: Yeah, we're, we're roughly there.* ***~~INT: Yeah, that's right and this is the, er, near where the Resour . . . , new Resource Centre is .~~*** *RES: That's correct, yeah.* *INT: . . . This is all* ***~~Phillipstown~~****, so whereabouts is it . . . ?* ***~~RES: Orchard, Orchard Street.~~*** *INT: So* ***~~Orchard Street~~*** *there. OK, so that's where you live. So what we're doing first is to ask people, er, what they feel is their community or their neighbourhood because people have different ideas about what that might entail, might be just the street, might be the whole of* ***~~Phillipstown~~****, might be the whole of* ***~~New Tredegar~~****, er, but I wonder if you could put a ring round what you feel is your community?* *RES: For myself?*	New Tredegar, Phillipstown and near where the new Resource Centre is located, are not part of the definition because they had not yet started talking about (the definition of) his neighbourhood
INT: But I wonder if you could put a ring round what you feel is your community? *RES: For myself?* *INT: Yes.* *RES: In general Phillipstown more or less.*	Phillipstown is part of (the definition of) his neighbourhood
INT: It would just be Phillipstown so if you could put a ring around Phillipstown, sometimes a bit difficult to see? *RES: That's technically not in Phillipstown but we always call it Phillipstown so . . .* *INT: You call, you, you call Fothersgills Road Phillipstown?* *RES: But it's actually* ***~~New Tredegar~~****.* *INT: Yes, yes.* *RES: But we, we, we say oh, Phillipstown area, myself anyway.*	Fothergills Road is part of his neighbourhood, however, the road itself is part of New Tredegar, although he sees the road as being part of Phillipstown

Application:

Figure 7.23 Plot of the spatial expressions referring to places in the neighbourhood, as defined in scenario 3

Figure 7.24 Neighbourhood boundary generated by the system for scenario 3

Figure 7.25 Boundary drawn independently by the researcher for scenario 3; shown as the solid red line, overlaid on top of the boundary and the place representation generated by the system

Figure 7.26 The shaded area of intersection between the two boundaries in Figure 7.26

Stats:

Table 7.8 Comparison of the neighbourhood measurements for scenario 3

Description	Area (m^2)
Manually-created area	211302.851
System-generated area	193273.8819
Intersection area	175740.722519

Discussion:

The area of the intersection covers 83.17 % of the manually created map, which also indicates considerable consistency between the system output and the drawn map.

Scenario 4:

Table 7.9 Reference to places in the interview transcript and the researcher's interpretation of the spatial expressions

EXPRESSION	INTERPRETATION
RES: I would say it's gotta be my neighbourhood that's the question. I would say just my street to me (Derlwyn Street)	*Derlwyn Street is the neighbourhood*

Application:

Figure 7.27 Plot of the spatial expression referring to place in the neighbourhood, as defined in scenario 4

Figure 7.28 Neighbourhood boundary generated by the system for scenario 4

Figure 7.29 Boundary drawn independently by the researcher for scenario 4; shown as the solid red line, overlaid on top of the boundary and place representation generated by the system. The shaded white area represents the intersection area between the two boundaries

Stats:

Table 7.10 Comparison of the neighbourhood measurements for scenario 4

Description	Area (m^2)
Manually-created area	32567.22762
System-generated area	27193.6729
Intersection area	23874.86176

Discussion:

The area of the intersection covers 73.31%, indicating considerable consistency between the system output and the drawn map.

III. Summary:

The intersections between the manually created areas and system-generated areas have shown considerable consistency, despite the first scenario, which is also justified. The precision of the manual drawing is inconsistent, especially the drawing by the non-professional, which is as expected for data obtained from such a study with the public; sometimes, the precision will be high, but more often it will be low. Thus, when these variations are transferred as part of the data into the GIS, this may be problematic and confusing for the explorer when comparing between different depictions. Consequently, this gives an advantage to the QPM-QGIS due to its ability to maintain the stability of the geometric representation of the spatial data envisaged in a standardised way.

7.4.2. User Evaluation

As mentioned in Chapter Six, the social geography research team assessed the analysis of the findings, that is, the notion of place and the neighbourhood concept, and at a later stage, the design of the initial prototype was revised to take into account the feedback obtained from the review sessions conducted by the researchers. The feedback was taken into consideration during the development of the QPM-QGIS.

After completing the final QPM-QGIS prototype version, used to prove the concept, the social geography expert and the researcher participated in applying the QPM-QGIS to real data, that is, the case study data. Within these exercises, the expert was interviewed to gauge his subjective judgment explicitly about the following:

- Quality of the model and system.
- Possible applicability of the system.
- Limitations and future improvements.

Two procedures were followed, which are, firstly, modelling a neighbourhood that comprises all spatial components and all associated qualitative characteristics, as in section 7.3. This aimed to demonstrate the efficiency and sufficiency of the QPM-QGIS to represent the concept of neighbourhood in a GIS environment. It also aimed to explore and test the manipulation operations implemented and their capabilities, as well as testing the ease of use, particularly for non-expert users in terms of entering data, retrieval and manipulations.

The second procedure, which is explained in detail in section 7.4.1, aimed to validate the system outputs by comparing them with other maps that were plotted on Google Earth manually, and for the same neighbourhoods.

Satisfaction has been expressed about the capacity of the approach for capturing the fundamental constituents of place notion, in particular, the ability to model place location and to associate other qualitative characteristics. Moreover, the efficiency of the mechanism used to describe place, and the coherent association between the components together to represent the concept of neighbourhood in a GIS environment, and in an intelligible way have been appreciated. Also, the manipulation operations implemented and their capabilities, as well as testing the ease of use, particularly for non-expert users in terms of entering data, retrieval and manipulations, were also valued.

The social geography expert stated that the approach easily enables the user to explore the related qualities of perceptions. For example, he stated that the system allows the user to look at time, and it allows different types of neighbourhoods to be looked at. He also explained the benefits gained from the modelling, as well as the application of the manipulation operations implemented on the derived or stored data. This is assured by the capacity shown, as he said: “each single thing that has been mentioned in the interviews I can plot it in GIS” and it can also be interrogated. In addition, the system allows much more nuanced data to be gathered, represented and manipulated compared to other traditional forms of GIS, which is something that, according to the expert, has required exploring for a long time.

In terms of the possible applicability of the system, and who is going to use the QPM-QGIS, this was a question raised by the social geography team in the initial evaluation. Two possible groups of people are suggested: the GIS group people who are interested in quantitative research, particularly in North America (e.g., Michael Kwan, Sara Elwood and Matt Wilson), and others across those areas that may be interested in it. In addition, criminologists, health researchers (as these pay considerable attention to neighbourhood), planners, architects and archaeologists, would all potentially be interested in it in different ways. Therefore, as he articulated, “I think it has a broad scope” and “it has a pretty wide potential. They would all be interested in it”.

Regarding the limitations and future improvements, the expert recommended that the system should allow the user to set up the non-spatial attributes as the user sees fit, through a special GUI. This will facilitate the configuration of the system to be suitable for the subject of research and prepare the data for answering the research questions.

7.5. Summary

Three evaluation methods have been addressed in this chapter. The effectiveness of the proposed place model was evaluated through demonstrating the ability of the GIS to define the concept of qualitative place, in particular, neighbourhood, in a homogeneous way. A high degree of flexibility and diversity in the definition of neighbourhood profiles was demonstrated, as individual profiles may overlap partially or totally in space and time. Secondly, a comparison exercise was undertaken between an expert’s own spatial interpretation of neighbourhoods in a realistic application, digitised using Google Earth, and those derived automatically from the QPM-QGIS. The results show significant agreement between the two interpretations and the advantage of the model for detecting possible manual interpretation errors. Finally, the social geographer expert was interviewed to gauge his views on the utility and quality of the proposed approach and developed system.

Chapter 8

Conclusions and Future Work

8.1. Introduction

This chapter provides a review of the way in which the main research objectives presented in Chapter One have been addressed; along with summarising the conclusions from the work as a whole, discussing the practical implications of the research and its achievements, and highlighting potential extensions for achievement in the future.

8.2. Conclusions

This thesis has argued that links to connect data on the Linked Data Web can be improved by geo-referencing RDF place resources, whereby links can be inferred between items by tracing their spatial footprints. Furthermore, the thesis has also argued that adding the ability to generate a definition of the concept of place, and then implementing the treatment of this concept in GIS can elevate its capabilities.

This research has developed two different models for a qualitative definition and manipulation of place location in two different contexts. Firstly, a qualitative place model on the LDW to serve the definition of place location from the quantitative representation available to enable qualitative representation; this work has been presented in Chapter Three and Chapter Four. Secondly, a qualitative place model in GIS to generate a definition of the concept of place in a GIS. This has focused on the definition of place location from qualitative expressions of locations to lead to a quantitative definition, which can be represented in GIS, and this aspect has been presented in chapters five, six and seven.

Data on geographic places is considered very useful for the LDW. Individuals and organisations are volunteering data to build global base maps, enriched with different types of traditional and non-traditional semantics, reflecting people's views of geographic space and place. In addition, geographic references to places can be used to link different types of datasets, thus enhancing the utility of these datasets on the LDW. The study has investigated the challenges that arise when representing place data using the simple RDF model, with different geometries used to represent location, and different non-standardised vocabularies used to represent spatial relationships between locations.

For effective representation, a linked place model known as *RelLoc* has been developed, which injects certain types of spatial semantics into the RDF graph underlying the place data. Specific types of spatial relationships between place nodes can be added to the graph to allow the creation of individual place location profiles that fully describe the relative spatial location of a place. It further shows how the enriched relative location graph allows Qualitative Spatial Reasoning to be applied to derive implicit spatial links and produce even richer place descriptions. Salience of place has also been introduced as a means of scoping out relevant and meaningful place location expressions. The representation scheme has been adapted to allow a flexible choice of place instances to be used in the model. The results obtained from the evaluation experiments for the basic model (i.e. *RelLoc*) and adopted model (i.e. SemRelLoc) demonstrate the possible significant value of the proposed model.

Thus, the study has shown one possible utility of the proposal. The capacity of the model to prepare the data successfully in order to answer various types of geographic queries that contain qualitative spatial constraints, has been presented, and various query plans that can be answered have been explained. Moreover, the work has allowed the application of qualitative spatial reasoning selectively within a framework, whereby the RelLoc model has been slightly modified. This adjustment has restricted the application of the RelLoc model by defining the proximity-directional relationships between objects in a constrained way, that is, between objects that are located within a direct container object. This was beneficial because it provided constrained searches for interrogating, and for the application of QSR. This is an idealised situation, and it provides a possible solution, as in the UK Ordinate Survey (OS) data, the representation of the hierarchy levels is maintained and available, and this was used.

The work has been designed to demonstrate how the modified model and the manageable application of the QSR engine qualify the data for answering qualitative spatial queries. The applicability of the approach to real data has been tested, and multiple datasets have been used in this experiment, that is, DBpedia [67] and Ordnance Survey OpenData (OS) [118]. Then, query plans that successfully answer spatial queries that contain qualitative spatial constraints have been provided and explained. Various queries that have been answered by the approach have been categorised as follows:

1) Find places near a place in which both places are in a simple level of representation, for example, *find Landmarks near Millennium Stadium*.
2) Find place(s) at a given direction from a place in which both places are in a simple level of representation, for example, *find Landmark(s) north of Millennium Stadium*.
3) Find places on a simple level near a place on a container level of representation, for example, *find Landmarks near Cathays Ward*.
4) Find places on a simple level at a given direction from a place on a container level, for example, *find Landmarks north of Cathays*.
5) Find places on a simple level inside a place on a container level, for example, *find Landmarks in Cathays*.
6) Find places on a container level near a place on a simple level, for example, *find Wards near a Landmark*.
7) Find places on a container level at a given direction from a place on a simple level, for example, *find Wards north of Millennium Stadium*.
8) Find places near a place in which both places are containers, for example, *find Wards near Cathays*.
9) Find place(s) at a given direction from a place in which both places are containers, for example, *find Ward(s) north of Cathays*.
10) Find places inside a place in which both places are containers, for example, *find Wards in the city of Cardiff*.

Related to the context of the qualitative model of place for GIS, a model that allows the representation of the concept of place in GIS has been developed. The development has passed through three main phases: The first phase was to come up with a general definition of the notion of place. The second phase identified the components of place (i.e. human factors, time of perception, significances and spatial aspects). The third phase defined the spatial component of place, and this definition has two levels: an upper level, which describes what a place consists of (i.e. defining place as a singular place, as a relative place and as a compound place). And the sophisticated level, which is the formulation of prototypical qualitative spatial expressions that convey the place location in a GIS environment.

The model was achieved by following two strands of investigation: 1) by reviewing the literature on the notion of place, and 2) by examining qualitative spatial data from a realistic case study from social geography research. This was to confirm the findings from the literature and to formulate qualitative spatial expressions that can be executed and translated into a GIS environment.

Reviewing the literature began with defining the concept of 'place' as a social and ontological construct, and thereafter revealing the general constituents of place, that is, human actors, time of perception, significances and spatial aspects, followed by the derivation of a qualitative spatial definition of place location. The review ended with the emergence of a conceptual model that defines the notion of place as a complex entity that comprises all the components identified.

The diversity of spatial expressions found in the literature shifted the focus towards identifying a manageable number of qualitative spatial expressions to describe place locations. The work examined realistic qualitative data (i.e. interviews and sketches) that had been collected during a case study research from social geography. Analysing the interviews side by side with the sketches helped to articulate prototypical qualitative expressions of place location. Qualitative and quantitative analyses were carried out. The process of the analysis was iterative, where all spatial expressions and all places' names were extracted from the transcripts, and then interpreted through an understanding of the context of the transcripts, along with examining the sketches together. Finally, the data was classified based on the type of spatial relationships that were used.

The analysis also included statistical analysis of the spatial expressions used, where the corresponding prototypical qualitative spatial relationships that were most frequently used were identified. Examining the data from the case study confirmed the literature findings on the definition of the notion of place. The expressions identified were formulated as follows:

1) A place inside a place.
2) A place equals a place.
3) A place containing a place/places.
4) A place next to a place.
5) A place between two places.
6) A place in a specific direction from a place.

In the non-traditional method that is used in a GIS environment, a prototype denoted QPM-QGIS has been implemented to demonstrate the application of the model using a practical example, that is, place location within a neighbourhood context. This step aimed to test the feasibility of the model, and to facilitate the use of the current GIS as a means for users who are interested in representing neighbourhood and interrogating people's perceptions of places' data, using a GIS environment.

The idea relied on associating qualitative and quantitative representations, therefore the focus on generalising and simplifying the qualitative definition of place, as well as the quantitative representation, in a way that they could match. The simplification led to a level that matches general qualitative spatial relationships (i.e. containment, proximity and direction relationships). These types of relationships have exclusively formed, implicitly or explicitly, the prototypical expressions, and at the same time, they are quantifiable and are already implicitly represented in GIS. What remained, based on that, was to find a mechanism for representing the expressions quantitatively in a spatial database.

The prototype system has been programmed as an extension on top of a current GIS package, which is Quantum GIS. The interfaces and modules implemented allow three main functions:

1) Facilitate the setup of the GIS interface to allow organisation of the data, to aid representation, and to link the main components of the personal place definition (i.e. time of perception, significances and spatial footprints).
2) Allow the inputting and interpreting of the prototypical qualitative spatial expressions identified, and ensure the quantitative capabilities are easily available. In this regard, a constant buffered zone for automatically delineating the different types of spatial expressions' footprints has been utilised. This constant zone was identified based on an experiment carried out to gain an idea of the average distance between objects in an urban setting, which is useful for sketching neighbourhood components, as required for the research. However, it is important to mention that the implemented system allows the size of the buffer to be tuned as the user sees fit. Even so, identifying the distance is used to maintain a fixed measurement for footprints' delineation, and to guarantee that the delineation, retrieval and manipulation are performed in a symmetrical and constant manner.
3) Provide the user with the ability to construct the place with all its constituents, while also making this easily accessible.

The development of the system passed through several phases of evaluation and gradual improvements to reach the initial prototype, before producing the final system. In a final round of evaluation, three metrics were used: Firstly, the effectiveness of the QPM-QGIS has been evaluated through the value of knowledge that has been obtained by adding the ability to generate a definition of the concept of place in a GIS. This concept was then utilised in the GIS in a homogeneous fashion for the treatment of layers and regions and non-spatial attributes. Therefore, all the operations that can be performed on layers and regions, as well as their non-spatial attributes' manipulation, are supported.

Moreover, the approach offers a high degree of flexibility and diversity in the definition of neighbourhood profiles, as an individual can be associated with many profiles, which may overlap partially or totally in space. The profiles are distinguished by the different attributes, which are, for a boundary's profile: time of perception and type of neighbourhood; and for an internal place's profile: period of perception, time of day, significance, and user of the place.

The second evaluation metric involved a comparison exercise undertaken between an expert's own spatial interpretation of neighbourhood extents using Google Earth, and those derived automatically from the prototype system. The results show significant agreement between the system outputs and the manually drawn maps on Google Earth. The average percentage of the compatibility between the scenarios used is 74.43 %, which is significant, although one of the manually drawn map's data is misleading. However, this has revealed a further advantage of the QPM-QGIS as it highlighted this issue, and the expert acknowledged the error.

Finally, the expert was interviewed to gauge his views on the proposed representation and the implementation of the framework in terms of the following:

- Quality of the model and system
- Possible applicability of the system and potential audience
- The limitations and future improvements

Even though this prototype requires some improvements, such as allowing the user to configure and setup the associated attributes, the expert assessor concluded that the QPM-QGIS is beneficial, useful, and definitely has potential.

Finally, it is important to mention that the thesis's objectives, which have been stated at the beginning of this work in Chapter One, have been achieved completely, and in some cases extended. The challenges associated with representing place information on the LDW have been identified and studied. A qualitative model of place to enable the effective representation of place information on the LDW has been designed and developed. The effectiveness of the proposed model for representing different types of place information on the LDW, using realistic data sets has been measured. The effectiveness of the proposed model for supporting the retrieval of place information on the LDW, using realistic data sets has been demonstrated in Chapter Four through the query plans work. A qualitative model of place for GIS has been designed, developed and implemented. The effectiveness of the proposed model for representing the notion of neighbourhood in GIS has been measured. Lastly, the effectiveness of the proposed model for representing and manipulating the concept of neighbourhood with realistic use case scenarios has been evaluated.

8.3. Achievements

1) Development of a qualitative model of place for the LDW that allows for the unique representation of place resources, and which forms an effective basis for the application of qualitative spatial reasoning
2) Evaluation of the effectiveness of the proposed model using realistic samples of different types of datasets on the LDW
3) Demonstration of the flexibility of the proposed model for the LDW, in particular, by considering place type as a variable in the development of the model
4) Design and implementation of a qualitative place model for GIS
5) Demonstration of the effectiveness of the model for representing the notion of neighbourhood in GIS
6) Evaluation of the proposed model using a realistic, social geography, case study scenario

8.4. Future Work

Qualitative place model for the LDW:

- Simple methods and assumptions have been used to compute the spatial relationships between places. Further study needs to be carried out to evaluate whether more involved representations would be useful [137]. For example, resources of linear features are potentially a valuable resource for establishing spatial links between these features.
- Similarly, simple methods and assumptions have been used to compute direction-proximity relationships between places. More accurate representation of these relationships can be tested and evaluated.
- The place resources that have been used in this work to generate the place profiles are restricted to one data source (i.e. DBpedia, in particular, for

creating the proximity-direction relationships). The application of the approach to other types of data sets on the LDW, as individual as well as combined resources, requires further study.

- A hybrid method has been used for the application of the qualitative spatial reasoning on the place profiles to infer implicit links, thus further study needs to be undertaken to evaluate whether more involved integration would be more effective.

Qualitative place model for GIS:

- The work is designed to be a proof of concept, thus the individual processes that have been used are not likely to be optimal but deemed sufficient for proof of concept. Therefore, further research needs to be carried out to evaluate whether more accurate representations would be useful. An improvement to the minimum bounding rectangle method for generating boundaries, for example, would ensure that areas stated as being outside were actually outside. Another improvement would be to restrict the boundary to geographically significant features such as roads.
- One method has been used for mapping the directional relationship, which is a 4-cardinal directions frame of reference. Further study needs to be carried out to evaluate whether more involved representations would be useful. For example, the intrinsic frame of reference to project the areas ‘in front of’, ’behind’, ’left of’ or ’right of’ an object, as this would expand the base of the qualitative expressions that are used in the solution.
- The temporal qualifiers are simplistic (e.g. the reference to the past may vary from one person to another), and the time range may be different according to specific research requirements, therefore it is recommended to improve this. Thus, the system should allow the user to set up the non-spatial attributes as the user sees fit, through a special GUI. This will facilitate the configuration of the system to be suitable for the subject of the research and prepare the data for answering questions.
- One type of feature class was used to map qualitative expression footprints, which is polygonal shapes. Point representation needs to be included within

the solution to allow the definition of exact places that are usually represented by points, such as trees or traffic lights.

An important aspect is that, at present, the qualitative place model for the LDW and the qualitative place model for GIS are not linked, however this would be possible. Place names and spatial relationships (i.e. those that indicate containment relationships such as 'dbo:isPartOf'), and also simple geometry representation, would provide a realistic connection between the two worlds. Using the place name of a feature in GIS (e.g. 'Cardiff') can be used in the LDW to retrieve spatial or non-spatial properties (e.g. the population or the direction of a neighbouring city of Cardiff). Therefore, linking the two models would enable the GIS to execute queries on the Linked Data Web, and that would provide the data necessary to complete the GIS aspects of a qualitative analysis. This development has not been addressed in this work and is recommended for future work.

8.5. Summary

This thesis targets qualitative place modelling on the LDW and in GIS. A qualitative place model on the LDW was proposed to serve the definition of place location from the quantitative representation of location available and to enable the creation of effective homogenous qualitative representation of place location on the LDW. Chapter 3 dealt with the development of the model, the application and evaluation, while Chapter 4 explained the utility of the model for supporting the retrieval of place information. On the other hand, a qualitative place model for GIS was designed to allow for the definition and manipulation of the concept of place within a GIS. In this case, the place location was defined using qualitative expressions of location, which can be used to determine a quantitative definition. Chapter 5 presented the derivation process for the model, as well as specifying the requirements for its realisation. Chapter 6 presented the application of the model using a practical example, while Chapter 7 has evaluated the proposed model and system. This chapter summarises the conclusions of the work as a whole, discusses the practical implications of the research, and highlights the potential for extending these achievements in the future.

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Appendix A

This appendix presents a sample set of relationships defining the location of "Techniquest": an educational charity in the Cardiff Bay area, Wales, UK, resulting from the application of spatial reasoning on the salient features on the map in Figure 3.8.

(Techniquest (sw) Barry_Power_Station)

(Techniquest (sw) Barry_Docks_railway_station)

(Techniquest (sw) Barry_Island_railway_station)

(Techniquest (sw) Barry_Dock_Lifeboat_Station)

(Techniquest (sw w) Cowbridge_railway_station)

(Techniquest (sw w) Llantwit_Major_Roman_Villa)

(Techniquest (sw) Barry_railway_station)

(Techniquest (sw w) Aberthaw_power_stations)

(Techniquest (sw w) Aberthaw_High_Level_railway_station)

(Techniquest (sw w) Aberthaw_Low_Level_railway_station)

(Techniquest (ne) Celtic_Manor_Resort)

(Techniquest (ne) Kingsway_Shopping_Centre)

(Techniquest (ne) Allt-yr-yn)

(Techniquest (ne) Caerleon_railway_station)

(Techniquest (n nw) Caerphilly_Castle)

(Techniquest (n nw) Argoed_railway_station)

(Techniquest (n nw) Brithdir_railway_station)

(Techniquest (n nw) Aberbargoed_Hospital)

(Techniquest (n nw) Aber_Bargoed_railway_station)

(Techniquest (n ne) Crosskeys_railway_station)

(Techniquest (sw w) Atlantic_College_Lifeboat_Station)

(Techniquest (nw) Coed_Ely_railway_station)

(Techniquest (n nw) Bargoed_railway_station)

(Techniquest (n nw) Cefn_Eglwysilan)

(Techniquest (nw) Church_Village)

(Techniquest (nw) Church_Village_Halt_railway_station)

(Techniquest (nw) Sardis_Road)

(Techniquest (nw) Cross_Inn_railway_station)

(Techniquest (nw) Aberdare_Low_Level_railway_station)

(Techniquest (nw) Aberdare_railway_station)

(Techniquest (nw) Coed-Ely)

(Techniquest (n nw) Cilfynydd)

(Techniquest (n nw) Abercynon_railway_station)

(Techniquest (n nw) Abertysswg_railway_station)

(Techniquest (n nw) Darran_and_Deri_railway_station)

(Techniquest (nw) Dinas_Rhondda_railway_station)

(Techniquest (n nw) Abercynon_North_railway_station)

(Techniquest (n nw) Bute_Town)

(Techniquest (nw) Mynydd_William_Meyrick)

(Techniquest (nw) Clydach_Vale)

(Techniquest (nw) Lluest-wen_Reservoir)

(Techniquest (n nw) Abercwmboi_Halt_railway_station)

(Techniquest (n nw) Abernant_railway_station)

(Techniquest (nw) Athletic_Ground_Aberdare)

(Techniquest (nw) Aberaman_railway_station)

(Techniquest (n nw) Cwmbach_railway_station)

(Techniquest (nw) Beddau_Halt_railway_station)

(Techniquest (n) Abercarn_railway_station)

(Techniquest (s) Alberta_Place_Halt_railway_station)

(Techniquest (w) St_Fagans_National_History_Museum)

(Techniquest (sw) Dinas_Powys_railway_station)

(Techniquest (e) Pierhead_Building)

(Techniquest (e) Mermaid_Quay)

(Techniquest (n nw) Caerphilly_railway_station)

(Techniquest (n ne) Ruperra_Castle)

(Techniquest (n nw) Birchgrove_railway_station)

(Techniquest (n nw) National_Museum_Cardiff)

(Techniquest (ne) Bassaleg_Junction_railway_station)

(Techniquest (ne) RAF_Pengam_Moors)

(Techniquest (n) Childrens_Hospital_for_Wales)

(Techniquest (w) Aberthin_Platform_railway_station)

(Techniquest (n nw) Abertridwr_railway_station)

(Techniquest (n) Cefn_Onn_Halt_railway_station)

(Techniquest (nw) Creigiau_railway_station)

(Techniquest (nw) Efail_Isaf_railway_station)

(Techniquest (n nw) Aber_railway_station)

(Techniquest (nw) Castell_Coch)

(Techniquest (nw) Whitchurch_Hospital)

(Techniquest (n nw) Hilton_Cardiff)

(Techniquest (w) St_Fagans_Castle)

(Techniquest (sw) Eastbrook_railway_station)

(Techniquest (w) Cardiff_International_Sports_Stadium)

(Techniquest (s) Cardiff_Bay_Barrage)

(Techniquest (sw w) Dyffryn_Gardens)

(Techniquest (n) University_Hospital_of_Wales)

Appendix B

This appendix provides information about the multiple datasets that have been used in the experiment presented in section 4.3: DBpedia and the Ordnance Survey (OS)[20] open data. These were chosen as they exhibit different representations of place resources and are typical of VGIs and AGIs respectively.

The OS Boundary-line[21] datasets for Wales, which are in polygonal representation, were downloaded from the OS open data web site and utilised. The data gives a range of local government administrative boundaries, that is, the Wales region, the Unitary Authority (UA) regions (e.g. Cardiff UA), and Community regions, that is, wards within the UAs such as 'Cathays' ward in Cardiff. The UA set contains 22 regions and the Community set comprises 855 regions. The second data source is the DBpedia, where a sample dataset containing 489 points representing all places in wales, has also been downloaded using the SPARQL query.

The number of places within DBpedia dataset was reduced to 461 places to restrict the data to the point of interest (POI) only. Figure (4.3) summarises the spatial hierarchical relationships between these levels of representation, as well as the relationships that were computed in each level.

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[20] https://www.ordnancesurvey.co.uk/about/

[21] https://www.ordnancesurvey.co.uk/business-and-government/products/boundary-line.html

Appendix C

This appendix focuses on analysing a combination of the text (i.e. transcripts), side by side with the sketches, to fully understand the following:

- How place location is expressed.
- How these expressions have been interpreted within the manual delineation process.
- What frequent interpretations give similar meanings.
- What kinds of qualitative spatial relationships correspond with these frequent interpretations.

It is important to mention that the group members expressed these descriptions of places' locations together and side by side with the drawing exercise. This means that these expressions may suffer from a deficiency in terms of expressing the meaning, because to understand these expressions it is essential to keep in mind that some semantic meanings of places' locations were stated during the verbal discussions, while others were implicitly expressed through the sketches and the accompanying gestures.

Place names and qualitative spatial relationships are more cognitively available to users than the geographic coordinates of place location, and are thus more commonly used by users when describing place location.

The paragraphs below present an analysis of the data from all groups (i.e. the four group interviews) in separate sections. Each section comprises the relevant sketch and lists of all spatial expressions that were used within the interviews. The lists also include the expressions' interpretations and the corresponding prototypical spatial relationships. The aim of the lists is to reveal some prototypical qualitative spatial relationships that are sufficient to describe place location. Each section ends with statistics on the number and percentages of these prototypical qualitative spatial relationships. Finally, a discussion of the results for all sections is provided.

In the first and second group's sketching exercises, the respondents were asked to map the place in any way that they wished. The sketches were produced as conceptual maps, focusing on showing the importance of places, that is, the most important down to the least importance places to them. The third and fourth group were asked explicitly to place more focus on drawing a topographic map.

- **Group 1**

The relevant sketch for group 1 (see Figure C.1) and list of places' names, as well as the qualitative description of place locations that were expressed within the interview, are presented and analysed.

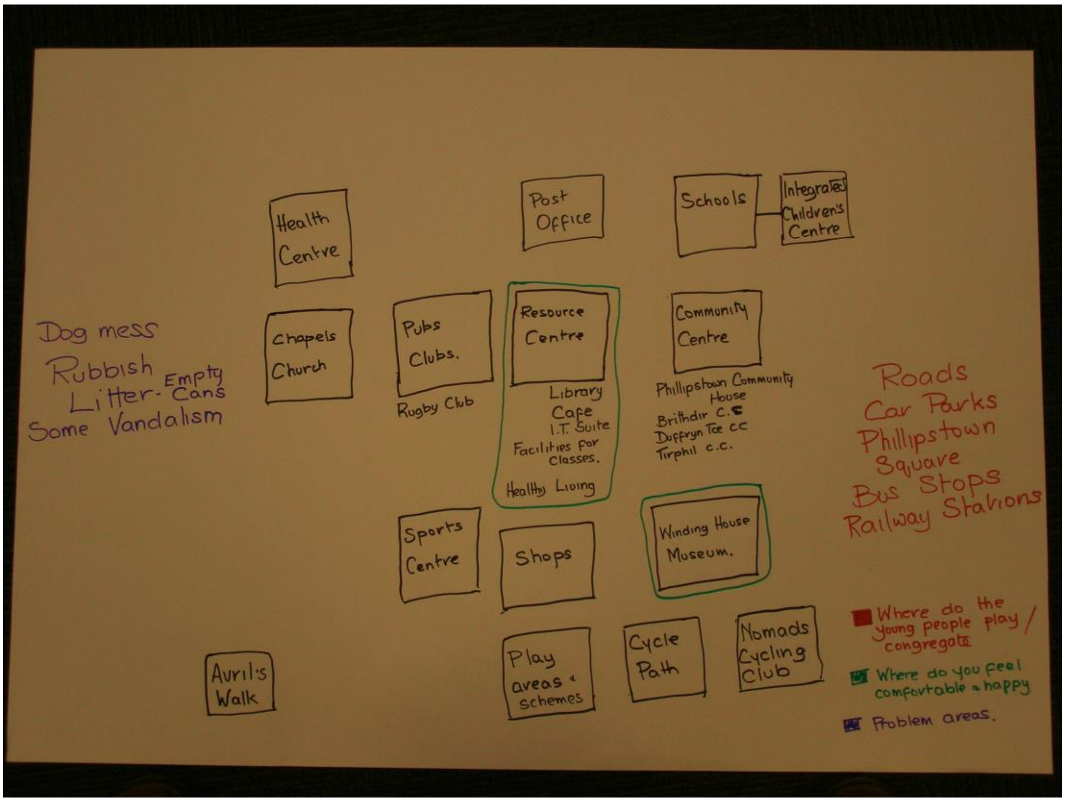

Figure C.1 A conceptual map sketched by group 1 to describe their neighbourhood

Table C.1: A list of all *place names and sentences that describe the place locations* expressed by the participants in the interviews. It also includes interpretations of these expressions and the correspondent prototypical spatial relationships.

Expression	Interpretation	Correspondent Spatial Relationship
Because we are meeting in a room that is classed different to the resource centre. Will that count?	A meeting place inside the resource centre	A place inside a place
Are you thinking about Brithdir or New Tredegar?	Using exact place by its name to define a place	Exact place
Everywhere really, Brithdir and New Tredegar, that's includes Phillipstown, Tirphil,	New Tredegar contains Phillipstown	A place contains places

everywhere, because it is under the umbrella of New Tredegar.	and Tirphil	
New Tredegar	Using exact place by its name to define a place	Exact place
Tirphil	Using exact place by its name to define a place	Exact place
Brithdir	Using exact place by its name to define a place	Exact place
There is the library, a café, so this would be one of the most important social buildings in New Tredegar	The library and the café inside New Tredegar	A place inside a place
Because the library is here to start with. There are classes run here.	The classes place is inside the library	A place inside a place
There's a café now, which is a new thing, but it has certainly brought people in,	The café inside the resource centre	A place inside a place
This place is used by the school as well, the library part, it has a lot of uses	The library inside the resource centre	A place inside a place
They do arts, they do computers, they do arthritis classes, they do everything really.	The arts, computers and arthritis classes inside resource centre	A place contains places
community centre	Using exact place by its name to define a place	Exact place
sports centre	Using exact place by its name to define a place	Exact place
there is a gym in the sports centre	The gym inside the sports centre	A place inside a place
Bargoed	Place name	Exact place
If you are classing things like the sports centre, then as far as I am aware they have still got the bowling club	The bowling club inside the sports centre	A place inside a place
The football boys practice down there don't they		
the rugby club	Using exact place by its name to define a place	Exact place
If you think of New Tredegar it is in various wards. Like you have a ward in Brithdir, there's a Cwmsyfiog ward, there's a Phillipstown ward, Tirphil is probably classed as a ward, so there are probably five or six different wards to New Tredegar itself	New Tredegar contains all these places	A place contains places
footbridge	Using exact place by its name to define a place	Exact place

my doctor's surgery, which is in Gilfach in Bargoed	Doctor's surgery location inside Gilfach, and Gilfach inside Bargoed	A place inside a place
surgery in Brithdir	The surgery inside Brithdir	A place inside a place
So do you have any facilities in Brithdir? Yes, we have a community centre.	A community centre inside Brithdir	A place inside a place
the technical school which was in the village	The technical school inside the village	A place inside a place
we have got 55 club in the community centre, for the old age	The 55 club inside the community centre	A place inside a place
I put community centre down because they are all in their little villages.	The community centre inside the villages.	A place inside a place
We have actually got three community centres is it? You've got Phillipstown, you have got Duffryn Terrace, there are four actually because you have got Tirphil and you've got Brithdir	There are community centres inside each region	A place inside a place
library and resource centre, because any thing to do with that then, for example you would have the library, you'd probably have the café, so these are all part of the resource centre.	The library and the café inside the resource centre	A place contains places
So you have put library down, who uses that library?		
And the café, you have put down. That's opened fairly recently? So nobody really uses the one in the village then?	A café inside the village	A place inside a place
Because before we closed the museum next door, we directed people to the café	The museum was next to the resource centre	A place next to a place
The sports centre. Ah yes, you were talking about the sports centre. So where would that be then? The sports centre is down the bottom end of the village.	Using exact place by its name to define a place	Exact place
The museum	Using exact place by its name to define a place	Exact place
You have got Cwmcarn Forest Drive, which is also a scenic route through part of the valley	Cwmcarn Forest Drive inside the valley	A place inside a place
Well I've got churches and chapels as well.	Using exact place by its name to define a place	Exact place
And pubs and clubs.	Using exact place by its name to define a place	Exact place
I've got the rugby club.	Using exact place by its name to define a place	Exact place

I've got the post office.	Using exact place by its name to define a place	Exact place
We have got cash machines, but they all charge. There's a couple of them, there's one in the shop on Duffryn	The cash machine inside the shop	A place inside a place
and I think there is one in the paper shop as well, but they charge.	The cash machine inside the paper shop	A place inside a place
Well, I have got the health centre. A lot of people meet there and they have got the chemist	Using exact place by its name to define a place	Exact place
And then I have got the shops	An area contains shops	A place contains places
in Phillipstown they have a community house, but it would probably be…. It is a community centre isn't it?	The community centre inside Philipstown	A place inside a place
Okay, so what we want to do now, we want to actually physically draw these on. So what we want to do is take the post it's off and just for it to be drawn on as a map. So, perhaps if we can do that once we have taken a picture. Does anyone want more tea or coffee while we are at it?		
Well, what if we put the central features in a circle, the most important things in the middle there and then the least important things there?		
Or do you want them in sort of where they are in relation to each other?		
Well, what would you really want to do? I mean for us, it's a kind of a map of your community, and that can either be as you said, kind of geographically located, or it could be from the most important, in to out, its really up to you, its your map.		
So just put resource centre?	Using exact place by its name to define a place	Exact place
Yes. And then what if we put a little set of branches under here for the facilities of the resource centre? So we have got then, the library, we have got the café, anything else?	The library and the café inside the resource centre	A place contains places
Well, if we think about it, what else is here? Meeting rooms, an IT room	Meeting rooms, an IT room inside the resource centre	A place contains places
our healthy living centre	Healthy living centre inside the resource centre	A place inside a place
winding house	Using exact place by its name to define a place	Exact place

Phillipstown community house gets a lot of use doesn't it, so Phillipstown community house would perhaps be the first one.	Phillipstown contains community house	A place contains places
So if I put Brithdir community centre, then Duffryn Terrace is it?	Brithdir contains community centre, and Duffryn Terrace contains community centre	A place contains places
Now, the museum, are we going to do that next, what do you think?	Using exact place by its name to define a place	Exact place
What's used more? Would you say the churches and chapels are used more than the community centre, sorry, the winding house? Or the pubs and clubs?	Using exact place by its name to define a place	Exact place
The rugby club, we don't want to list them all do we, you've got the TA, the Ruperra, you've got whatever is left in the village.	Using exact place by its name to define a place	Exact place
Tredegar Arms, the Ruperra, the rugby club.	Using exact place by its name to define a place	Exact place
What's the one up in Phillipstown?	A place inside Phillipstown	A place inside a place
What about in Brithdir you have got the Labour Club, the one on Tan Y Lan square, the ex-serviceman's club is it?	Brithdir contains the Labour Club, the club one on Tan Y Lan square, the ex-serviceman's club	A place contains places
The Royal Legion.	Using exact place by its name to define a place	Exact place
What's the one up Fothergills? The silver band, but I don't know if the silver band club is still going, it was a year or two ago.	Fothergills contains the silver band	A place contains places
Playgroups, where would you put them, lumped with schools? Perhaps down off schools. Its one that probably has less use than the school doesn't it?	Playgroups next to the school	A place next to a place
we had a charity shop in the village for a time	Charity shop inside the village	A place inside a place
Do they still have the carnival up in Phillipstown?	The carnival location inside Phillipstown	A place inside a place
Okay, so now on the kind of map that we have drawn, the next thing we want to do if that's okay is just add some further detail to what we have done, so whilst Steven is taking a picture, it would be good if we can talk about, you can add on any physical features of the areas that you like or you don't like.		
So then if we could find a way of marking that on, and then I was going to ask, where do		

children and young people play?		
Outside on the open bit between the school and the library, they play and that out there.	Children and young people play between the school and the library	A place between two places
What they do in our place is they play on the road.	The play location inside the road	A place inside a place
They used to play down on the field that was adjoining the school but of course, since they have done all this they have taken the field and that school hasn't got a playing field.	The play location inside the field, and next to the school	A place inside a place
		A place next to a place
They were going, I understood, they were going to keep the field there and use it for this school as a playing field, because it was where they had their sports day and their football and everything.	The play location inside the field, and next to the school	A place inside a place
		A place next to a place
So it's any open space really. They play down on that car park down there; I've seen them playing down there.	The play location inside the car park	A place inside a place
We have a terrible problem with children down the station, and they are more teenagers, the kids that go down the station	A problem location that is used by teenagers is next to the station	A place next to a place
They were down White Rose Way last night when we came home	A problem location that is used by teenagers next to the White Rose Centre	A place next to a place
there was a gang of boys on the corner in Abertysswg	The place of the gang of boys next to a place and on the corner	A place next to a place (needs to be discussed)
	A place inside Abertysswg	A place inside a place
there was a different load of boys on the square in Pontlottyn,	The place on the square, and the square inside Pontlottyn	A place inside a place
we came down here to White Rose Way and there was another pile on White Rose Way.	The place can be interpreted as either the place between the White Rose Centre and the place that the speaker started from	A place between two placers
	, or a place that is next to the White Rose Centre.	A place next to a place
I tell you where they do hang out are the bus stops.	The place next to the bus stops	A place next to a place
Yes, the train stations and bus stops	The hang out places are next to the train stations and next to bus stops	A place next to a place

The trees down White Rose Way, they have snapped them all off	The trees area near White Rose Way	A place next to a place
If somebody's washing machine broke and they couldn't get rid of it, it would go down over the side of the railway station.	The place next to the railway station	A place next to a place
They hang out in that garden that they made for the	The hang out place inside that garden	A place inside a place
Down by the community centre is it? Yes. Where the old school was, they have sort of made a garden.	The garden occupies the old school location	A place inside a place
I have seen, I mean I haven't walked over that bridge for a good couple of months, but it used to be always on that new bridge, I would be wary about there.	Using exact place by its name to define a place	Exact place
I'm not aware of it anywhere in New Tredegar that we have a problem with needles and things like that.		
No. At one time they used to have it in the park behind the play area behind the houses.	The problem area inside the park that is behind the play area behind the houses	A place inside a place
		A place is located from a given direction from a place
he went to the local shop, and these children were on the steps and they swore and he said oh don't do that, there's no need to do that.	The children's place next to the shop	A place next to a place

Results:

Prototypical Spatial Relationship	Records	Percentage
A place contains places	11	13%
A place inside a place	32	39%
A place next to a place	13	16%
A place between two places	2	2%
A place is located at a given direction from a place	1	1%
Exact place	23	28%
Total	82	

- **Group 2**

The relevant sketch for group 2 (see Figure C.2) and a list of places' names, as well as the qualitative description of place locations that were expressed within the interview, are presented and analysed below (see Table C.2).

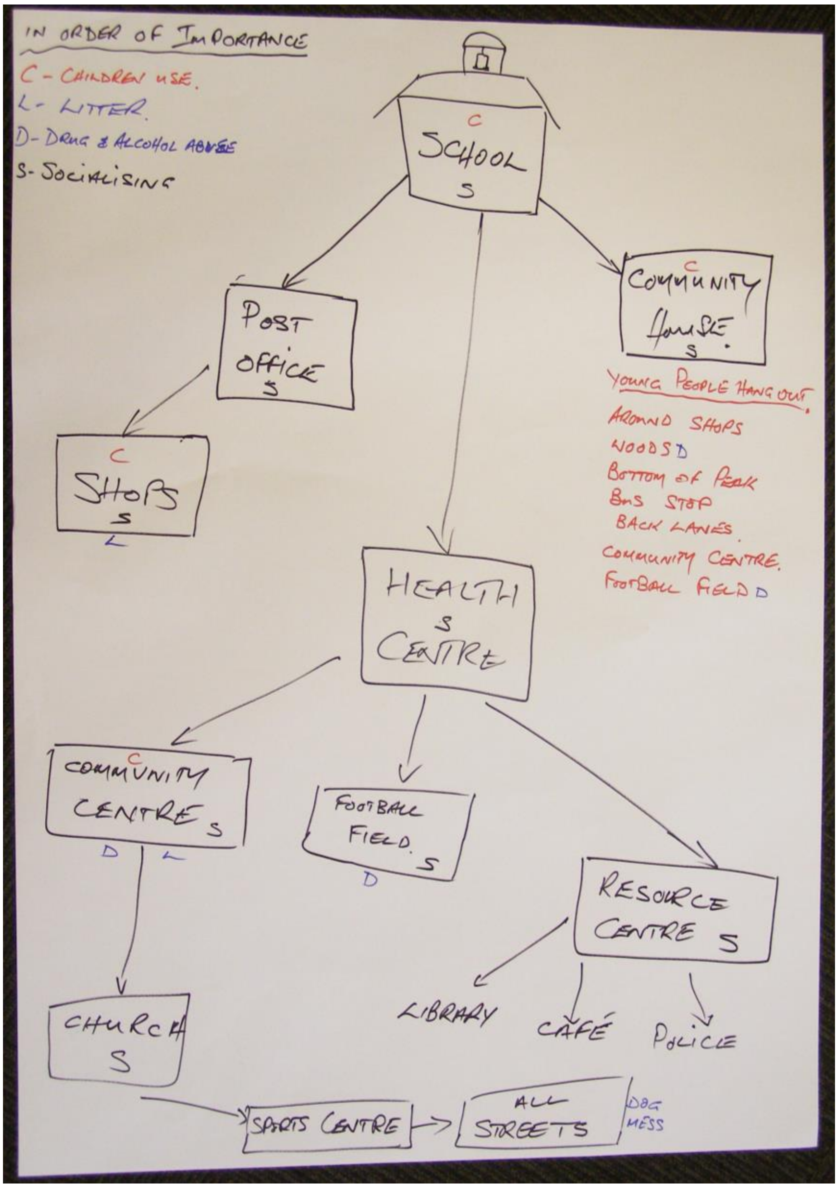

Figure C.2 A conceptual map that has been sketched by group 2 to describe their neighbourhood.

Table C.2: A list of all *place names and sentences that describe the place locations* expressed by the participants in group 2 during the interview. The correspondent prototypical spatial relationships are provided.

Expression	Correspondent Spatial Relationship
Phillipstown School	Exact place
Post office?	Exact place
We haven't got a bank. We've got to go to Bargoed. We got hole in the wall now. Where to? In between Crozzies and the kebab shop,	A place between two places
train station	Exact place
Asda	Exact place
And if you want to go to the local hospital which Faulty Towers in Prince Charles	A place inside a place
the resource centre down into Elliotstown	A place inside a place
I mean they've got more resources down in New Tredegar.	A place contains places

They've got the library now.	
Firework display down in New Tredegar .	A place inside a place
Temporary location, user defined uncertain boundaries.	
No the young ones come down here and we have a, what we call it a cyber café…	Exact place
Community House	Exact place
we can put there, so if it's an event that has happened here we can put that in the same place. No that's fine	A place inside a place
We got the Citizens Advice here, that's once a month isn't it	A place contains places
The AM come here, the PMs come here	A place contains places
Health Centre	Exact place
The doctors are there, the chemist are there.	A place contains places
There's a chemist next door.	A place next to a place
Okay, what other places can we put on this map?	
Library.	Exact place
I've got the community centre.	Exact place
We have a computer suite upstairs.	A place contains places
We've got photocopying facilities here for people.	A place contains places
Sports centre.	Exact place
Come under that white bridge, just past there on the left, they should have put it there and a swimming pool and all.	A place next to a place
	A place is located from a given direction from a place
Well it is, the youngsters go down there and play five aside and do the football. They do the training inside	A place inside a place
sports club	Exact place
Police station.	Exact place
Okay by the resource centre.	A place next to a place
It's by the library, isn't it?	A place next to a place
The church.	Exact place
We used to cross over to the TA and then go back.	A place between two places
Shops	Exact place
And a fish shop, a shoe shop (talking over one another), in Phillipstown.	A place contains places
We used to be five shops and a bakery in	A place contains places
And what we're going to do next is turn it into a drawn map, so if we can nominate someone to draw	
Because the resource centre has got the library, the police station	A place contains places
Do you want us to actually say that the library and the police and cyber cafe or the cafe are in there?	A place contains places
Because that's not just the resource centre, but all the other things are under the same roof.	A place contains places
On the corner.	A place next to a place
Out on the top of the bus stop.	A place next to a place
Down by the community centre. Up by the top by the VG shop, against the walls, lanes	A place next to a place
	A place is located from a given direction from a place
when we had the institute, it was by the institute	A place next to a place

Where do children hang out and cause problems? What sort of places? With problems?	
In the back lanes, down in the woods, up on the mountain	A place inside a place
Around the community centre.	A place next to a place
They tend to meet at the top shop to play football	A place next to a place
And in the woods at the moment.	A place inside a place
It is part of Phillipstown	A place inside a place
Well around the shop, they hang around VG shop	A place next to a place
they hang around the fish shop	A place next to a place
Around shops	A place next to a place
Around shops, woods	A place next to a place
And the bottom of the peak.	A place inside a place
And back lanes.	A place inside a place
They took the seat down, all sitting up there on the top grass.	A place inside a place
Around shops, woods, the peak, bus stop, back lanes. And the community centre.	A place next to a place
all the drunks and druggies would sit under the shelter. Sit under where? The community house.	A place next to a place
Well up by the VGs mainly (talking over one another). Garage.	A place next to a place
The shops are the worst. Around the shops	A place next to a place
Bottom of Pritchard Street would cover the shops	A place contains places
We used to have a skip up in the community garden	A place inside a place
Drugs. Again in the same places	A place inside a place
That's where they're handing out in the woods.	A place inside a place
There's all those needles by the football field	A place next to a place
So the fronts of the houses. They're sociable as well? Yes	A place is located in a given direction from a place

Results:

Prototypical Spatial Relationship	Records	Percentage
A place contains places	12	19%
A place inside a place	14	22%
A place next to a place	19	30%
A place between two placers	2	3%
A place is located in a given direction from a place	3	5%
Exact place	14	22%
Total	64	

- **Group 3**

The relevant sketch for group 3 (see Figure C.3) and list of place names, as well as qualitative descriptions of the place locations that were expressed during the interviews, are presented and analysed.

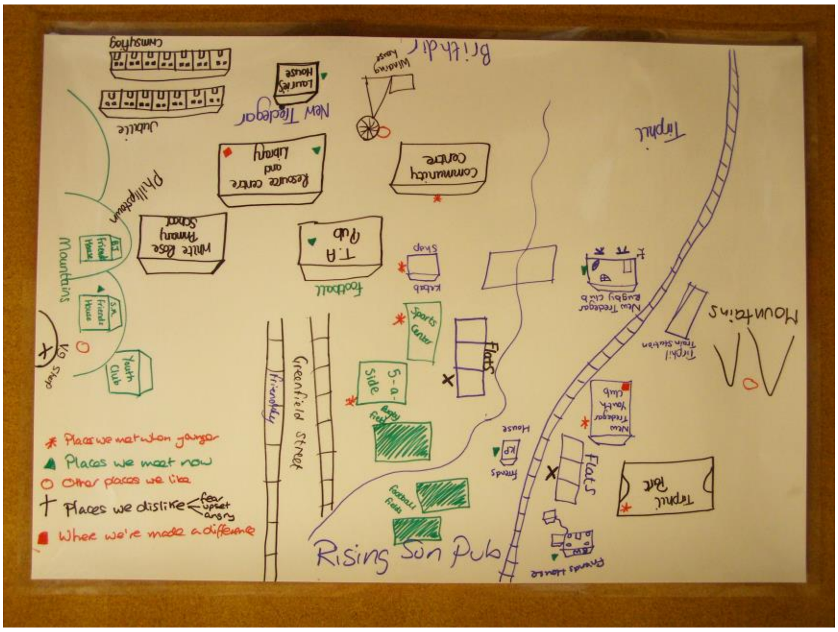

Figure C.3 The mental map sketched by group 3 to describe their neighbourhood

Quotes from the interview indicating how the interview was conducted:

Stephen: The first thing we're going to do is we're going to create a map. Now, this is a very folded up (nice version?) of a map of New Tredegar [shows them a topographic map] but this is not the map you are going to draw	
you are going to draw your own map and we are going to try and put these places where they are geographically, if that makes sense, so we're going to make our own map.	
But the first thing [to do?], obviously this map has got edges to it, but this is just a map we have printed off, and it doesn't, you know, these edges might mean nothing to you or they might mean something to you.	
So what we'd like to do is that, thinking of this as a map, and thinking of your community, where would you say these edges of the map represent? Where are the edges of your community?	

Table C.3: A list of all *place names and sentences that describe the place locations* expressed by group 3 during the interview. The corresponding prototypical spatial relationships are also presented.

Expression	Correspondent Spatial Relationship
The tops of mountains. It's the two sides and then… On both sides	A place contains places
Brithdir,	Exact place
Brithdir, you stop at Brithdir and then you stop	Exact place
Eva: So that would be… where would that be [pointing to edge of map]?	
That mountain.	A place contains places
Brithdir say	Exact place
some mountains.	A place contains places
Stephen: Where does, in terms of your community, where does it end at the top then, this side (pointing to map edge roughly north of the area)?(in a given direction from a place)	
By the Rising Sun isn't it? Yeah, it's a pub at the top by there.	Exact place

That's a pub. Ok shall we…It's called Graig Rhymney.	Exact place
Yeah, it's the street, the last street in Tirphil.	A place inside a place
Eva: So where's this edge then? Is that um...	
Eva: To the Rising Sun.	Exact place
Yeah, Graig Rhymney innit	Exact place
Eva: Shall I put the Rising Sun? B,S & K: Yeah	Exact place
Stephen: Ok, so this is, they are the edges of our maps. And now the next thing we need to do is we need to put all of our places on the map, where they belong.	
The football matches will go… Hmm, by the sports centre.	A place next to a place
Stephen: Ok and are they at the sports centre are they? S: No they're behind it on a field.	A place next to a place A place is located in a given direction from a place
Behind it on a field	A place inside a place A place is located in a given direction from a place
The youth club. That's in Tirphil.	A place inside a place
there's a youth club in Philipstown and there's a youth club in	A place inside a place
Ok I mean if there are, and the rising sun pub's in Tirphil as well did you say? B: Yeah	A place inside a place
S: Tirphil is part of New Tredegar but it's …	A place inside a place
S: That's the rugby club, shall I write on it because I like to go down to the rugby clubs and have a pint, because they are in different places.	Exact place
Then Kelsey's the Tas	Exact place
S: It's by the bridge.	A place next to a place
S: Because they're on the same street aren't they, the TA and the rugby club.	A place contains places
S: Shall I put my youth club as the one in Philipstown?	Exact place
K: Should we write like the five a side? Because we used to go there when we was younger.	Exact place
S: It's like a sort of, the court where we play football and stuff on there but we just used to hang around in there.	A place next to a place A place contains places
K: That's just up from the sports centre that is. Its right next to it really…	A place next to a place
K: …it's behind it.	A place is located in a given direction from a place
Resource centre	Exact place
K: (?) like a library by here (?) library. Should we put the resource centre and the library in together cos they are aren't they?	A place contains places
B: Yeah, then do the other, what was it, it was the football pitches behind there ain't it?	A place is located in a given direction from a place
the school	Exact place
S: New Tredegar rugby club is called New Tredegar rugby club and is in Tirphil!	A place inside a place
K: Shall we put like little areas like places like Cwmsyfiog and places that, to just show where they are?	A place contains places
K: Right, we have got Phillipstown, where would we label them all	A place contains places

now?	
B: Yeah. We could put the communal as well because people go there, and the kebab shop.	Exact place
S: Yes, and the Chinese and Joanie's	Exact place
S: No, that's just where there's woodland, and Greenfield Street and Powells Terrace.	Exact place
B: And then the mountains behind, there's nothing else up there	Exact place
	A place is located in a given direction from a place
S: Yes, Cwmsyfiog, they are rows of houses.	Exact place
K: I think there's like a MUGA up there on the end of Jubilee Road, but we don't use that one, we use the five-a-side down by the field.	A place inside a place
	A place next to a place
S: The five a side and the kebab shop and the gardens. We haven't put the gardens on either.	A place contains places
S: Yes, because it's before that and after that.	A place between two placers
S: In the gardens in the summer	A place inside a place
S: Sports centre?	Exact place
S: We did used to sit in the railway. And where else? Laurie's house.	A place inside a place
S: We used to walk from the kebab shop up to the five a side; we would just be roaming the streets really.	A place between two placers
K: They are down the kebab shop now, if you go down there about seven o'clock, they are all stood there.	A place next to a place
S: And they are all sat outside the shop by here.	A place next to a place
S: I know what we forgot to put on there, Tirphil park.	Exact place
K: Then there's **the rough places** around here like the flats, that's where all the druggies hang out.	A place next to a place
I don't like walking past the flats.	A place next to a place
S: And there's that place in Phillipstown up the top	A place inside a place
K: What can we do for a horrible symbol? A black circle? S: The flats down by the sports centre, down by there.	Exact place
S: Its just like an area, it's like the top of the road and it just comes off it, a piece of concrete. K: Yeah, and it's by a shop. S: It's like a lay-by type thing.	A place next to a place
Stephen: The top of the road by the school?	A place next to a place
K: Its down in New Tredegar, it's like a long street.	A place inside a place

Results:

Prototypical Spatial Relationship	Record	Percentage
A place contains places	9	15%
A place inside a place	12	19%
A place next to a place	12	19%
A place between two placers	2	3%
A place is located in a given direction from a place	5	8%
Exact place	22	35%
Total	62	

- **Group 4**

The relevant sketch for group 4 (see Figure C.4) and list of places' names and qualitative description of place locations that have been expressed within the interviews are presented and analysed.

Figure C.4 A mental map sketched by group 3 to describe their neighbourhood

Table 4: A list of all *place names and sentences that describe the place locations* expressed by group 4 during the interview. Interpretations of these expressions and the corresponding prototypical spatial relationships are explained.

Discussion	Expression	Correspondent Spatial relationships
where's the edges of where you would call home?		
M	At the shop.	A place inside a place
So we'll make that edge where the shop is.		
M	No because the new buildings is at that end, right at the top.	A place contains places
M	New buildings and you go down.	A place contains places
Okay so what are these new buildings then?		
M	That's what it's called.	
M	Orchard Street.	Exact place
So these houses on Orchard Street then.		
M	This is Jones Street.	Exact place
M	Like first things first, this is what is down the bottom of my street, Jones Street right, this is what's down the bottom.	A place contains places
M	Well they have five a side, they have sports centre, all that stuff and what we got?	A place contains places

M	Leisure centre and everything.	A place contains places
M	We have yeah. There's this and the community centre.	Exact place
So on Jones Street there's a tractor company.		
M	At the bottom.	A place is located from a given direction from a place
M	MJ Plant.	Exact place
Okay. So if you want to play football where do you go?		
M	Field.	A place inside a place
Okay so we've got Orchard Street here, Jones Street here, what's the bottom, where's the furthest down the bottom?		
M	Derwent Street.	Exact place
M	Derwent is up here love.	
M	No Perry is up there.	
M	The park is down there.	Exact place
So the community centre and the park are down the bottom end of Philipstown. Yeah and that's what you think of as the bottom end of Philipstown, right okay.		
M	This is the park this is.	Exact place
M	The swings.	A place inside a place
Does someone over there want to draw in this, so what did we say was this side?		
M	Farm Terrace.	Exact place
So which one is Farm Terrace? That's not the long road into Philipstown is it?		
M	There's a tree at the bottom.	A place inside a place A place is located in a given direction from a place
M	It's in the middle at the top isn't it? Drawing on the map	A place is located in a given direction from a place
M	It's in the middle at the top isn't it? Drawing on the map	A place is located in a given direction from a place
M	Where is the community house?	Exact place
M	Top is just.	
So what do you want to draw at the top up there? Is that the place up by the shop?		
M	Yeah.	
M	It's a shop.	Exact place

M	The shop, the road, top that's where we stand like just.	A place contains places
M	There's a camera.	A place inside a place
Shall we label that camera then?		
M	Crime camera.	A place inside a place
M	That's Maggie's shop.	Exact place
M	That's on top isn't it.	A place inside a place
M	Yeah the Peak, that's where we hang out.	A place inside a place
So what goes on in community house then? Because you used to.		
M	Pool table.	A place inside a place
And why is it important to you? What's good about it?		
M	Computers.	
So do you want to write it on the map?		
M	MG Plant.	Exact place
M	The farm.	Exact place
Chill out and drinking place yeah.		
M	And Vicki's, that's another shop for us.	Exact place
M	Got two shops, a fish shop and a post office.	Exact place
So where do the girls hang out?		
M	Jo's fish.	Exact place
M	In their house.	A place inside a place
M	There's a pub up here.	Exact place
M	One for definite that is the farm like.	Exact place
M	Maggie's shop is another one.	Exact place
M	Fish shop and Vicki's.	Exact place

Results:

Prototypical Spatial Relationship	Record	Percentage
A place contains places	6	15%
A place inside a place	10	25%
A place next to a place	0	0%
A place between two places	0	0%
A place is located in a given direction from a place	4	10%
Exact place	20	50%
Total	40	

All results for all groups:

Prototypical Spatial Relationship	Record	Percentage
A place contains places	38	15%
A place inside a place	68	27%
A place next to a place	44	18%
A place between two places	6	2%
A place is located in a given direction from a place	13	5%
Exact place	79	32%
Total	248	100%

Appendix D

This appendix presents the experiment that has been carried out to define the footprints of the buffered zone. The proposed method computes the distances between the centre of a reference object (RO) and the nearest neighbours in each 8-cardinal direction (*RO_Distance*), and then uses the average of these distances (*RO_Buffer_Distance*) to plot a buffer footprint using this average around the RO. The rationale for this is that the area that represents 'next to' is the area directly adjacent to this given object, and at the same time it must not exceed the 'next to' area of the adjacent object.

$$RO\_Distance_{(1\text{-}n)} = RO\_\ Distance_1 + RO\_\ Distance_2 + \ldots + RO\_\ Distance_{(n \leq 8)}$$

$$RO\_Buffer\_Distance = RO\_Distance_{(1\text{-}n)} / n$$

Two approaches have been tested: plotting a buffer from the centre of the RO, or plotting a buffer from the BORDER of the RO instead. When applying the first approach to realistic data, it has been shown that, in some cases, the resultant buffer footprint is less than the RO area, and this is logically not acceptable, as the footprint neglects a lot of the areas that surround the RO (see Fig D.1). When applying the BORDER approach, it is shown that the approach is logically acceptable and practical (see Fig D.2).

Fig D.1 the yellow colour represents the RO and the shaded circle represents the buffer zone

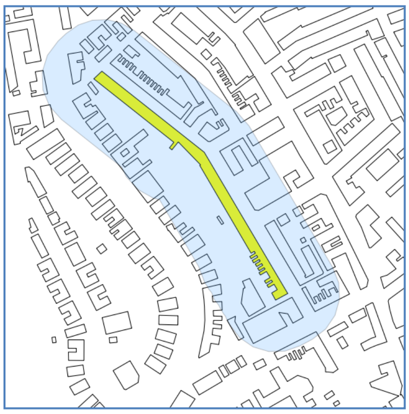

Fig D.2 the yellow colour represents the RO and the shaded section represents the buffer footprint

This confirms that the average distance to the neighbours from the centre should be sufficient, unless drawn more accurately from the border, if the boundary of the objects is known. To evaluate the approach, an experiment has been carried out on a realistic dataset. An Ordinance Survey (OS) dataset containing all buildings in one of Cardiff's electoral wards, that is, Plasnewydd, has been downloaded and utilised. The file contains 986 buildings (polygons).

A bespoke software using Python programming language was developed. For each place, its size and the distances between this place and the nearest neighbours (places) in all 8-cardinal directions were computed and recorded. The step produced 4888 distance records and 986 size records. The purpose of the calculation was to answer the following question: is there a correlation between the sizes of objects and the distances between these objects? That is, the greater the size, the greater the distance or vice versa. The assumptions were:

a) If there is a ***strong correlation***, this supports calculating the average for each RO with its nearest neighbours, and then this average can be used to plot the buffer from this RO. The same computation should be applied each time for each place separately.

b) If there is no correlation, or the correlation is weak, this supports calculating the average of all distances in the scene. Then the resultant average will be utilised as a general measurement to specify the buffer that represents the envisaged places' footprints.

A Pearson product-moment correlation coefficient has been calculated to assess the relationship between the size and distance. The result, shown in Table D.1, indicates that there is a positive correlation, but it is a ***very weak correlation,*** between the two variables [r = 0.2, n = 4888, p = 0.000]. Fig D.3 shows a scatter plot that summarises the results.

Table D.1

Correlations

		Distance	Size
Distance	Pearson Correlation	1	.200**
	Sig. (2-tailed)		.000
	N	4888	4888
Size	Pearson Correlation	.200**	1
	Sig. (2-tailed)	.000	
	N	4888	4888

**. Correlation is significant at the 0.01 level (2-tailed).

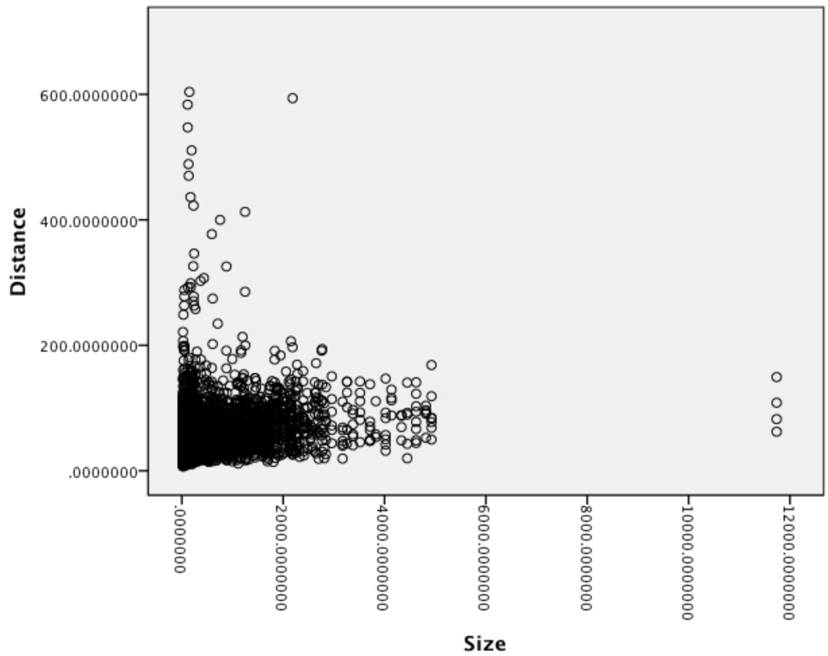

Fig D.3 The weak relationship between size and distance

Overall, there is a very weak, positive correlation between distance and size, and increases in distance are not adequately correlated with the increase in the size of places. This supports the computation of the average of all distances in the scene between objects, before utilising the resultant average to specify the buffer that represents the envisaged places' footprints.

The experiment gives an idea of the average distance between objects in an urban setting, which is useful for sketching neighbourhood components, as required for the research.