SENSMOD

Computational Design through the lens of Henri Lefebvre's Spatial Theory

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Abstract. Spatial productivity is the first of the elements comprising sensMOD, a student elective that implemented a methodology addressing the exigent need of our time for transformation in the architecture, engineering and construction (AEC) sector. The second and third elements of sensMOD are parts and interaction which focus attention on the nature of complexity and connectivity in our networked world. The paper proposes a methodology that was used to guide the teaching of an elective for third year architecture students at a UK university. Its wider purpose is to contribute to discussion concerning the dysfunctional state of an AEC sector that needs to consider its productivity as projections of wider networks of resource and energy relationships. Henri Lefebvre's spatial theory (1991) guides the narrative and formulation of sensMOD.

Keywords. Computational design; spatial productivity; modularity; interaction design.

1. Introduction

Can change occur without expectation, without exploration of the possible and the impossible? (Lefebvre, 2014, p.27)

This paper defines sensMOD, a student elective comprising a methodology used to guide the teaching of computational design principles and methods for a third year, RIBA accredited, BSc architecture elective at a UK university. Its premise is that the design and production of space by the global AEC sector needs overhauling because its buildings are responsible for 32% of global energy consumption. Stabilised global warming of 1.5°C requires new construction to be fossil-free and near-zero energy by 2020, with building emissions reduced by 80-90% by 2050 (IPCC, 2018). However, this paper does not examine the problem using the tools of scientific analysis but instead proposes a radical methodology, viewed through the lens of Lefebvre's spatial theory, that would transform the AEC sector. Accordingly, sensMOD considers space, parts and interaction as essential elements of the methodology, with each viewed from perspectives which are overlooked in conventional approaches to design and production. Space is examined as a phenomenological rather than abstract conception in accordance

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to Lefebvre's notion of the production of space (1991) and with reference to Gaston Bachelard's reflections on the 'corner' in The Poetics of Space (1994). Parts are studied in relation to the whole with concepts borrowed from the manufacturing sector including slot, sectional and bus modularity, as described by Karl Ulrich (1995). Interaction, an essential element of the methodology that binds connectivity in space and between parts, is studied with reference to Malcolm McCullough's (2005) examination of pervasive computing and its influence on architecture.

A carefully chosen and disregarded 'corner' of the School of Architecture was the site for explorations by the students implementing sensMOD with the aim of developing an appropriate architectural intervention. The spatial realm was initially explored using 1st order modelling (Stasiuk, 2018) - sketches, observations, photos, videos and text - so that no predefined conventional representations would dominate and to limit the abstracting influence of computational design tools at this stage. The elements of parts and interaction combined 1st order modelling outcomes with 2nd order modelling techniques using the procedural method of parametric modelling with Rhino and Grasshopper, and computational modelling with Firefly and Arduino which included the use of scripting, sensors and actuators.

2. Space

...the spider, for all its 'lowliness', is already capable, just like human groups, of demonstrating space and orienting itself on the basis of angles. (Lefebvre, 1991, p.173)

Lefebvre alludes to the notion that through activity the living organism produces space that is networked to a field of activity that projects relationships into manifestations of the living organism. Accordingly, sensMOD challenges the notion that space derives from an analytical, centrally authored, hierarchical description of functions and adjacency relationships because it is a notion that supports interests which ignore decentralised, local activities and resource availability. Furthermore, this notion has encouraged architects to consider space as an analytical abstraction that is separate from behaviour. Instead, architects believe that the functional specificity of ordered spatial configurations will determine behaviour, as noted by Bryan Lawson who criticises architects lack of training in the ability to 'observe and evaluate buildings as social phenomena' (2001, p.200). Tim Ireland's study of sensory-based space extends Lefebvre's spatially oriented view of the world by focusing on the productive qualities of an 'archetypal organism-in-its-environment' which generate configurations in space (2015, p.383). Furthermore, Ireland promotes an architectural method of 'social' or 'projected geometry' implemented by computational modelling to configure spatial configurations and forms which he depicts as a fluid, decentralised and distributed intelligence arising from a 'cell-centric', agent-based strategy produced by the living organism (2015, p.389).

But the purpose of this stage of the methodology of sensMOD is to dwell in the realm of the phenomenon in all its manifestations and not be diverted by scientific

explorations. Returning to Bachelard's 'corner' the intent here is for the students to remain as long as possible in this '...sort of half-box, part walls, part door' where 'nothing is ever empty' and to continue to reflect on his notion that words are 'little houses' where we might go upstairs and withdraw or descend to the cellar to dream (1994, pp.137-147). The focus narrows to our interaction with space through our senses and the way that we affect the world through our capacity to affect - and to impart the idea, as alluded to earlier, that rather than planned the space of architecture is moving inexorably towards fluidity because function no longer commands attention as it once did. Indeed, as noted by William J Mitchell (2003, p.162), program and functional specificity have been eroded by 'continuous fields of presence' and the 'destabilisation of person-to-place relationships'. He goes on to assert that as a result of these processes we should be witnessing an architecture of,

...continually reconfiguring clusters of spatial events characterised by their duration, intensity, volatility, and location. (Batty, M. 2002 in, Mitchell, 2003, p.163)

The idea that connectivity matters more than functional adjacency relationships was propounded earlier by Nikolas Habraken in Supports (1961) and depicted in Cedric Price's Inter-Action Centre (Lobsinger, 2004). But the difference today is that connectivity is networked and reconfigured seamlessly and digitally, whereas these pioneers attempted to represent connectivity as a network of large-scale, reconfigurable physical relationships. This emphasis on networked seamlessness was developed by Lefebvre's The Production of Space (Lefebvre, 1991) originally published in 1974, which asserted that 'productive' space is correspondingly connected to a networked world. McCullough advanced the theme of connectivity imagining 'responsive place' instead of 'anytime - anyplace' with the additional insight that connectivity is 'inside of architecture' rather than 'instead of architecture' (2005, p.67). McCullough's description of interaction design connects with Lefebvre's field of phenomenology as they are both concerned with perceptions that are unrelentingly fluid and emergent yet sensuously responsive, hence he calls for,

...interaction design to use the prospects of ambient, haptic and embedded interfaces as a way to reinvent computing. (2005, p.153)

Correspondingly, Lefebvre had already noted that,

...space...is first of all heard (listened to) and enacted (through physical gestures and movements). (1991, p.200)

The notion of space as sensed and affected by our senses initiates the first stage of the methodology of sensMOD. The intention was to allow awareness of sights, sounds, touch and taste, and an interoceptive (i.e. inside) and proprioceptive (i.e. outside) sense of the body in space, to produce a response to a pre-existing spatial configuration in the School of Architecture. At the same time, the connected and networked nature of this productivity was introduced (Figure 1).

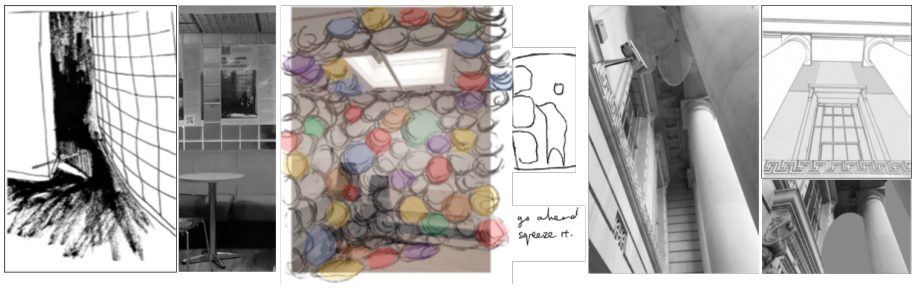

Figure 1. Development of concepts: Team 2 (SeeWhatHappens); Team 5(Release); Team 9 (Airhead).

3. Parts

...before the advent of the abstraction devised by human societies, information was no more distinct from material reality than the content of space was from its form: the cell receives material information in material form. (Lefebvre, 1991, p.178)

Lefebvre verifies that nature's spatial envelope, the atom or the cell, has a boundary that is relative because its permeability must allow for the exchange of energy (food, air, excretion) and information (sensory data). Correspondingly, in human society boundaries are relative, that is permeable, but the envelope may also be closed for security or privacy reasons or to exclude outsiders. As Lefebvre observes, the spatiality of the office, or more generally the 'space of work', exemplifies relative or permeable boundaries,

...as one network among others, as one space among many interpenetrating spaces, its existence is strictly relative. (1991, p.191)

Thus, in this conception, atoms, cells and parts have permeability and porosity and they don't exist as independent entities but within connected wholes that produce and are the product of networked space and form. The part, like its function, is a relative concept and while it may be an atom, a molecule or a cellular complex, it may also be regionally defined as an arm or an office, but the common conditions of these parts are relativity of definition and connectivity. Furthermore, the bodily or holistic manifestation goes beyond these parts via networks as Lefebvre explains, again by reference to the office which manifests from these networks as the result of the 'gestures' and 'actions' of productive labour, divisions of labour, operation of markets and property relationships that are the ownership and management of the means of production (1991, p.191).

Therefore, the part was introduced to the students as a notional object which is relative rather than absolute, connected by networked links, and to enable the management and understanding of complexity. This facilitated further discussion of parts as modules that are responsive to sensory input and output. We utilised the manufacturing sector's concept of modular architecture which is different to architects' conceptions which include: the potentiality of the brick or block as a module, as demonstrated by Alfred Farwell Bemis (Bemis, 1936); the modular arrangement of standard components as exemplified by Rudolph Schindler and

Walter Segal (Broome, 1986; Schindler, 1946); the modularisation of parts as proposed by Konrad Wachsmann and Walter Gropius with their Packaged House of 1941-2 (Davies, 2005, p.23); and also recent examples of volumetric or modular containment (KieranTimberlake, 2017; SHoP, 2014). By contrast, for all scales of production in the manufacturing sector the concept of modularity has been refined by Ulrich (1995, pp.419-428) to include the strategies of slot, sectional and bus modularity (Doe & Aitchison, 2016) (Figure 2).

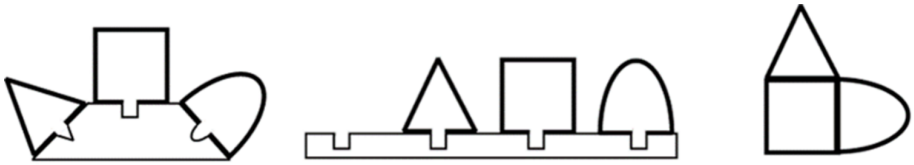

Figure 2. Slot, bus and sectional modular architecture strategies (Ulrich & Eppinger, 2016, p.188).

With slot modularity, each of the interfaces between components is of a different type from the others, so that the various components in the product cannot be interchanged e.g. a car radio whose interface is different to other components in the car. With sectional modularity, all interfaces are of the same type and there is no single element to which all the other components attach e.g. office partitions, computer systems. With bus modularity, there is a common bus to which the other physical components connect via the same type of interface e.g. expansion cards for personal computers, shelving systems. Thus, it's the interface, or point of connectivity, that defines the difference between these modular architecture strategies and the students were encouraged to nominate one or several of these in response to their spatial explorations and in the development of their architectural intervention (Figure 3). Rhino and Grasshopper seminars supported this approach by demonstrating how modularity can be interpreted as a 2nd order, parametric modelling method. But, as previously stated, the purpose was not to create specialised spaces or interventions that required supporting equipment, instead, as Mitchell suggests, the intention was towards,

...creating flexible, diverse, humane habitats for electronically supported nomadic occupation. (Mitchell, 2003, p.162)

This approach also confirmed that we are already carrying out our activities in connected, networked spaces where we determine function on the fly, and brought to awareness the realisation that it is now the 'software programmer' not the 'architectural programmer' who controls space use and 'thereby expresses power' (Mitchell, 2003, p.167).

The modular or component based element of the methodology advocated here is relevant and timely because it re-focuses attention towards the part and its interfaces where we can reconfigure spatiality using appropriate and adaptable materials, and where energy flows may be sensuously distributed and responsively networked in a decentralised way.

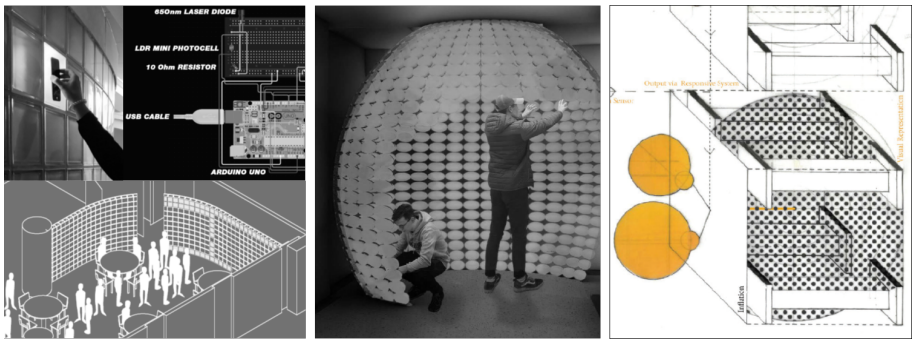

Figure 3. Development of prototypes: Team 2 (SeeWhatHappens); Team 5(Release); Team 9 (Airhead).

SensMOD counters the reproduction of homogeneity and its outcomes which are the creation of confounding places where formal geometry and visual spectacle dominates, leading to feelings of discomfort and unease. Instead, it reinforces Lefebvre's observations that the space of architecture should be produced in a distributed and decentralised way that acknowledges partiality and its interfaces, and that arises from our sensual capacity to hear, interact and enact through our 'physical gestures and movements' (1991, p.200).

4. Interaction

...life has been...an incessant diversification and intensification of the interaction between inside and outside. (Lefebvre, 1991, p.176)

Lefebvre infers not merely to what passes through the permeable membrane of the cell, but is attesting to his enduring interest in space and his unusual awareness of his own body's sensuality with drives poetic desire to 'vivify' the body's 'rhythms and senses' (Lefebvre, 2014, pp. 34-35). Interaction is the key element of this relationship between the inside and outside of the part or module and, correspondingly, of the methodology of sensMOD. Concerning the importance of interaction, McCullough's enquiry into 'contextual computing' is instructive as it examines the phenomenological thinking that led to theories of 'embodiment', 'contextual perception' and 'situated action' (2005, p.178). In summary, this thinking explained that modern buildings' lack of responsiveness to place arose from their emphasis on the representation of abstractly geometric space. Essentially, this amounted to a failure to interact, but more poignantly Lefebvre, lamenting the influence of urban planners on architects' work, described such resultant non-places as '...the forgotten, obliterated location - of the architectonic work' (2014, p.3). These commentaries prompted further questions about intention, expression and implication which were relevant to the students' spatial explorations focussed around interaction:

- Intention. How can we make responsive modular interventions that renew and embody 'the joy of lived experience' (Lefebvre, 2014, pp.26-27)?
- Expression. If 'background experiences', rather than 'foreground objects'

(McCullough, 2005, p.154), are the path to connection between interaction design and architecture, then how is this achieved?

- Implication. Is a responsive approach that uses ambient, haptic and embedded interfaces a way to 'reinvent computing' (McCullough, 2005, p.153), reinvent architecture, or both?

To answer these questions students explored ways of collecting sensory data to influence pattern, form and interaction using Grasshopper and Firefly, and examined how to use sensors and actuators with Arduino that were relevant to their initial responses to the spatial enquiry of their 'corners'. With contributions from an artist working with light, DMX controls and other sensors, and an artist working with found objects, 'upcycled' e-waste, Arduino sensors and actuators the students were also introduced to ideas and methods by which spatially located, responsive modular interventions could be realised. The technical challenge of scripting using 2nd Order abstracted logic, territory unfamiliar in conventional architectural training and practice, was taken on by the students utilising the visual data flow graphs of Grasshopper and the imperative programming required to instruct Arduino's microcontroller with its associated inputs and outputs.

Throughout these explorations the emphasis lay on spatial understanding, and on the process of design and production, rather than on the creation of a finalised representation or form. 2nd Order computational modelling was instead employed to enable spatial configurations to emerge - or in Lefebvre's terms, for production to be 'secreted' from spatial practice (1991, p.38). The early explorations of the concept of the 'corner' guided students understanding of the patterns of activity that were of importance and that would embody 'the joy of lived experience', thus contributing delight for participants and passers-by. Rather than a centralised approach to design and making teams of four worked as distributed co-workers, sharing tasks and responsibilities. In such a setting, each team also represented all imaginary stakeholders' interests, needs and desires from a technological, social, environmental, economic and political perspective, thus grounding the work and connecting these stakeholders via a network of relationships to their realised productions. And, rather than rigid, functionally specific spatial outcomes, the goal was to produce interaction bound, connected and distributed, spatially and partially responsive interventions that would be adaptable to quick, digitally driven change (Figure 4). Accordingly, and in recognition of the exigency to change the way that we design and produce buildings so that our limited resources and energy are utilised with appropriate care and attention, sensMOD's radical approach aims to address the tacit norms of architectural practice and the AEC sectors' dysfunctionality in general.

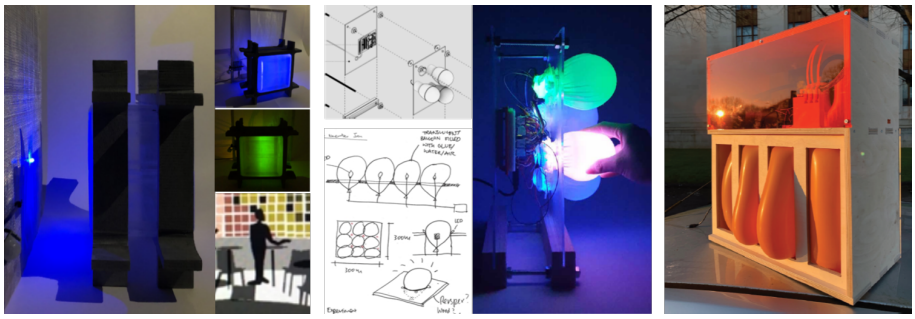

Figure 4. Development of final work: Team 2 (SeeWhatHappens); Team 5(Release); Team 9 (Airhead).

5. Reflection and conclusion

The architect (demiurge or hack) and limits of architecture (as specialised activity, aesthetic or technical) are secondary. It is a question of 'mankind' and its future. (Lefebvre, 2014, p.29)

The methodology defined in this paper addresses the exigencies of Lefebvre's exhortation by reconfiguring the way that architects are trained to design and produce buildings. Additionally, as a responsive modular approach, sensMOD has included discussion of part to whole relationships, defined more broadly by Daniel Koehler (2019) as mereology which 'can gather the techniques of bonding, joining, interlocking, entangling and overlapping of parts' (Koehler, 2019, p.33). Mereology underpins the recently defined movement of 'discretism' which Mario Carpo also conflates with 'particlised computation' (2017). Furthermore, the techniques which Koehler lists can be seen in Phillipe Morel's Bolivar Chair (2004) and Kengo Kuma's Kodama Pavilion, 'a new "democratic" way of construction' (Kuma, 2018). These techniques can be implemented using an aggregational computational method derived from a 'new kind of science', a notion first described by Stephen Wolfram (2002), and linked by Carpo to the design movement of discretism because the work of its proponents reflects,

The inherent discreteness of nature... which is made of 'discrete chunks of matter' (Carpo, 2017, p.71)

Clearly then sensMOD's methodology shares some of the attributes and characteristics of mereology and discretism but it is distinguished by its focus on interaction which links the production of space to activity and to projections beyond via networks of relationships, in accordance with Lefebvre's spatial theory.

The methodology of sensMOD has explored the possible and the impossible, aiming to instruct and inform in the field of academia, and to encourage discussion and urgently needed change in the AEC sector. What is possible is that architects could be trained to observe and evaluate buildings as social phenomena, using Lefebvre's way finding suggestions as a guide. What seems impossible is effecting change in the dysfunctional processes of design and production that the AEC sector engages in which ignore the limitations of resource and energy availability. A

methodology that considers parts and their interactions as projections of wider networks of resource and energy relationships attempts to bridge this gap in knowledge and understanding. Further research will examine the results arising from the implementation of sensMOD in the academic context and its wider implications for teaching and practice.

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