Author(s): Coates, Paul; Thum, Robert
Title: Parallel systems and architectural form
Year of publication: 2000
Citation: Coates, P. and Thum, R. (2000) 'Parallel systems and architectural form' *Proceedings of the Greenwich 2000 Symposium: Digital Creativity International Conference*, January 2000, London: University of Greenwich.

Parallel systems and architectural form

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Abstract

This paper describes the work of students in Unit 6 of the Diploma school at the UEL during 1995-99. The unit in association with the MSc has been investigating parallel systems with the aid of computers in order to explore the idea of emergent form as a way of generating designs. The first part of the paper intention is to clarify motivation and the conceptional stance of the unit. Here we will define the terminology important for the ideas. We will also sketch out to pedagogical as well as architectural aims of the course.

The main body of this paper will discuss five student projects representing a variety of parallel systems which are used by the students to tackle set design tasks. The projects covered are:

- *Sean Macmillan Generating housing as a vernacular infill algorithm taking account and micro environmental concerns*
- *Michel Mesut redensification using Japanese models of space and urbanism*
- *Riko Sibbe Emergent patterns of use from multi mapped urban fields and hill climbing agents*
- *Claudia Schmid Agents with vision deforming & folding surfaces to provide programmatic enclosures*
- *Pablo Miranda Parallel models of spatial organisation – accessibility indices and isovists*

The changing Paradigm in architectural education

In the now emerging 'non-linear' understanding of biological, psychological, social and urban phenomena, the mechanistic conception of architecture is becoming increasingly in need of extension. It no longer performs within the currently changing socio-cultural environment. Rooted in the modernist tradition the architectural discourse of today has only started to come to terms with the dynamic nature of architecture. Informed by the modernist paradigm architecture has been understood as something static, factual and objective with the design of form as well composed objects in the centre of the architects pursuit.

In understanding the city as an embodiment of action and interaction of individuals and groups it can be re-describing as a fundamentally parallel system, a self-organising entity. On the whole, unit six work concentrates on people as progenitors of global urban form in contrast to the modernist approach where mechanistic and reductionist problem solving is based on statistical data and naïve rationality.

In this epistemic shift away from the primacy of the physical guise of the architectural environment towards a reading of its dynamic nature Unit 6 has used computers as a “perceptual aid” for creating geometric mappings. These mappings are intended to capture the parallel nature of urban processes and subsequently provide the informational environment for architectural interventions.

The significant character of these interventions is that the procedural principals by which urban and architectural form is generated are designed and not the overall form itself. In these ways unit 6 finds alternative ways of constructing form, seeing space enclosing form as an emergent property. In this case space is understood as a configurational task rather than a picturesque one.

Parallel systems

Part of the problem that architecture currently experiences, particularly building in urban environments stems from the way the task of architecture is perceived as well as the conceptual framework at hand to describe and structure the task. In the light of this Unit 6 has been experimenting with various models offered by 'non-linear' sciences in order to arrive at a different architectural perception which is able to overcome limitations inherent in the traditional, modernist view. This alternative way of observing necessarily results in new formal solutions as will be demonstrated below. Common to all these models is their parallel nature.

Whereas modernist Cartesian method was highly successful in dealing with systems of unorganised complexity which are understood with statistics, the laws of change, and in the last resort the second law of thermodynamics the main interest which the unit take from contemporary science is that of systems of organised complexity. Concepts like those of organisation, wholeness, teleology, control, self-regulation, differentiation and the like are alien to conventional discourse.

A system describes a whole which in contrast to the elementary consists of parts. The term system always refers to the whole in the sense of unity. In the traditional modernist conception an architectural entity is that of a complete whole made of components or parts in some summative manner. The whole is developed or made on the practical basis of putting parts together and making them fit. In this conventional way of working, the whole develops by integration of the parts.

Wholeness as emergent property.

Parallel systems constitute a unity made from parts, which are related in a reflexive and non-linear manner.

The term 'system' in this sense draws on its definition by 'system theory' a relatively new scientific discipline. A biological critique particularly on classical physics. Biology failed in its efforts to describe the central phenomenon LIFE, because of the tool set provided by modernist paradigm, particularly physics. As a consequence the epistemic shift away from discrete phenomena to systems was necessary. A living organism with its behavioural characteristics than could be understood as a whole which emerges from the interaction of its constituting parts.

From the beginning Von Bertalanffy(Bertalanffy 71), the father of general system theory was interested in the transferability of his theory to other domains. In sciences such as Population, sociology as well as large parts of biology, systems that cannot be properly described by physical-chemical regularities can be observed if the right 'view' or the right model is chosen. There are logical homologies which are derived from the general characters of systems.

Another important distinction explored by the unit in the past that Von Bertalanffy has introduced is that of open system - closed system.

Open system - closed system

Closed systems are in reality impossible to find. They exisit only as very useful abstractions of the real world. It is a theoretical position first formalised by Rene Descartes in his book 'discourse de la methode...' Closed systems do not maintain any exchange with their environment. Examples of physics experiment or in architectural terms the consideration of an problem in separation to its context, for example the representation of the problem of housing reduced to the variables such as circulation and the provision of sunlight and fresh air. These closed systems do not allow for organised complexity. They exist scientifically speaking thermodynamically closed in a state of stable equilibrium.

In contrast open systems are thermodynamically open. They are able to extract or dissipate entropy from their environment. Because of these possible exchange processes the system is able to develop an inner dynamic which allow is to settle into a stationary stable state away from thermodynamic equilibrium. The relation of the parts of the system can also be maintained if a material exchange happens. Some parts fall away and are replaced by others.

On one side the constant material and energetic exchange with the environment makes the open system only possible in its context. On the other side as a result of its inner dynamic, the open system is autonomous and stable independent of the environment.

In this sense the system selects that 'information' from its environment required for the maintenance of a stable state far from equilibrium. The environment, ie. everything which is not part of the system on the other hand is not able to influence the system in a linear causal manner. Environmental changes can not determine the system's behaviour directly. The open system has the ability to respond to perturbation of the environment but this is achieved by structural changes within the system itself. (Maturana79)

This ability of open systems is summarised in the term self-organisation. This term summarises the systems capacity to rearrange its internal organisation in case of environmental changes. Consequently it is from outside that open systems are not linearly causally determinable. They have a life on their own.

Emergent spatial knowledge using agents exploring an environment

In an attempt to introduce and explore these issues, we have for the last three years been studying areas of east London and using computer modelling (of both the traditional and dynamic kinds) to look at urbanism and the renewal of existing environments.
It is a commonplace nowadays to say that cities are systems, and cyberneticians from Pask onwards (Pask 68,76) have shown how interesting insights can be had about topics from social dynamics to traffic flows. The Architectural teaching tradition is essentially project based and therefore it is assumed that to understand a system you have to design your own. The agent-based approach was initially developed enthusiastically by students who first experimented with StarLogo in 95/96, having grown dissatisfied with the intractability and sluggishness of 3d cellular automata which we developed in Autolisp and latterly in C. StarLogo is a massiveley parralllel computing

environment written and supported by the Epistemology & Learning group at MIT. It provides a set of high level tools for exploring in 2D the phenomena of emegent form and structure (Resnic 1994). Microstation Basic turtles were developed, and a set of simple routines for sampling the 3D model in which they moved. The agents were defined using the Microstation Macro programming language Microstation Basic, an extended version of Microsoft Basic. This provided a language for the unit to write the agent definitions in and all links to and from the 3d model. These and other routines are available at http://ceca.uel.ac.uk/. The students job was to decide what (local) aspects of the database would be interesting to the turtles, and what changes they could make to the model including changing themselves and other turtles. Early 97-98 experiments led to the 98/99 year when the object of study was a medium sized area of east London.
The system in this case is the site model (including certain global characteristics of the model – chiefly the position of the sun), which affects the agents, and the agents which affect the site model (by building or demolishing things) and the set of rules which the student writes in basic to define the interaction between the two.
The task was to consider the area of the Kingsland corridor and design housing and associated buildings to be located in the area. As part of the introduction to the project we discussed generative and analytic models of urban space, particularly the UCL Space Syntax project and the later work on configurational analysis. Cellular automata and diffusion models were explored as part of the MSc programme, and students used StarLogo as an introduction to agent based algorithms (hillclimbing, agent to agent communication global versus local rules).

A three dimensional CAD model is constructed of mostly urban environments in various degrees of abstraction. Layers of non-physical information are added to the model as data is gathered from the environments, such as density, public/private thresholds (entrances), social and behavioural data for example crime figures and subjective experiential data.

With the aid of computers topographical maps of these informational structures are constructed and subsequently researched in different ways -as raw material. Urban facts are formulated as theory or as quantity, numbers of things and events are brought together to form contexts as programme-generators, specific data relationships lead to particular architectural interventions. Unit 6 has continued to explore and develop these Data to Form techniques, the means by which data from the urban context, or the environment, or the programme is used to create architectural proposals.

Another example of a powerful tool to investigate the data fields has proved to be a particular type of parallel system: Agent-based modelling. Artificial life agents are programmed to interact with the environment of the model. Components of the model and the layers of data are interrogated by characteristics such as type, size, orientation, as well as specific interrelationships between the data. The role of the agents can be such things as to find suitable places for urban interventions in the city context, and in some cases the definitions of the interventions themselves.

Pedagogical Value

The aim of course was to make a system out of these components whose emergent outcome was in some way an answer to the themes of re-densification and re-urbanisation which many saw as a desirable outcome for the area, and is current policy. Early experiments with the model led to a great deal of anguish since, while everyone could make global proposals and statements about the area, and several were making the most minute analysis of every inch of the streets, it was impossible to cast such knowledge and strategy into the minds of the turtles. Far-fetched schemes to make the turtles visionary planning committees were scotched as too difficult, and Occam's Razor was waved about. Eventually interesting dynamic systems with the right amount of positive feedback were invented. These were mostly based on the cumulative behaviour of many foraging turtles with complementary goals.

Knowledge as distributed in the environment

Initial agents are seeded onto open areas of the 3D model of the Kingsland corridor, where they begin the simple business of moving around the open space between buildings, laying down a trail as they go. Fig S1 shows the trails formed by agents walking between buildings in the northern part of the area.

In the simplest cases, the students built ready made knowledge into the model, such as the global location of tube stations and bus stops, with a view to imposing top down rules in case the emergent structure was "inappropriate" in their terms. Later, more sophisticated strategies were tried, in one case agents were equipped with extra variables to count and remember the types of building encountered. Various totals and conditional expressions based on their values were used to trigger insertions or demolitions This, we all agreed was more interesting, since the history of the agents allowed them to make running totals along trajectories determined by the model, rather than crow-flies calculations about tube stations. This lead to redefining the problem from a many to one system to a many to many system. The available sites were no longer ranked by top down planners criteria, but by their position on a series of networks of all available sites. This seems to us a valuable way of experimenting with urban theories and the possibilities of 3D databases. In this example the agents are defined with a range of sensors;

- General purpose building and road avoiding sensor
- Building type sensing with a repertoire of use types and for new buildings, types of interventions
- Wide area sensors for calculating local concentrations of building types / interventions
- Camera to calculate overshadowing in a range of headings, and to provide data for other sensors
- And a range of effectors
- lay down a trail - a line which can be read by agents as a message that other agents have passed this way
- place a marker
- Place a building of a particular type

And a set of rules, which apply to each agent, based on the results of the sensors that trigger appropriate effects. The rules are the result of trial and error, a mixture of simple rules of thumb to do with overshadowing and orientation, and a set of checks for available space etc. The rules are defined in different ways depending on the context, with some agents acting as prospectors, some as builders and others as rehab/upgrade agents.

The feedback between the site geometry, as defined by the camera wielding agent, and the possible shape of an insertion, and hence the lighting and overshadowing onto the surrounding model, is complex and difficult to extrapolate by hand. Using builder agents who check overshadowing before building, and surveyors who define unshaded potential sites in an agent based model allows many satisfactory solutions to be generated. By inspecting the results the students were able to refine their rules and to develop new ones, and then run the agents again.

Raising the level of abstraction

This familiar design cycle was taking place through the medium of Microstation basic, which only allowed changes to the local behaviour of agents in the short term, with major rewrites of the global design only taking place after lengthy discussion. In order to control the outcome students had to establish simple local rules for generating global design outcomes. This is a useful reorientation from conventional diagrammatic procedure where overall rules are solely defined as overall proscriptions defined at the largest level (such as zones, radii from fixed points and other top down devices). Though geographically large, the level of abstraction is quite low. In particular the way that fields are treated allows the dynamic approach to provide the experimenter with a much closer insight into the actual forces which give rise to the fields.

Examples

Sean Macmillan A system based on the generation of terraces of small buildings
Michel Mesut Dynamic model of regrading built fabric
Riko Sibbe Hillclimbing on datasurfaces
Claudia Schmid modelling the formation of enclosure by folding

Space as configuration

StarLogo experiments
The use of Agents to calculate many-to-many configurational measures of space provides an interesting alternative to the global network analysis reported by Hiller & Hanson (Hillier 82). In the Hillier experiments, the visible space of an urban system is represented by an arrangement of the least number of longest straight lines that cover the space. This network of lines can be analysed and segments differentiated by (for instance) global accessibility per segment. These diagrams can then be compared to actual use of space, where good correlations are observed. The StarLogo patches on the other hand are used to represent a tiling of space into large numbers of small squares, but whose surfaces are traversed by turtles walking randomly over them from initially random positions. Each patch receives a score when it is walked over. As in the Hillier examples, the resulting emergent properties of the patches in fig P1 (a map of the Kingsland Corridor) show higher accessibility indices for Dalston in the North and the Hoxton square area, both of which are the areas with most activity, and the central area showing dark, not so accessible – this is an area currently the target of regeneration plans and a new tube station.
The outcome is a consequence of the way the turtles are forced to visit the patches in the “correct” way (i.e. not walking off the street system, only visiting patches which are actually directly connected the one you’re standing on). Thus, it is the spatial organisation that controls the turtles, who “sample” the surface to aggregate global accessibility indices. This approach owes its origin to Hilliers more recent work (Hillier 96) where cellular tilings are used to extract global accessibility patterns, albeit using the network algorithm.

A parallel version of all to all Isovist generation

An Isovist is a geometrical description of the amount of space visible from a particular vantagepoint in a spatial organisation of walls, columns and partitions. As a mobile visitor to any spatial organisation, what you can see is determined by the obstructions, obviously, and is part of

the mechanism of navigation, the way that a visitor decides how to move at any point. The original idea (Benedikt 79) which was essentially a method for graphically representing cones of vision from a particular viewpoint, has been expanded by Peponis into all-Isovist calculations and, as a method of describing emergent properties of space ties in with other measures of configuration, such as RA and the measures described above. Using StarLogo agents to explore spatial organisation in terms of visibility is another example of the advantages in terms of algorithmic transparency of the parallel approach, in contrast to the top down BFI approach described in earlier papers (Peponis 98).
In this case, the spatial organisation is again defined at a set of coloured patches, and turtles are randomly positioned over the patches. Each turtle is provided with a number of "lives" (of which more passim)
Each turtle then selects one of the coloured patches and attempts to walk straight towards it, however should this result in the turtle walking off the edge of the coloured patches (walks into a wall) then the turtle jumps randomly to another coloured patch, but in doing so, and in recognition of the difficulty, subtracts a life from its store. If a turtle reaches a patch, then it deposits its lives on the patch. Patches who are generally easy to see thus get higher scores than hard to see ones. The example (fig p2) is based on the visible spatial structure around hoxton square

In all these examples the use of StarLogo has provided an exemplary introduction for the students to see the way that global outcomes such as average visibility can be the emergent outcome of the operation of a parallel system, in this case of patches and turtles, but more generally of some process which inhabits a spatial organisation.

After these reports it is instructive to record the way in which the approach affected the student learning experience, and how it altered the way they went about their studio work.

Pedagogical observations

1. The becoming of form

This approach helps the students to overcome the 'blank sheet of paper problem'. Faced with an empty sheet of paper on one side and the overwhelming design task on the other the student very often falls into a state of paralysis. Where to start?

The problem is inherent to the self-conscious design process. The wilfully making of architectural form implies the superior position of the maker. It entails a full grasp of the problem in its 'objective' light and the possibility of properly representing the problem. It requires an instantaneous placement of an architectural object into an environment. In the process of designing, the designed object is slowly refined and towards the end only minor adjustments can be made. In the Unit's way of working it is always possible to regenerate the total design solution from initial principles to final outcome at all stages because the computer not only holds the geometrical information about the project, but how to generate it as well.

This 'becoming' of form is the emergent property of parallel systems. Working with the Becoming of architectural form requires knowledge of the parallel structure of such systems and their generative processes. It favours dynamic processes over static form. The design evolves on the blank sheet of paper and as the form unfolds the process structurally couples the developing form with its surrounding condition. The architectural process as well as its resulting form is therefore intrinsically tied to its environment.

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2. Different kinds of cases

Another aspect of this working methodology is the fact that the experimentation with parallel systems prevents students from recycling previous rehearsed formal solutions. Instead the appropriation of algorithms often borrowed from other disciplines confronts the students with novel formal solutions which require creative interpretation in an architectural context.

This challenges preconceived notions of the relation between form and functionality and form and meaning. Functionality is not metaphysically inherent to matter or form but it is socially constructed through repeated interaction between the form and the user as well as the communication about this relation in language.

3. Design intentions

Working with computers requires the student to translate tentative and fuzzy ideas in the hard and discrete form of machine language. The formulations of design rules acting on the low level of the system embodies the student's design intention. Embedded first in an algorithmic language and at a later stage in a computer program the validity of rules / intention can be tested in a computer simulation.

In the above description of the units approach to design it has become apparent that the work has been inspired by scientific theories as well as the exploitation of individually formulated design hypothesis set in scientific tradition. It is therefore helpful to clarified unit six position towards theory and scientific methodology.

Individual theory

Scientific practice as example: Scientific practice has accomplished a methodological condition of 'contingent transparency' with regard to expertise, intersubjective control, documentation, consistency, replicability of results, etc. Ideas and the understanding of phenomena are thus made communicable and comparable within the scientific community. This conversational structure builds the basis of the successful advancement of scientific ideas. In this conversational structure lays the generative power of scientific explanations.

On the contrary the traditional architectural discourse often prevents this conversational progress.

The main points of reference for UNIT SIX are therefore experimental procedures and the subsequent formulation of a 'individual theory'. In doing so the Unit positions itself in opposition to conventional design procedure, where the point of reference usually is the designers experience and personal judgement or statement. The formulation of an 'individual theory' makes the design intention of the student transparent and embeds his personal discourse into the conversational structure. It unlocks to generative power of the design proposal which can be shared and discussed collectively within the Unit.

Thus the unit is primarily interested in the generative power of scientific theory. Its interest in theory is not in its explanatory function or the validation of specific truth structures. Instead, the conceptual metaphor for theory is that of a map generating new vistas and pathways guiding the student designer through the design process. With this stance the unit brings science labour closer to an artistic pursuit since all artistic endeavours, all maps are, as well as all scientific theories are, contingent. They describe the 'real' landscape differently for different purposes, stemming from different historical backgrounds. They are dependent on the time and culture. Therefore not one theory can be said to be more fundamental than others.

This position is not to be confused with arbitrariness, it does entail the impossibility of evaluation or comparison between theories. Not only in the context of architectural education the evaluation of these 'individual theories' is crucial and possible. A good map provides guidance for the designer through the terrain. Using what Francois Lyotard (Lyotard 84) labelled the 'performative principle' it is possible to make statements about the quality of one approach in comparison to another in the same given cultural, socio-historical context.

Although the rigor of scientific inquiry is exemplary to the unit's working the following constraints of the course have to be considered. The diploma and MSc research are conducted in the framework of a 'traditional' architectural education. Interdisciplinary theory fragments are bastardised into an architectural discourse. Whereas in 'pure' research the failing of an experiment is a productive outcome in the architectural education - like in the architectural profession - a positive outcome is only solution that provides an adequate response to the design problem. In practice this means compromises and sometimes deviation from conceptual foundations.

Conclusion

The resulting interventions have produced emergent form sometimes exhibiting self-regulating properties of biological systems. This is a first step towards achieving in the built environment the symbiotic behaviour and metabolic balance that are characteristic of the natural environment.

Limitation of time and machines means we are only at the beginning of a process where not only the location but detailed morphology and vernacular can emerge as well. One of the useful side effects of the automated production of geometry is that students can design in quite a lot of detail over a large area without having to rely on repetition.

However, we are still having to make assumptions which are not yet sufficiently unpacked from particular ways of form generation. Agents should be able to evolve their morphological repertoire possibly along lines explored by the unit / MSc (Coates et al. 96,97,99) where genetic programming is being explored as a means of evolving shape constructing algorithms.

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