Agent Based modelling

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This paper describes the work of students in Unit 6 of the Diploma school at the UEL during 1998-9. The unit in association with the MSc has been exploring ways of using the computer to explore the idea of emergent form as a way of generating designs, and a way of focussing the pedagogic process on a new and interesting set of determinants of form.

Introduction

Architectural design teaching using computers has been a preoccupation of CECA since 1991. All design tutors provide their students with a set of models and ways to form, and agent based modelling is one of a set of approaches including cellular automata, genetic programming and shape grammars that the unit has to offer as additional tools with which to explore architectural (and architectonic) ideas.

Scientific practice has to accomplish certain methodological conditions with regard to expertise, intersubjective control, documentation, consistency, replicability of results, etc. The main points of reference are therefore experimental procedures in contrast to a conventional designer, whose point of reference usually is his/her subjective judgement or statement. The most prominent task of sciences is the making of theories which implies the construction of a conceptual network and the application of this conceptual network to a certain set of phenomena within an action frame. In this sense a theory could be described as a scientific action-frame which is not identified with the conceptual network nor its verbal representations but as a pragmatic form. Acting within the frame of theory generates experiences and as a consequence some form of pragmatic, operational or how-to-do knowledge. Furthermore this knowledge is dependent on the selection of examples of phenomena, the number of cases analysed, the uniformity of performing and the observational techniques used. In this sense a theory is more like a strategy to achieve a practical aim.

Architecture as Artificial life

"Artificial life", is the study of algorithms that try to explain the patterns and structure that we observe in the world, as the emergent properties of parallel behaviours of autonomous processes, which are very simple. The complexity happens because of the interactions between the processes. It developed from "Artificial Intelligence" due to a breakdown in the power of the top down "thought" paradigm, which relies on building predicate calculus expressions for the whole of the problem to be solved. Alife chooses to abandon the overall logical structure, and rely on the interaction between a system (like a learning program) and its environment. It has been observed that , since the "intelligence" (say in solving a maze) could not be developed (during a training session) without the maze, then what ever intelligence there is, is shared between the robot and the maze, leading to the embedded view of both learning and intelligence(Bowden 96).

At the largest scales it is easy to see the built environment as the emergent outcome of the interactions of many different actors. The Sana experiment (below) is an example of this, but it is also possible to focus on the maze as it were, and see digital representations of space as a learning environment for rule based agents, who might represent the design intentions in an appropriate way. The interaction between the agent or learning system and the environment can be represented as a form of architectural designing, as a set of simple parallel rules from many interacting virtual designers. The trick is to come up with simple but useful representations and rules for the virtual designer to use in interacting with the environment. What is inscribed on the heart of every AL experimenter is "simple rules - complex outcomes". Baroque rulesets are self-defeating, they already specify the majority of the problem solution, and anyway they take too long to program. much better to write small programs that you can chuck away and try again with another terse summing up of the way to behave. Unit 6 tutorials often seem to be about solving technical problems of coding, data representation and the design of experiments, but really underneath are discussions about how to do this summing up. Coming up with simple but powerful rules requires a deep understanding of the “rules of the game”. In an ideal world, discussions would take place at the level of systems behaviour, and it is a struggle to maintain the rigour of the discussion and not get side tracked into essentially tautologous top down strategies.

The definition and development of the new conceptual and computational techniques known as "Artificial life" have a number of different implementations and have been used to explore emergent structure or form in different domains.

Robots

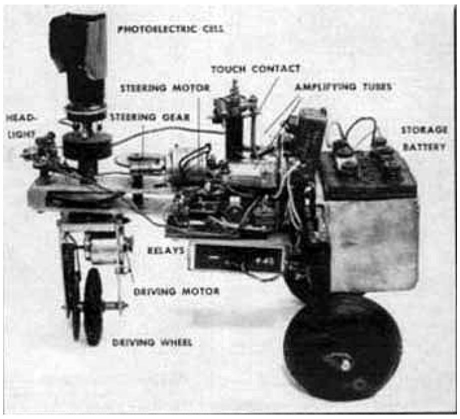


Fig 1. Elmer (or Elsie)

W Gray Walter's (Walter 55)original 1948 robots "Elmer & Elsie" (which he dubbed M.Speculatrix in cod Latin) were equipped with two (thermionic)valves , a motion sensor, and a photosensitive cell. They tended to move towards the light, but away from objects that they bumped into (and bright lights) , they also kept track of their battery charge, and as this dropped the relative strength of the light tropism increased, guiding them back to the battery charger (which had a light on top). He noted the emergence of "intelligent" behaviour with these simple feedback loops :

If there is a single light source, the machine circles around it in a complex path of advance and withdrawal; if there is another light farther away, the machine will visit first one and then the other and will continually stroll back and forth between the two. In this way it neatly solves the dilemma of Buridan’s ass, which the scholastic philosophers said would die of starvation between two barrels of hay if it did not possess a transcendental free will.

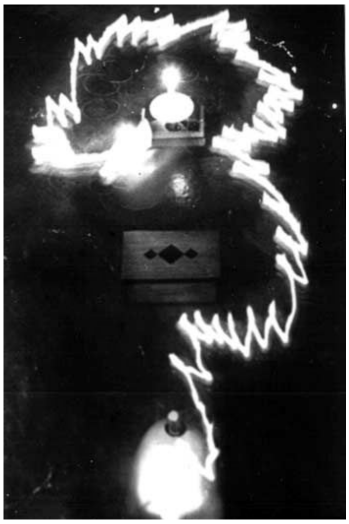


Fig 2 Single agent moving

When Walter put a candle on both Elmer and Elsie:

Two creatures of this type meeting face to face are affected in a similar but again distinctive manner Each, attracted by the light the other carries, extinguishes its own source of attraction, so the two systems become involved in a mutual oscillation, leading finally to a stately retreat.

Fig 3. Two agents

Computer science Agents

The original software agent was developed as an autonomous data processor, which navigated intelligently through fields of information. In this they are like worms or viruses , or the ancestor of them all ,the TSR (Terminate & Stay Resident) / Demon applications which are invoked by operating systems as autonomous information handling processes in a computer.

Parallel systems Agents

Since the development of Complex systems research at such centres as Santa Fe, MIT & Cal Tech agents have been conceptualised as populations of autonomous objects whose interaction with each other and their environment gives rise to emergent organisational structures. In 1994, under Dr. Christopher Langton`s direction, scientists and programmers started their collaboration on a project called Swarm. The intention was to create a general-purpose simulation tool for the investigation of concurrent, distributed systems. With the growing importance of computer programs as scientific equipment, Swarm was an attempt to create a standardised software tool, which is freely available to the science community and usable on a variety of systems. In Swarm a collection of hundreds or thousands autonomous agents interact via discrete events within a dynamically changing environment. Swarm itself makes no assumption about the model being implemented and it was used in such diverse areas as chemistry, economics, physics, anthropology, ecology and political science.

The basic unit of the simulation is a swarm, organising a collection of agents in the form of events. Thus the swarm represents an entire model: it contains the agents as well as the representation of time. In addition swarms can themselves be agents and an agent can also itself be a swarm. This structure allows the building of hierarchical/multi-level models. It can be used to model systems where multiple levels of description dynamically emerge or it can be used to model agents that themselves build models of their world. Within computer models of this kind it is common to speak of agents living in an environment. The environment in Swarm is usually defined as just another agent, which might have some more influence than the others but is considered fundamentally equivalent.

Another interesting feature in Swarm is the possibility of the use of observer agents with the ability to collect data while running the simulation. This data can be represented as graphs or data storage in files for later analysis. The observer agent is a swarm itself. In this way a complete, self-contained model is created.
The logical structure of Swarm is implemented in Objective C, providing in addition a variety of object oriented libraries.

The Star Logo software (MIT 97) written as a parallel computation machine which provides another powerful experimental device for exploring and demonstrating the effects of massively parallel populations of interacting agents in biology, physics, geometry, social systems and ecologies. It has the advantage of being descended from Symour Papert's Logo, which was an early attempt to define a computer language for children (Papert 80).

Star logo experiments

The Start Logo software can be used with both "turtles" - autonomous programmable agents who move about , and "patches" which are a grid of squares that make up a cellular automaton on which the turtles move. Waldemar Bandosz (diploma student 96-98) experimented with both turtles and patches to explore emergent movement patterns and land use on the Stratford railway site.

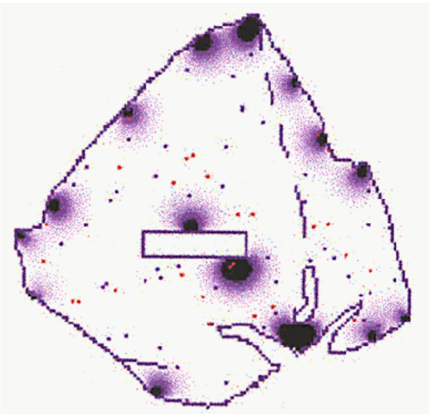


Fig 3. Hotspots on site

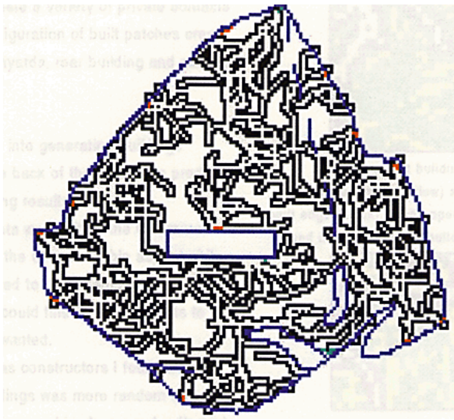


Fig. 4. Roads made by turtles

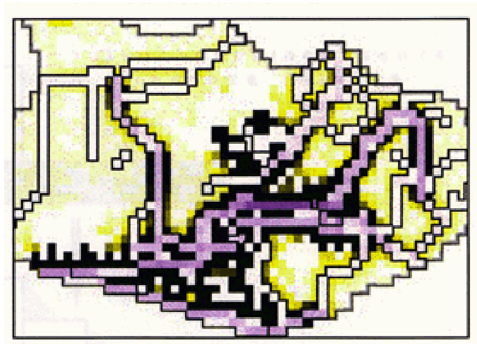


Fig. 5. Use density by turtles

Waldemar's project started by identifying points around the site where access was possible (the railway lands is a large enclosed area with access limited to a few points around the periphery, since it has been private railyards for the last 150 years). These points were used as the site for the creation of turtles. Once created turtles walked about essentially at random except that

1. they were attracted to distant "interesting" locations which "leaked" a scent providing a gradient up which the turtles could walk if they were near enough
2. as they walked they laid down a trail of their own scent which other turtles were attracted to
3. if they found the trail, turtles would follow it, adding to the strength of the scent

These rules were derived from ant foraging models, where the interesting locations are food, and the scent is a pheromone used as a marker by ants who have found food and are returning home.

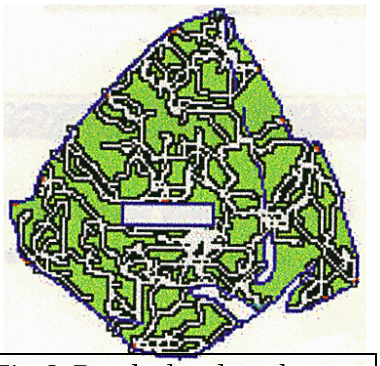


Fig 6. Roads developed on site

the result was to form a limited number of routes, which began at the entry points around the site, and converged on the hot spots. The process of route formation was amplified by the action of the patches over which the turtles moved, which slowly (with increasing traffic) became changed to permanent road stuff, with bordering house stuff. this model was taken by waldemar from mediaeval Prague, which he used as an exemplar of a well-defined urban morphology of suitable scale for the site and appropriate grain.

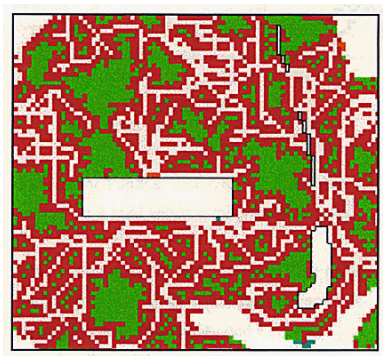


Fig 8. With buildings

The action of forming the roads triggered a set of cellular automaton rules, which developed the streetscape and open space behind the buildings according to plot ratios borrowed from the Prague studies.

What was interesting about the outcomes was the way that , because of the tendency of the turtles to gravitate towards the interesting parts of the site (as defined by the scent emitters) a complex street system developed, which often resulted in highly urban squares and city blocks, unlike the more distant "suburban" areas. In particular the zone of high-density traffic was particularly marked in the area between the new EuroStation and the existing Stratford station, with clear evidence of a different grain emerging at this point.

Fig. 9 Worked up 3d model from starlogo experiments

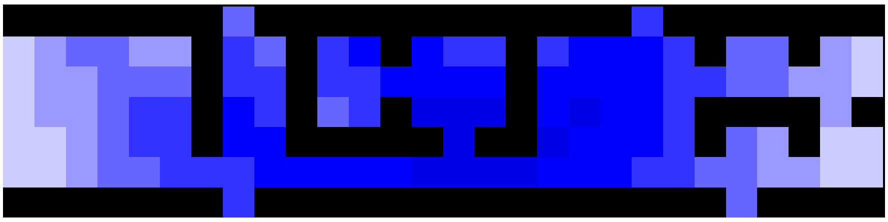
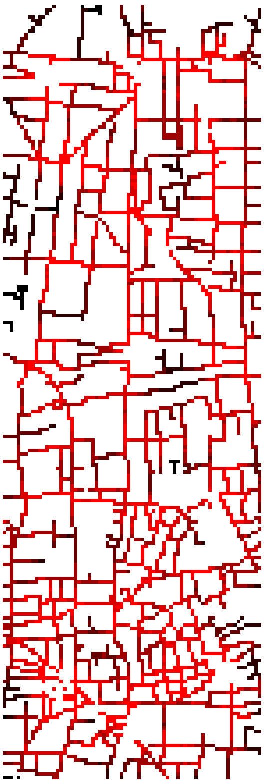


Fig10. Starlogo verification of Hillier's Analysis of domestic space configuration

Pablo Miranda (1998-) also used starlogo to verify and then extend the scope of the spatial analysis described in Bill HIllier's "space is the machine". The configurational analysis of space tries to model the way in which arbitrary agglomerations of space are trafficked by users. Research has shown that the geometrical configuration is enough to explain many of the factors influencing



human use of space. The idea (as explained in the book) is to chop up the reachable space of a building or urban area into a grid of small squares, which are then treated as nodes in a network or lattice of points. Calculations are made on the number of steps needed to get from each node to all the others, and the cumulative totals are used to label each node with a value which corresponds to the average number of steps needed to reach all other nodes per node. These kinds of many-to many calculations are ideal for parallel systems, and can be easily implemented in StarLogo patches. Pablo treated the urban space of the Hackney corridor as his configuration, and Starlogo calculated the overall emergent structure of the space according to this method.

Interestingly the "hot spots" (places which were in closest touch with all other parts of the system) were found at points where street markets and / or new urban regeneration can be found.

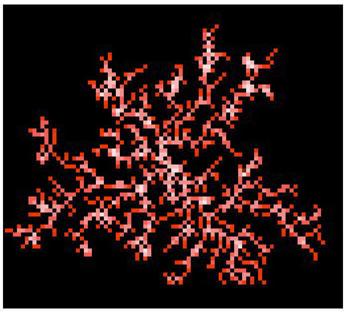


Fig 11 DLA

Mike Batty (Batty 94) has reported on the use of starlogo using Diffusion Limited Aggregation - a model of growth first defined by Alan Turing in the 50's -. Pablo also experimented and extended the starlogo DLA models that we provide as tutorial examples .
These results convincingly reproduce the global form of the growth of cities such as London & Cardiff, with marked radial dendrites and clumps of satellite suburbs.

Fig 10 Hot and cold spots in the Hackney corridor

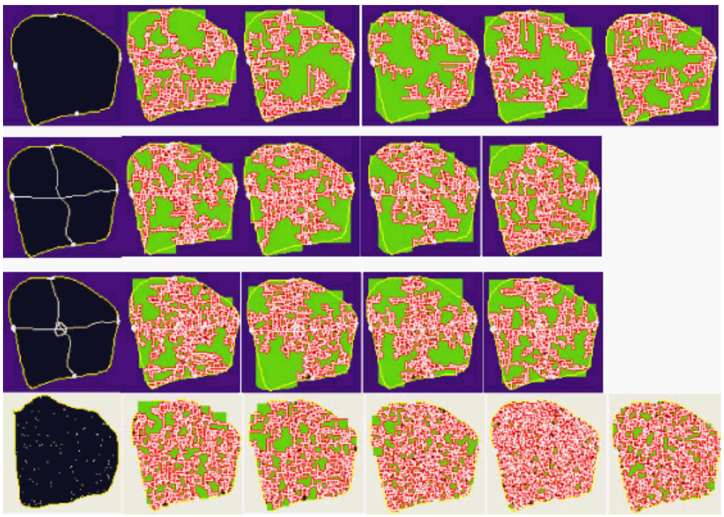


Fig 12 some experiments with different seed conditions

Paul Coates worked with A.Khudair (MSc student 1998-1999) on developing the rules for a cellular automata model of the growth of traditional cities in the Yemen.
Ali (who speaks Arabic) was able to obtain useful information of the historical development of San'a, and in particular the social and cultural factors behind the different components of the town. In particular the Yemeni towns are slightly more complex in structure than the traditional north African and Mediterranean towns (which have been modelled using the Alpha Syntax notation after Hillier ref...) because they have large communal gardens behind the houses. Associated with each garden is a mosque, and access is not permitted to these gardens from the surrounding houses.

The use of Starlogo patches to develop a CA made the definition of rules easy, and after much experimentation we discovered a simple adaptation of the basic Alpha Syntax model which had the effect of generating streets,houses and gardens in the correct morphology. As a serendipitous extra, we also noticed that there were a very few "unallocated" cells, always on the edge of the gardens, which seemed to be in just the right places for the mosques!

Using StarLogo's interactive painting mode it was possible to define the town wall, and entrance gates, and to experiment with different seed conditions. The most convincing outcomes were obtained when the seed condition was a random low density sprinkle of initial dwellings, and this accorded with the cultural history which indicated that Yemeni towns emerged from isolated encampments of families, rather than along an existing street or access point.

CAD Agents

Our approach is to define an agent as a computational object inhabiting a 3d point in a 3d data environment (a CAD model). This paper explains the implementation and results from a range of projects all carried out using Microstation / Microstation Basic.

1. Agents with vision

This project involved defining a set of agents with behaviours such as Looker: Constructor:Mover, and feedback loops between agent > model, model > agent, agent > agent. The emergent outcome was the deformation of the NURBS surfaces into enclosure/ structures.

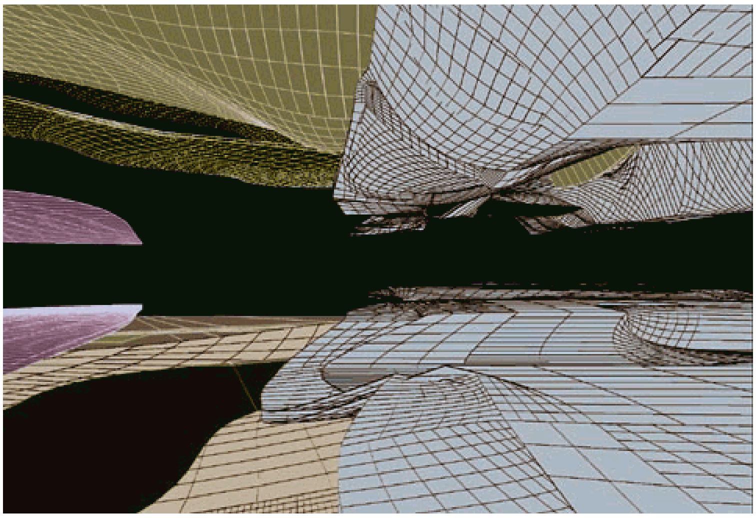


fig 13. Nurbs Meshes - initial study

The conceptual framework of this simulation was oriented on the interdisciplinary theory called radical constructivism. This new science is concerned about the relationship between knowledge and reality. One of the main principles is the thesis that human cognitive systems can only compare perceptions with perceptions, so that there is no direct access to the "real world". In this view, humans are not passive lookers on a fixed reality, but active constructors of a world. The consequence scientifically is a shift of questioning the "what" to questioning the "how" . (not what the world is but how this world is constructed)

The level of description in this simulation was reduced to a primarily psychological one. Within a psychological terminology a domain of sensory images and perceivable architectonic facts were defined.

Architectonic relationships from a psychological viewpoint were established, like:

horizontal-vertical,
inside-outside,
frontality-depth,
grounded-raised,
solids-hollows,
wholes-parts,
connectivity-isolation,
frontality-depths

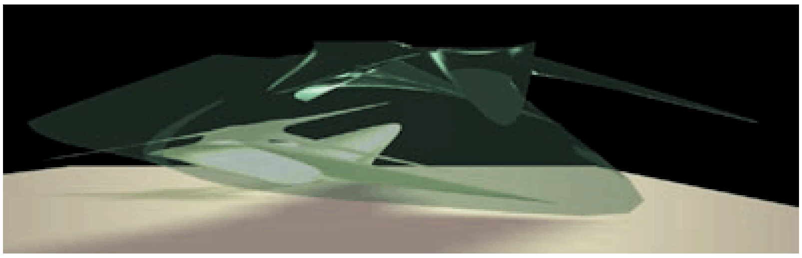


Fig 14 study 1

The main architectonic idea behind this project was the attitude that architecture can be distinguished from other 3 dimensional objects in space if it meets at least two conditions : - any kind of sheltering one state towards a different state (below-above, inside-outside, noise-silence,etc) - any kind of intentional shaping (gestalt) of the shelter (a design process which is able to be duplicated in some way)

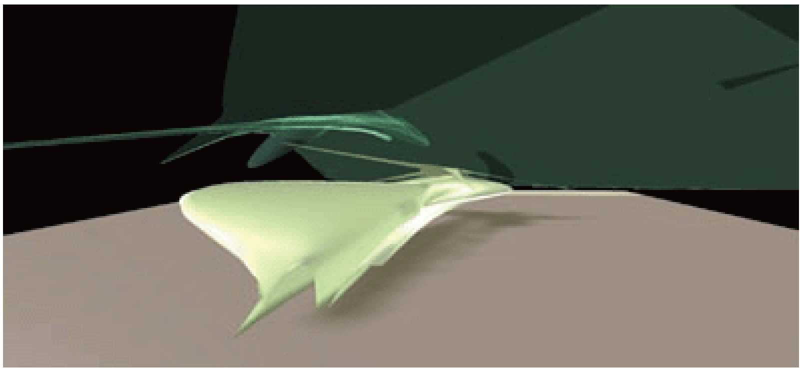


Fig 15 study 2

The aesthetic concept behind this simulation can be described as a general preference towards organic forms with the notion, that convex/concave curves define per se functional concepts like containing and guiding as opposed to rectilinear forms which just separate.

The system of agent actions took place within a spatial environment, modelled as a 3 dimensional site model. The basic unit of action in this simulation was an agent defined by certain modes of behaviours. Within one time step a certain schedule of actions were executed.

This schedule was defined by following components :

1) the movement of the agent into a certain direction, represented by a data point and a line
2) the slightly , random deviation of the movement into a certain direction
3) the vision of the agent, represented by a geometrical eye-level perspective
4) the confinement to a certain frame of action within the perspective
5) the ability to modify a nurb-surface within the perspective, represented by a data point and a vector into a certain direction
6) the ability to interrogate some aspects of the 3 dimensional data environment, , represented by numbers which function as multiples of the modifying vectors

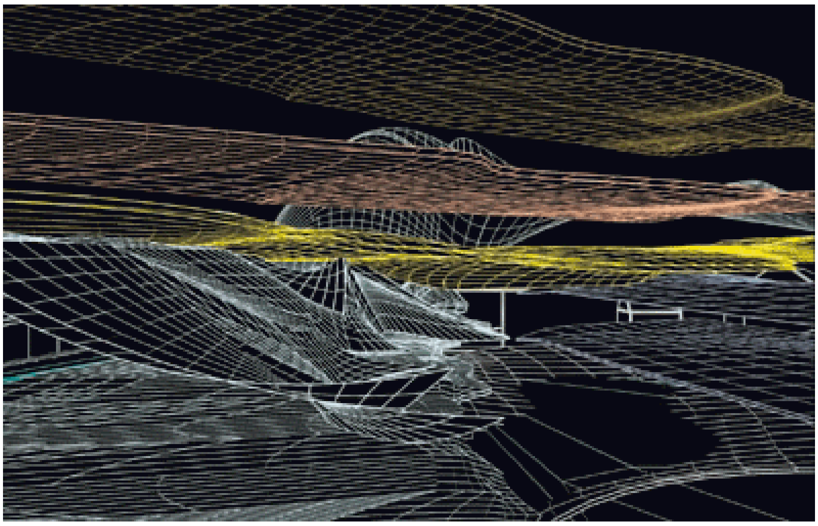


Fig 16 Perspective from agents point of view

The starting point of the simulation was a setup of planar, parallel, rectilinear nurb-surfaces that represented different functional areas like living space(apartments), meeting space (conference area), various sorts of leisure space (art, physical culture) and working space (offices). The points of departure for the movements of the agents were oriented on the existing movement system of the site environment. The simulation was represented on screen with 4 different view windows showing the same situation from different viewpoints all at the same time : a top view, a front view, an isometric view and the perspective view of the agent. After several runs with many different agents coming from various directions and heights the planar nurb surfaces were gradually transformed to complex interwoven enclosures.

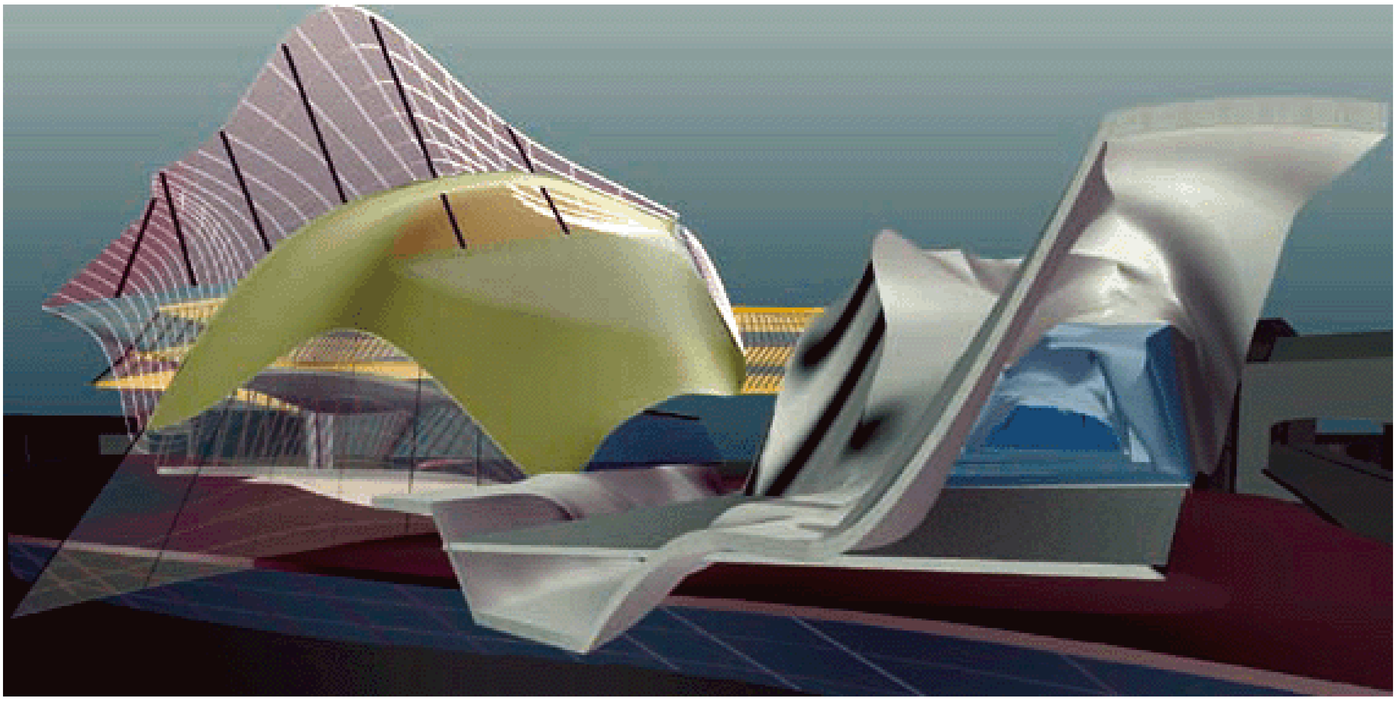
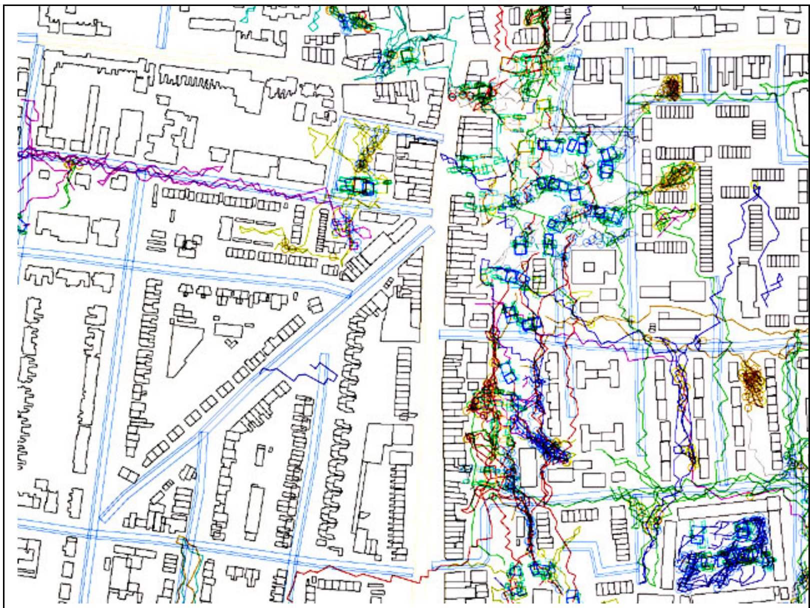


Fig 17 Example of a Final outcome

This kind of simulation was intended to give insight in the 3 dimensional perception of architectonic space dependent from a human cognitive system with sensorimotor behaviour. Relative to these perceptions and behaviours the new enclosures emerged.

2. Urban Walkers

Michel Mesut, Sean Macmillan & Rio Sibbe worked on a 3D CAD model of the Hackney Dalston corridor using agents with behaviours such as builders of entrances, rooms, utilities, feedback between agents and the environment, and each other.



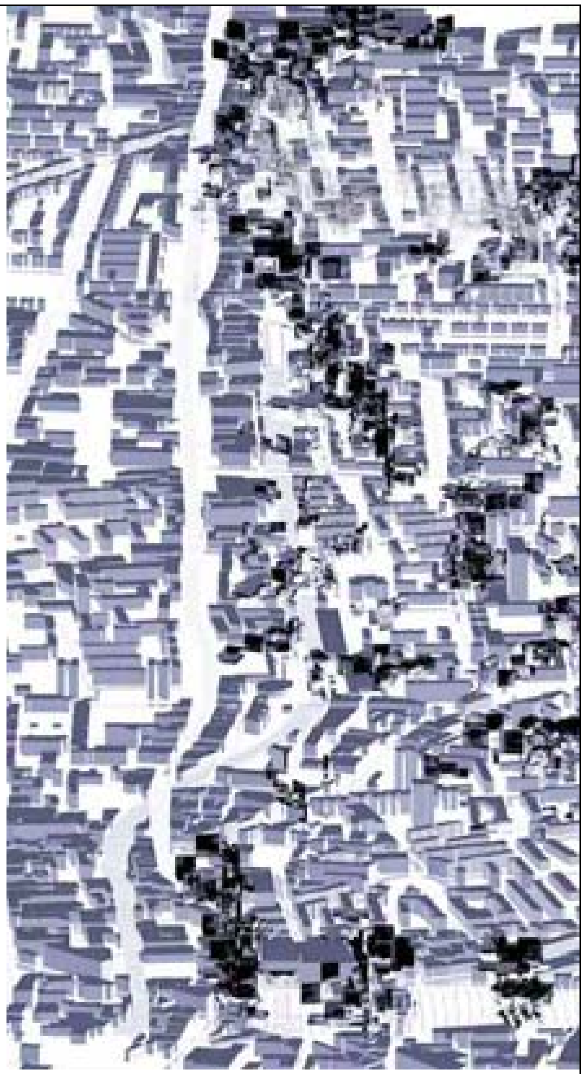


Fig 18 Agent trails and markers	Fig 19 3D model of Kingsland corridor with interventions.

The three experiments used as a basis, a detailed block model, originally derived from the work of Christopher Frike (1996-8). Components of the model can be interrogated by type, size, orientation etc. Generally speaking the role of the agents was to find suitable places for different types of urban intervention. The agents are started off at chosen or random points and headings in the model and told to walk along the ground, not through buildings. As an example of the kind of rule that agents were given was an early one to find "backwaters", small bits of unbuilt space which act as turtle traps.

1) As agents move they leave a trail (coloured line) behind them
2) If an agent senses its own trail, then it remembers, and adds up how many it has found
3) After reaching a threshold, the agent deposits a marker (coloured circle)
4) If an agent meets a marker it may (depending on other rules) make an intervention

The diagrams below show clusters of markers in Mesut & McMillan's projects.

	
Fig 20 Sean's villas	Fig 21 Michels invaders

The behaviour of Agents can be also influenced by gradients of information, defined as 3d surfaces of density data (using interpolation algorithms such as TerraModeller). These allow the agent to get information on the gradient of globally defined variables allowing the agent to act as a hillclimber on these datasurfaces. This allows the definition of another rule to the walking rules; "other things being equal, walk uphill on datasurface n". This translates into biasing the direction of travel towards local maxima on the surface.

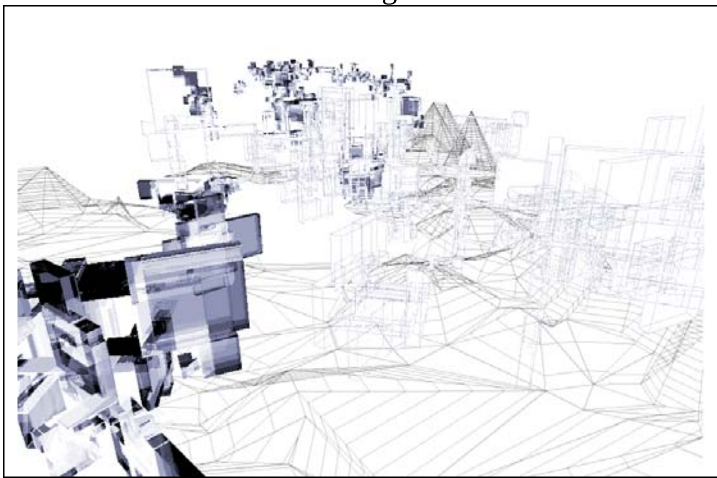
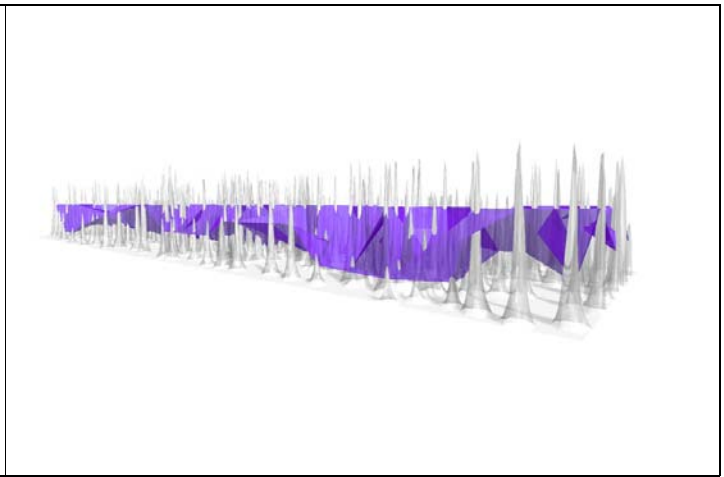
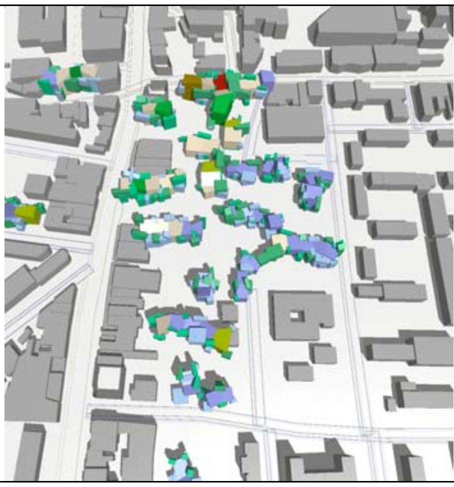
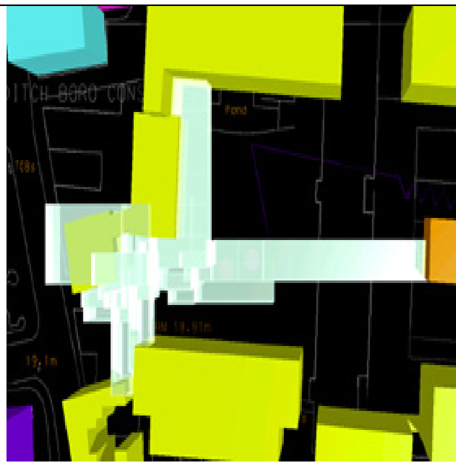
	

Fig 22 Data surface and agent building	Fig 23 Example of two datasurfaces

Examples of such surfaces are:
Crime
Fear (subjective!)
Density per landuse
Thresholds
Accessibility

Turning the idea of hill climbers upside down this can be seen as altering the flat maze in which the walker moves to a rubber sheet with different shaped depressions in the form of dents and valleys into which the unwitting walker can be drawn.

The end result of these projects included the definition of the interventions them selves. In each case ranges of parametric generative objects were devised, with the parameters supplied by the agents. The images below show that the definition of these objects ranged in level of abstraction, and particular attention to local conditions.

		
Fig 24 Rio Sibbe's public/private	Fig 25 Sean Macmillan's housing	Fig 25 Michel Mesut's interventions

Sean in particular explored the use of Microstation camera views to assess the sunlight and overshadowing characteristics of a site before building, and using data collected from these views as a way of defining details of house construction including roof angles and internal atria design.

Control and conceptualisation

In the end the walker experiments are just new ways of creating and/or organising form, employing the bottom up, suck it and see, way of experimenting. The process of devising rules, and getting the computer to display the result allows new forms of speculation which allows students/designers to pose different questions, in the form of simple rules for agents than are only answered by the parallel computation of many interacting processes over simulated time. It allows a focus for theories of architecture, form and society. and the definition of a series of experiments to test the theories.

Computers are ideal machines for studying the result of lots of computations, and understanding how they happen. Observing the effects of such processes in the world is inspiring but eventually disappointing, because its impossible to track the dynamics, only the end result is observable. By trying to define rules for parallel agents, we can try another way of explaining the form of the world we see around us.

With the notion of a scientific approach towards architectural and urban design certain questions have to be raised.
What is the main concern of a designer ?
How can these concerns be achieved in a scientific way ?

Essentially the work described here is related to the paradigm shift in the second half of this century, put forward by movements/philosophies/sciences like systems theory, radical constructivism, complexity sciences, chaos-theory, theories of self-organisation and artificial life, which usually comes up with an operational knowledge of how things can be done, the answer to the first question can be seen as a shift from designing a specific result to designing a process to achieve a result.

So the result is something emerging, which focuses the attention to the operables and operations of the process. The Operables (agents for example) and Operations (processes of interaction for example) are to be judged and

tested whereas the result is only the consequence of these preconditions and somewhat out of the primary control.
The Operables and Operations are mutually related to each other and they can be characterised on different levels of description. The modes of describing these thematic items already imply decisions about the identity of these items. They have to be identified in one way or another for sakes of consideration, analysis, explanation, etc. The questions how different types or levels of description are related to each other may cause serious identity problems. In terms of urban design these problems could be described in terms of scale, grain, social and cultural factors, etc

A cognising subject (student) setting up the interplay of these operables and operations and observing the results is making some kind of scientific experience. So the conscious and intentional making of experiences may be characterised as a kind of experiment. The outcome of these experiments can be called operational knowledge. This knowledge is always dependent on certain constraints/preconditions/presuppositions given at each point of the experiment and also shaped by the culturally disciplined student him/herself

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Starlogo home page
http://www.media.mit.edu/~starlogo

SantaFe Al Home page

http://www.santafe.edu/projects/swarm

examples :
Swarm-based Modelling of Prehistoric Settlement Systems in Southwestern North -America
(Timothy A. Kohler, Washington State University; Eric Carr, Santa Fe Institute)
School of Archaeology, University of Sydney NSW 2006, Australia
http://www.archaeology.usyd.edu.au/resources/documents/kohler/

Honey Bee Simulation, Mathematics Department, UMIST
Multi-Agent Simulation of Honey Bee Colonies (David Sumpter, supervised by Professor David Broomhead)
http://www.ma.umist/dsumpter/beesim/index.html

Fractal Cities web site
http://www.ucl.geog./casa