Smart Solutions for Spatial Planning

A Design Support System for Urban Generative Design

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Abstract. SSSP is a Government funded knowledge transfer project under the overall umbrella of the UK ‘building sustainable communities’ initiative. The paper describes the innovative techniques being developed by the partners to build urban modelling tools for multiple simulation or regeneration scenarios in the Thames Gateway region of London. This knowledge transfer scheme is between the main partners and the London boroughs of Newham and Tower Hamlets. The main aim is to demonstrate the use of digital data in the development of planning scenarios. The aim is to demonstrate a workflow, which should provide stakeholders with a way of testing regeneration options, which are grounded on ‘real’ data and are capable of providing rapid feedback for policy makers and inhabitants alike.

Keywords: GIS: Data Analysis: Urban modelling: Ant Colony Optimisation: Dijkstra shortest path algorithm.

Multiple births of systems approach to planning

The recent enthusiasm for generative urban modelling would seem to be a new departure, but as the quote below shows, the ‘rebirth’ of planning has happened before.

“In recent years physical planning has begun to emerge from a long sleep, Since its inception as a respectable activity of government in the early years of the century in parts of Europe and in North America it has had a chequered history.” (McLaughlin 1969)

McLaughlin was introducing his readers to some new ideas about planning;

“The identification and description of complex situations has been greatly aided by the techniques of systems analysis which itself rests on the foundations of general systems theory. Perhaps the most exciting prospect of synthesis is offered by cybernetics, the study of the processes of information transfer, communication and control in very large and highly complex systems, especially those found in living matter. For it is now clear that the fundamental principles of control in complex systems are universal, irrespective of the actual nature of the system - real or conceptual, animate or inanimate.”
Thus it was that 40 years ago the ideas of cybernetics and systems theory were being invoked as suitable tools for the study of that complex system - the city.

As Andrew Pickering noted in (Pickering 2005) the old British cyberneticians, Pask, Ashby and Beer – had never really been much studied in the US, and at home were sidelined by ‘real’ scientists, and for that matter ignored by the social scientists in the UK for years. New interest in the early pioneers has developed since the explosive growth of systems thinking and the new epistemology (as for instance embodied in the development of the software platform StarLogo from MIT). Pickering sees the early British pioneers as more interested in new Ontologies than new epistemologies however; new ways of becoming instead (or as well as) new ways of knowing.

Prompted by the inexorable progress of Moore’s Law which has finally (probably since about 2000) broken through the bangs per buck barrier, so that memory is essentially free, and processing speeds are nearly adequate for people without a military budget to do useful research. It has also become possible to explore the notions of distributed representation, to experiment with emergent morphologies and self organisation at a practical level. As a concomitant of this, the once recherché Artificial life algorithms of cellular automata, agent based modelling, ant pheromone optimisation etc, which require huge computational resources to do anything interesting have become increasingly doable. Thus it is that the promise of 40 years ago is now realisable – pen and paper models can now be embodied in real-time simulation tools, usable by planning professionals who may now join the other players in the built environment as part of the ‘digital chain’ & BIM systems.

**Patterns vs Systems**

So, once again after many years of inactivity, it seems the field of computational urban modeling has become live once more. The original explorations (Haggett & Chorley 1969, McLaughlin 1969) were left to develop into the more large scale area of GIS, and computational geography, and computational focus on the spatial morphology of settlements did not arise until Bill Hillier’s seminal paper (Hillier 1976); ‘Space syntax’ which in its first incarnation was a proposal for a set-theoretic syntax for cellular agglomeration models. Batty’s work (Batty 1996) at the regional scale began to explore diffusion limited aggregation models of urban growth, and more recently work on cellular automata and self organizing feature mappings (Diappi 2004) has lead to developments in the emergent systems approach to urban decay and gentrification. Since then the recent work of Koenig (forthcoming) & Mueller (e.g. 2001) has shown the use of L-systems and other pattern-making systems, many of which are now in use in the games industry for generating ‘realistic looking’ urban space for scenarios.

In most computational work there has been, we suggest, a dichotomy between the study of people in cities and urban systems, and the study of spatial systems as geometrical entities. Hillier’s contribution was to link these two things together. Thus, the development of models of urban structure can be seen as both simple descriptions of the spatial consequences of aggregation in the plane, and also a way of describing social relations. Because the syntax is related by what Hillier calls an ‘inverse law’ (space constitutes society and society constitutes space) then it becomes a simple but powerful descriptor that welds together the over elaborate a-spatial models of society and non-social models of space and form.

We suggest that the actual practice of urban design has to some extent reverted from pattern making back to this original cybernetic approach to urban coding where relationships and systems are defined (Kropf 2001), and the urban morphology emerges from a synthesis of both the site structure and societal data. Our project, then, was to work closely with the regeneration units of Tower Hamlets and Newham (two inner London boroughs) and a team of Urban designers to understand their
workflow and strategies so that we could build our simulation models to fit in with their way of working. To this end we built a set of urban design support methods – analytical and generative – that can iteratively be plugged into their workflow.

The SSSP system was designed as a ‘scenario builder’ and was intended to demonstrate how by embedding the generative urban modelling component into a feedback loop a series of different masterplanning outcomes could be tested against policy and other criteria. This is an iterative process, to explore options, and to achieve target policy goals, in particular sustainability criteria.

**Working with the London boroughs’ planning authorities**

Tower Hamlets and Newham are both London boroughs situated in traditionally ‘deprived’ areas of London – the ‘east end’ as was. The Thames Gateway initiative is a Government funded project to deliver ‘sustainable development’ in this region. The teams we worked with were part of the Local Authority regeneration aspect of the statutory role these public bodies are given to achieve.

As well as improving the local area in terms of infrastructure and community provision they must also control and mediate between the community...
and the pressures of development from commercial interests. With the development of the London Olympics (also in the area) the local authorities are under tremendous pressure to handle the scrutiny and assessment of planning applications, to develop policy, and to balance the conflicting desires of all the stakeholders in the region, with limited budgets, and historically slow moving paper based workflow.

**Simulation components**

**Gis Mapping**
To build the digital chain we needed to convert and adapt the GIS datasets held by the local authorities to be usable for the downstream components, ultimately CAD files for passing on to the stakeholders who prepare planning applications and developer proposals. A lengthy data cleaning process was needed to prepare files that contained both topographic data and landuse data.

The site for this knowledge transfer exercise, sits on the border between two London Boroughs – Tower Hamlets and Newham – within the Lea River valley. The site therefore is subject to two sets of policies (Local Area Action Plans) and is also topographically divided by the river itself. Those conditions let to the main issue on site, which is the lack of accessibility.

Further, the London Borough of Hammersmith and Fulham have developed an accessibility mapping method, called PTAL – Public Transport Access Levels – which serves most urban planners as an initial briefing instrument for density levels, land-use distributions and transport strategies.

Hence, the present approach uses ‘accessibility’ as a backbone, which underpins the overall strategy of building a digital chain from regional data sets, topographical data, social deprivation and access to services. The accessibility network feeds straight into the urban/ masterplan scale and the urban block scale. Using a derivative of Dijkstra’s shortest path algorithm, all context paths, routes and access points are integrated to serve as a stimulus for generation of further axes and circulation paths.

**Accessibility Levels**
Using the underlying accessibility levels, the system can indicate places in the network where new links can improve the overall accessibility of the system, for instance optimal locations for bridges over the canal and river, or new ‘short cuts’ between otherwise isolated parts of the network.

Building on the PTAL measure, a ‘walkable’ routes and distance mapping was also introduced to produce a hierarchy of routes throughout the site and later generated circulation networks which indicate likely pedestrian routes and the times it takes to travel between a set of either imported or live-tested access or destination points.
Urban Scale
While the urban block and its relation to public space is fairly well described and quantifiable, the urban scale structure lacks explicit design approaches. However, the most common heuristics of urban designers/ planners pointed towards differentiation of the urban structure by connectivity of ‘activity’ locations including linear spaces (knitted into external location points).

Therefore, a series of studies was undertaken to evaluate computational approaches for urban structure through connectivity (always embedded in the accessibility strategy), which were evaluated with our urban designer and council planner partners.

The most appropriate method proved to be a more literal transposition of urban design heuristics by implementing a K-minimum spanning tree (KCT) on a grid with a minimum average aspect ratio for urban blocks. The spanning tree calculates the sub-tree through an ant-colony optimization (ACO). The activation locations serve as the K-input vertices and produce unpredictable yet rational urban blocks.

Block Definition & Plot Uses
For the block definitions and land-use allocations, either hand-drawn outline urban blocks or the results from the KCT graph serve as input. Two methods are in progress:

Aggregate Hill-Climber
According to context conditions, social data and local planning frameworks, a massing is generated dependent on the outline blocks (circulation graph). Single plot units ‘hill-climb’ within an unstructured grid and slowly aggregate towards the desired total area set in the masterplanning brief. The units hill-climb in order to reduce the errors in their adjacency preferences and distance requirement to functions and conditions. Each local change is benchmarked globally and continues until all criteria are satisfied. If the masterplanning brief is un-realistic according to density and accessibility (and other) planning criteria, the applications indicate alternative area schedules. In this version the hillclimbing is achieved using a quantum annealing algorithm.
In this process the activities are attracted to either transport nodes (retail commercial) or riverside places. The three activities are chosen for this run as commercial, residential and green, with set propensities to ‘drift’ towards likely spots. Other combinations and spectrums of desire can be set for simulation.

**Pareto Optimization**

The above images show a system that was deliberately diagrammatic in representation. As with all the tools defined we were guided by the Local Authority as to what would be useful as part of their development control and policy making process. However, as part of the original proposal for this project we...
also offered to explore an evolutionary approach at a more architectonic level, where smaller scale optimizations of building massing and geometry could be demonstrated.

As part of this, the multi-criteria Pareto optimization was developed to optimize the distribution of uses within a given urban block to achieve mix, density and environmental criteria. The target values are taken from policy documents used by the planners, which set out dwelling densities for a range of building typologies. In the example of a test block the target density is of a dense urban scale with quite high ratios of retail to residential. Using the Pareto outcome of Genetic evolution for block system Optimization allows balancing of non-commensurate criteria and targets including individual building typology and open space policies. In this model the criteria for optimization were:

- Rooms per hectare targets
- Ratio of residential to retail units
- Aspect ratios and percentage of frontages to the street
- Maximize the number of units facing south

**Conclusion**

The most important outcome that was demanded of the project was that this knowledge transfer exercise could be shown to have a positive effect on ‘building sustainable communities’ within the terms we had set ourselves. In the case of the SSSP we hoped to provide the Local Authority planners with tools for scenario building to explore the underlying criteria for sustainability. These were:

- achieving good mixes of different land uses
- checking and adapting layouts to satisfy access to services within set walking times
- ability to query developer proposals for compliance with planning policy on these and other matters, preferably quickly and easily
- begin to check environmental and economic factors in development in masterplanning
During the meetings with the regeneration teams the development of the tools was constantly under query for ‘usefulness’. The key factor that was appreciated was the way such tools could be used to make the planners better informed and to make them ‘tougher customers’. Pre-planning application meetings with developers were mentioned, as times when the more sophisticated tools for route measurements could be used to query developers’ simplistic measures of accessibility and access to services.

Urban Generative Models in Education
The authors are used to encouraging our master’s students on the computing and design program at UEL to study and explore a range of aspects of urban modelling by developing computational models of urban form and structure. Deriving from our own work in this area we have explored Cellular Automata, shape grammars and neural nets as ways of generating and representing networks and agglomerations of form and space (Coates & Derix 2001 2003, Derix Coates & Finucane 2006). These new computational tools provide a platform for urban studies and we are in discussions with the UEL School for Distance Learning to develop curricular for urban simulation based on the tools described here.

The components already described can be used in the curriculum as part of an urban design project, and can cover site analysis, with scenario building structured to use the tools in an iterative fashion for design exploration.

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