ISSUE Interactive Software Systems for the Urban Environment

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The research reported here sought to examine the prospect for linking data sets which are currently isolated within specific departments or held externally by utility companies or businesses each of whom are likely to benefit from pooling resources. These data sets are potentially capable of being merged into one comprehensive system with the prospect that the sum of the parts would be worth considerably more than their individual worth suggests.

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1 Introduction

Many cities in the UK, and indeed throughout the developed world, are characterized by the all too familiar symptoms of urban blight caused by insensitive intervention in the environment. The common denominator within this class of problem is the lack of a coordinated, integrated approach to the planning, design and maintenance of our cities. The cycle of development and redevelopment involves input from a diverse range of disciplines relating to architecture, civil engineering, transport engineering, and the management of city utilities. This lack of a common, updatable, information base renders access to a global view of the city difficult if not impossible. Naturally the introduction of this strand of the information technologies into local authority usage is not a straightforward matter due to the constraints involved. These include funding, UK central government's enthusiasm and willingness to encourage uptake, information availability and quality, localized initiatives and the influence of EC policy. These factors are currently more pressing than technological advancements, although progress in the relevant technology is also vital in order that systems can continue to meet user requirements and expectations.

The developmental thread of this project is a natural progression brought about by the escalating potential of hardware technologies linked to expanding expectations and desires of the users. In the mid 1980s all that was asked, or expected, from a CAD system was the ability to model a single building, yet in a very short space of time it became possible to create and model ever larger groups of buildings. With this came the realization that the quality of the information content increased with the quantity. Given a group of
buildings more evaluations become relevant, studies of blocking, massing, methods of access and egress all become apparent and the ability to view a larger context makes all these evaluations more telling.

Our initial activities in urban modelling stemmed from a purely academic interest in how large scale urban data-sets could be captured, manipulated and stored. This resulted in the capture, at varying levels of detail, of much of Glasgow's city centre. However, interest was such that the model became self perpetuating and now extends to some 20 square kilometers encompassing around 10,000 buildings. The format of the model allows the logical data-structure of three interlinks sets of entities, the underlying terrain, the transport networks and the building stock. Within the limitations of this format (which is discussed later) the model proved adequate for our then current needs which were largely limited to the evaluation of new developments in their surrounding context.

As the model was applied to an ever greater range of problems, we became frustrated by it's innate inability to respond to a growing number of queries. While it was ideal as a tool to evaluate and communicate the spatial and aesthetic design issues relating to building development, we were increasingly having to turn away requests for other information. These requests related to data that the model did contain, and could potentially provide, yet because it lacked that basic level of intelligence the answers remained locked inside the data structure. The nature of these requests was in essence quite simple: “Can you show the relative proportions of commercial, retail and residential accommodation within a given area?”, “Can you calculate the total length of footpath between here and there?” This is all information that is intrinsically held in such a model yet the lack of basic attributes to the geometry required its extraction to be performed by hand, if at all.

The level of interest and usage of the model was a clear indication that a unified urban information tool would find a ready audience in all who were involved in all forms of urban management or development. This tool would provide a virtual abstraction of the city, containing not only the spatial information contained in the geometry but also the ability to harness the diversity of other existing urban databases. The goal of this research was to develop the, admittedly Utopian, concept of ISSUE, an Interactive Software System for the Urban Environment.

2 The Concept of Urban GIS

In an urban context, the wealth of spatially attributable data means that the scope for potential applications is limited only by the imagination. Proprietary systems are already utilized in numerous fields including planning, property management and appraisal, transport planning and routing, policing, health and environmental monitoring, marketing, land use management and in many more related areas. These data sets are often collated independently, either by the bodies concerned or acquired from external sources, notably the applications relate to information handling in both public and private sectors.

UrbanGIS, in this context, means a networked system which contains disparate yet standardized data sets linked to what is essentially 3D cartography. This would enable an indefinite number of data sets relating to the same urban environment to be linked and cross referenced by their unique spatial co-ordinates, giving added value to each piece of data through the spatial manipulations allowed and their interrelationship with other relevant data sets. Each data set could be maintained by the principal user of that data but the important factor would be that, during any particular query, data from separate data bases relating to the same geographical location could also be accessed and merged.
To consider urbanGIS implementation and maintenance on this scale, the incorporation of data relating to all major aspects of urban management is undoubtedly a huge undertaking, implying the incorporation of massive amounts of data relating to each of the applications mentioned above and also the centralization of effort. This would most likely be held by one principal coordinating body. Regional and local authorities, as the major collators, processors, disseminators, and users of urban information are the natural accommodators and users of urbanGIS. It is a major objective to illustrate that urbanGIS implementations on this scale carry significant benefits for local government planning and policy making processes and therefore to society as a whole.

2.1 Local Government and Urban Management
Although the general economic climate is primarily the responsibility of central government policies, it is evident during periods of economic growth or recession that variations occur in the extent to which regions are affected by swings between either extreme. It can be assumed that the ability of individual local authorities to successfully manage and coordinate the resources under their control will impact on the relative wealth created and hence the opportunities available to inhabitants as producers and consumers. Consequently, the social well being and quality of life for the population as a whole, at a localized level, may be related to the performance of local planning and policy. Moreover, this wealth naturally contributes to overall national prosperity and economic growth.

Aside from the complexities of urban management, which naturally place increasing demands on management and planning practices, there are other influences which will affect changes in structure, role, and orientation of policies. These changes are themselves instrumental in pushing policy makers to use their information resources to greater effect in an attempt to produce better and speedier judgments.

Pressure from central government to be cost effective and efficient in the ability to produce solutions to infrastructure, management, and social problems in urban centers is passed down to local authority level along with an increasing burden to police various legislative changes, notable domestic rates, but also in education, social services, and housing. These changes, with accompanying financial constraints are part of a shift in emphasis from service provision towards some form of “enabling” function, where the principal role is that of management within a framework in which services would be provided from the public sector. In order to support such policy it is obvious that information management will play an increasingly important role and, to an extent, will become the essence of good management (particularly the management of change) and decision making practices.

2.2 Applications and Users
A detailed study of two English local authorities carried out by the Local Authorities Management Services and Computer Committee (LAMSAC), evaluating GIS strategy benefits for local authorities, produced the list of potential application areas given in Table 1. The list is extensive but not exhaustive and many more application areas would potentially benefit. It does, however, serve to illustrate the diversity of services and applications which might be integrated into and served by urbanGIS. However this would bring its own technical and managerial problems that must be addressed. Whether local authorities continue to provide services from within their own departments or to assume an organizational role for outside contractors, in either case they must possess the relevant information.

The principal objectives of an urbanGIS targeted at local government can be tabulated in order to define the extent of information requirements, internal and external users,
and desired system capabilities (Gault and Peutherer, 1990). Information systems should not be application specific but should be designed to meet corporate goals. The needs of all levels and parts of an organization must be met; identifiable key groups fall into the following categories:

1. Senior management and strategic advisors;
2. Service managers and function planners;
3. Service deliverers;
4. Elected representatives;
5. The public; and
6. Special interest groups.

The following have been identified as key issues:

- The system should be able to provide each part of the organization with the information required, when it is required, but must avoid both information overload and information starvation;
- Information has to be available to be used selectively and used to measure progress towards planning objectives;
- The system should be integrated, interactive, and networked to allow mobility of data between source and user;
- Such systems should be able to provide information on the entire gamut of spatial units of interest to the organization;
- The system should be capable of holding or generating, past and current information in order to allow time series analysis. The system should also contain simulation modules to enable trend extrapolation and policy testing; and
- The data must be of good, or at least of defined quality.

3 Spatial Data Concepts

Geographical Information Systems have been a major advance in land management. Their success is in no small part due to the ability to communicate the information via associated mapping packages. Given that the urban model can be considered an extension of conventional cartography, enriched by the addition of the third dimension, then this spatial data set must be seen as an intrinsic part of the system. The urban fabric is the single common denominator that associates all the disparate data that may lie underneath and the ability to spatially reference attributes is a prerequisite. The geometric information affords a number of advantages; first since it is a potentially accurate digital representation it can itself be a focus of evaluations, in terms of area, height, volume, orientation, etc. Second, because it is a “natural language” representation it can be easily used as both an interface to the layered information beneath and, at the other end of the process, a vehicle for conveying more abstract information.

3.1 Geometrical Data Capture

The original Glasgow model was pioneered in order to study the methods of data capture and representation required by such large scale endeavors. This activity is potentially the most time consuming as no single source can provide all the data. The methods
employed covered source material ranging from cartography, aerial photography, and street surveys through to historical archives. However, an increasing amount of data is available in a digital format. The Ordnance Survey (OS) basic scale plans cover the scale range 1:1250 to 1:10,000 and comprise a total of over 220,000 sheets; 1:1250 is the largest scale of publication and the 55,000 sheets in the series cover the major urban areas.

A collaboration with the OS and Laserscan, a commercial company with a long history of digital cartography, lead to an investigation as to how the OS digital 1:1250 maps could be used as source material for three-dimensional urban geometry. The OS maps are available as raster images or vector data sets. Increasingly, the vector data is being made available in a structured format. Currently much of the data is unstructured, for example several records may separate parts of the same feature. However, demand from CAD systems means that the provision of structured data will become more available. Structuring the data requires that separate vectors defining features are "structured" into polylines or, if applicable, closed polygons.

In order to exploit this source we developed a filter that was capable of taking structured output from OS data or associated packages, stripping unnecessary information, and adding inter-record headers where required. The output being a series of geometrical entities formed by the base polygon, where each vertex is given a “Z” coordinate at ground level and a mean height inserted into the roof level field of the header information. When this output is accessed by the system it results in a scene which is surprising realistic, considering the effort involved. The use of OS data ensures that the building footprint is highly detailed and each building is accurately positioned with reference to the terrain. Obviously roof profiles are generated by flat planes, which is seldom the case in reality, yet the model gives a recognizable impression of the distribution of buildings in the given area. Further development requires an increasing investment in fieldwork, especially to gather accurate information on roof heights and formation. It is estimated that one working day would have to be invested to gather the heights of all building blocks contained on a 1:1250 scale sheet. The use of an Abney level at a paced distance from a known location would produce an accuracy of +/- 0.5m in the height of eaves or ridges relative to the building base. A further man day would be required to process the geometry and patch the data into the file listing. The resulting data set would then be adequate to represent the urban context for most needs Further refinement is increasingly expensive in terms of manpower, to provide architectural embellishment calls for a greater width of source information and, in general terms, the effort involved is in direct proportion to the quality and quantity of this provision.

4 Implementation

At the outset of the project the Glasgow urban database did exist, yet it was in a format that required significant knowledge and skill to utilize. The prime aim in assembling a demonstrator was to increase the ease with which it could be assembled and accessed to those without the experience of proprietary tools and operating procedures. With the prospect of urban geometry becoming increasingly available from sources like the OS the methods of creation, manipulation, and storage of such quantities of data are of paramount importance.

4.1 Interfacing

Through experience an obvious method of control suggested itself. This was to maintain a hierarchy of detail, accessing the geometry through a series of interfaces similar
to the familiar atlas concept. At the highest level a user is presented with a graphic representing the city in broad outline (Figure 1). Glasgow’s grid-iron road layout within the city center lends itself well to this concept. A user can then descend through this layer, being presented with ever increasing detail until the base level of building entities is reached. The user can browse the interface at any stage, accessing further details, building names or addresses, with a mouse pick. In this manner, the user can ascend and descend the hierarchy accessing data at different levels of definition.

Figure 1. Glasgow Interface.

4.2 Representation

In order to interface with such extensive geometrical data sets there has to be a hierarchy of representation depending on the spatial scale of the application. This has meant that such a model should exist on a number of levels of representation. If the intervention was on a city-wide scale then a basic, simplistic model is required. If, however, interest is focused on a specific area then a greater level of detail must be adopted. Determining what level of representation to adopt is a major factor in the usability of the system. Too much and response is slow, too little and not enough information is present. Very early on it was realized that even if the model was totally accurate in plan, users still had great difficulty in orientating themselves and as a result, minimal detail was added to “landmark buildings”—the stations, churches, and civic buildings. This led to a further level of detail in which buildings were just caricatures of themselves again accurate but minimalist in terms of representation. In a typical application the basic levels of detail would form the context for the intervention, minimal detailing would be applied to the immediate surroundings, and the object of attention would be represented by the fully detailed architectural model. By maintaining this layering of detail, large areas can still be manipulated without incurring unwelcome overheads.
4.3 Attribution

The geometry is attributed with spatial coordinates relating to the OS grid reference system. Each basic unit carries a reference to the 1:1250 map sheet which then may be broken down as the urban layout best suggests. Once the level of an urban block is reached, each building is individually identified. This layout uses the UNIX file system as a structured database, a hierarchy of directories maintaining a unique path and filename for each building. For every database field one record will point to this filename, equally every file has a field relating its spatial reference to common data. By this means a query can originate from the graphics, a "what is that?" style pick of a building, or may originate from a query relating to age, usage or other such data, and traverse the databases in both directions. This was the prime aim of the implementation, to be able to respond to the "show me" type of question. Here, the graphics are indispensable as a means of communication.

4.4 Database Functionality

The application was built on a range of machines to prove that the concept could work at the low, as well as the high end of technology. Although these implementations were "stand alone" in that they did not access a central resource, it did serve to prove that the concept was portable. The low end implementation was directed at IBM compatible PCs running Dbase4 and our own graphics front end. Although the graphics were limited to 2-D maps, the system proved that it could provide the necessary functionality. On UNIX workstations the system was built around an ORACLE database and could accept much greater functionality. An SQL interface complemented the graphics and while the attribute data was limited, the limitations were due to resources available and not to the limitations of the system. The image in Figure 1 represents one stage in the evolution of the system. The features available demonstrate that the implementation can access graphics from the 3D data set, attribute information from the relational database and multimedia data sets in terms of scanned raster images and even audio data. In a multi-tasking environment, the interface can coordinate a range of applications, invoking geometry editors to manipulate the data, filters to provide import/export functionality and access to associated peripherals. Given a suitable programming resource the technology that is readily available today would be well matched to the requirements of the proposed system and would not, as is often the case, limit the application.

5 Conclusions

Local administrations have the most to offer and the most to gain by moving towards an integrated philosophy regarding information collection, collation, and dissemination. The motivation to move towards this goal comes from a number of sources, primarily through the increasing complexity of urban management but also due to central government policy to progress towards the decentralization of services. Fiscal pressure to increase efficiency, lower manpower resources, and arrive at speedier judgments all point towards an increasing reliance on the information technologies.

The quality of planning and decision making processes can be substantially improved when valid data is appropriately and efficiently handled. Relevant information systems which support the activities of planning and decision making must be based on a thorough and clear analysis of the planning processes adopted. The use of an urbanGIS allows information to be assembled and applied in new ways. It offers practical means to manage large and diverse spatial databases and provides effective tools to understand relationships between disparate phenomena. An increasing number of decision makers and
managers have recognized that these technologies will be essential if they are to address the expanding mandates and complex decisions they now face.

The use of a graphically orientated urbanGIS system has a threefold advantage. Firstly, since 80 percent of urban information can be spatially referenced it is a logical format under which disparate data sets can be collated. Secondly, communication is of paramount importance. The ability to use a readily understandable and recognizable medium with which to communicate proposed strategies and outcomes will make the task of disseminating policy open to all. Finally the use of a digitally accurate urban model will open up greater roles for simulation based tools.

An increasing knowledgeable and aware user base will be a significant factor in the uptake of urbanGIS. Users will demand systems that accept data in diverse formats from existing databases, that they be easier to use and present higher levels of performance. Market forces will provide the incentive for the incorporation of advanced graphics, simulation and animation facilities, faster processors, more competent data exchange and query functions and expert system shells to reduce areas of complexity identified by the users.

Developments from all corners of the information technologies will aid the uptake of urbanGIS, emerging standards, the move towards open systems, increased networking infrastructures and greater availability of data in digital formats will increase the mobility and sharing of databases. These factors coupled with a growing user community will create an environment that will foster an increasing growth rate.

The issue of financial justification will be important, especially in a local authority context. Although hardware costs are on a downward trend, many of the costs associated with the system remain high. Budget expenditure will be greatest at early stages while many benefits will only accrue once the system is in widespread usage. A complex issue is one of asset management. The better the existing internal asset management, the more difficult is the justification for new technology. For example, the authority which has recently invested in high quality OS paper map coverage of its land coverage may find it difficult to justify recapture in a digital format.

Given all the factors that influence the success of an implementation such as that discussed here, the technical aspects of authoring the software and targeting a suitable hardware platform, are undoubtedly in the minority. The real challenge is in the legal, ethical, political, and economic barriers to promoting the sharing of data and encouraging centralized management of assets. Even within the tight boundaries of local and regional authorities the duplication of effort, the adoption of mutually incompatible formats, and the lack of willingness to pool resources all tend to negate the potential benefits. In short, the only remaining barriers to ISSUE are essentially human ones.

Society is increasingly dependent on information, in all forms. It is easy to see the move towards a critical mass where enough interested parties hold enough information to make the move towards the philosophy of centralization of information assets self perpetuating. Once this occurs, the potential benefits may be realized.

References