USER REQUREMENTS FOR THE THIRD DIMENCIONALITY

S. Zlatanova and T. Bandrova

ITC, the Netherlands **UACG, Bulgaria**
zlatanova @itc.nl **bandrova_fgs@uacg.acad.bg**

Abstract

The third dimension attracts a lot of attention in the last several years. Despite the variety of problems in data acquisition, storage, maintenance and visualization, an increasing number of 3D urban models have been reconstructed. Many of them leave out the world of advertisements, entertainment and games and attempt to serve real applications. In this contexts, the experience of the user with 2D applications is a valuable indication for further research and developments in 3D.

The paper presents a study on user requirements completed with the help of 15 firms dealing with wide range of urban and non-urban tasks. The focus is on real objects of interest and frequent spatial and thematic analysis as their importance for the third dimension is discussed. Some aspects of 3D visualization and symbolization are investigated as the intentions are clarification of expected level of realism and interaction.

Analyzing the results, we outline the most important urban objects with and without spatial extend. The complexity of tasks in urban areas as well as the complicated interrelation between spatial and non-spatial objects, has convinced us to appeal for an integrated information system, capable to maintain and analyze any kind of objects (buildings, streets, people, documents, etc.). Moreover, the information system of the future must provide high realistic 3D models allowing free navigation and exploration, as the scope of operations required may vary from institution to institution. The 3D models have to allow multiple geometric representation including symbolization. 3D symbols are expected to have extended guiding, routing and informative functions similar to their analogues in real world.

1. Introduction

Not a long time ago, the user had at his disposal only 2D maps and media to depict real phenomenon, which have restricted some analysis of processes, relationships and behavior of real objects. Resent achievements in hardware and software technology, which have shown encouraging results toward storage and maintenance of large amounts of data, motivate us to expect a dominance of the third dimension in the next millennium. In this respect, quite interesting question is the preparation of the user for 3D applications. The subject is very difficult to investigate due to several reasons: a high 3D production price (no experience with 3D models), lack of a functional 3D GIS (prevalence of CAD models), a lot of information kept in 2D GISs (traditions to complete spatial analysis in 2D), large amounts of data and complex visualization (need of conceptually new software).

This paper explores readiness and requirements for urban three dimensional models as the aim is facilitation of the software development. The issue is rather intricating because the development of an information systems always faces the dilemma: technology or application driven approach. On one hand, users are the most aware of tasks they deal with and it seems logic to rely on their requirements. On another hand, being tied by legal, policy and long-time traditions, confronted with organizational, financial and market problems, users hardly can identify revolutionary new requirements. The technology driven approach is not the optimal solution, either: the system developed may appear to have extra (or not sufficient) functionality for a particular application. However, the hardware and software industry has always been the generator of ides. In historical aspect, the powerful hardware and software were first born and after that 3D models of real world were created. Apparently, a balance between the two approaches is needed: user problems and routine operations have to be studied to be able to offer them contemporary, advanced solutions.

The way of gathering user requirements may influence the investigation, as well. A simple questionnaire of the personal responsible for a certain information system could create very subjective view. In contrast, ignoring conversations with the staff, an important observation gained from a long term experience could be overlooked. To facilitate investigation, a particular strategy was followed. First, methods to determine user requirements are studied to select the most appropriate manner to identify real objects of interest and their characteristics. Second, the questionnaire among producers of spatial information was completed to clarify the information utilized by different applications, the most often executed spatial analysis, and some specific 3D visualization necessities. Third, a supplementary study on the information kept presently in a municipality (an important body responsible for urban development) is discussed to outline existent and potential users and their interests (in terms of objects, relationships, most often questions and outcomes). On the basis of these preliminary results, an elaboration on 3D requirements is presented in following order: 1) identification of important for 3D applications objects and their geometric resolution, 2) clarification of spatial relationships, 3) expected realism and 4) demanded level of 3D interaction and manipulation of data.

2. Methods to study user requirements

Plenty of methods are discussed in the literature regarding requirement determination (Coad et al 1991, Norman 1996). Most of them are business oriented and related to overall analysis of processes in the organization (company, firm, agency) starting from the mission and ending with the final outcome. A large group of methods, i.e. object-oriented methods follow a slightly different approach. The focus is on objects of interest as the characteristics considered vary from method to method (Norman 1996). The Coad's object-oriented framework concentrates on *objects* (items of interest), *responsibilities* and *scenarios*. Responsibilities are associated with objects and their characteristics ("what the object knows about itself"), relationships ("who the object knows") and behavior ("what the object does"). Scenario is referred to the sequence (time-ordered) of object interactions. The method is data oriented, i.e. it stresses the information, which has to be maintained in the system. Essential advantages of Coad's object oriented method which contribute to our intentions are:

- high emphases on information.
- ability to concentrate on a separate model component, e.g. human interaction and data management
- ability to identify *objects*, *attributes*, *relationships* and *behaviors*

The exploration of user requirements in Bulgaria is organized under the object-oriented frameworks on the basis of *global* and *individual* methods for gathering requirements. The *global method* evaluates mostly the experience with existing systems, as the intention is to eliminate the human factor. The method is based on 1) reviews of current reports, 2) conducting of research what is already done (by the company), 3) visiting similar system installations. Foundations of the *individual* method are *interviews*, *observations*, *questionnaires*, and *prototype* systems. More details regarding methods to collect requirements can be found in Norman 1996.

Inside the framework, the aspects explored are related to *objects* and *responsibilities*: objects of interest in urban areas and their resolution, spatial relationships of interest and most often spatial analysis applied, Graphic User Interface (GUI) and level of realism preferred, and editing operations. Bearing in mind the principals of the framework, a questionnaire on 3D was prepared and distributed among 15 companies in Bulgaria. The companies are a representative sample of producers and were selected with respect to 1) the dimensionality of the maintained data (at least 2,5D) and 2) the application orientation (urban or mixed). In addition, the consortium report of a project on a 2D GIS implementation plan (Croswell et al 1994) supplied valuable information about current status in a municipality in Bulgaria.

3. Objects

3D real objects of interest for urban applications are often being specified in the literature as the scope varies with respect to the approach followed (software or application driven). The common understanding is that the most important objects are buildings (Grün et al 1997, Kofler et al 1997, Tempfli 1998). The 3D city models created so far consider primarily buildings and DTM represented as TIN. Fuch C. 1996 presents a broad study on objects for 3D City models completed on questionnaires among 55 participants from Europe. The interest in five groups of real objects is investigated: buildings, vegetation, traffic network, public utilities and telecommunications. The results show clearly prevalence usage (need) of buildings, traffic network and vegetation. The study does not provide information about the need for DTM. Razinger et al 1995 present a virtual model of a square in Graz (created upon a municipality request) containing buildings, traffic network (streets and tram railways) lampposts and trees. Some 3D city models assume flat terrain others incorporate DTM (Leberl et al, 1996). Dahany 1997 suggests three groups of objects to be considered: terrain, vegetation and built form. Many authors (Flick 1996, Pilouk 1996) concentrate on geometric representations (e.g. *0-cell, 1-cell, 2-cell, 3-cell* or *solid primitives*) assuming that any urban application would make use of the abstract objects applied. Templfi 1998 focuses *topographic* objects and discusses a 3D urban model consisting of buildings (*body* objects), DTM, streets, parking lots, gardens (*surface* objects), lamp posts (*line* objects), trees and man-holes (*point* objects). Although, many of the real objects, elected from the questionnaire (see Appendix, Table 3) are predefined by state instructions, the results are not much different than those already discussed above: objects maintained by topographic maps have a crucial importance for urban development.

In general, most of the authors address real objects with spatial extend and less (or no) attention is paid on non-spatial objects. The motivation is bigger problems and higher complexity occurred in geometry domain. Operational data needed for urban planning in 2D sometimes goes far beyond the objects of interest discussed above. In principal, the ambition while developing a 3D GIS must be preservation of existent 2D functionality and then extensions toward the third dimension. Consequently, real objects of interest should not be reduced unless they become meaningless in 3D. Therefore, prior the concentration on spatial objects, we will give a broader classification of real urban objects. Intentions are depicting of all the real objects even those staying asides of the intensive research.

A look at the organizational and information structure of a municipality reveals the following picture: 1) plenty of spatial and non-spatial items stored under different descriptions (DBMS, GIS and CAD) and 2) complex interrelations among different types of data and institutions. For example, personal data is stored in several information centers: three Municipal offices and the Regional tax office. Is a *person* an object of interest? How to specify relationships with other object? The information needed to reconstruct a number of buildings is hosted in four centers: the Municipality Offices, the Electricity, the Telecommunication company and the Water and Sewerage Corporation. Each of the companies has its own structuring and coding of data, e.g. *deed* is an object according to the Department of State and Municipal properties while it is an attribute in the Municipal Land Commission. Is the *deed* an object of interest or an attribute of the parcel? The Department of Architecture maintains general plans for urban development, which are extremely important for any new planed construction activity. How the plans or information inside should be referred: as future objects or as future status of exiting objects? The geometric characteristics of real objects are mostly related to their position, shape and/or size and topology and thematic information represents attributes and specific functions. A detailed description of the records can be found in Croswell et al 1994. Table 1summarizes the real objects discovered in the 2D information systems running in a municipality and related institutions.

Table 1: Real Objects in 2D GIS

Layers in 2D GIS	Real objects
General map reference	Grid, streets, street names
Administrative units	Districts and suburbs
Parcels	Parcels and sub-parcels, rights–of-way, public vending and public transportation areas
Regulation plan	Project development boundaries
Buildings	Buildings, floors
Road-related paved areas	Paved street areas, parking places, pedestrian walkways, sidewalks
Street centerlines	Center lines of street segments, delimited by intersection points
Project development plan	Development plan outlines
Water distribution system	Water pipe segments, valves, hydrants, service tabs, service lines
Sanitary sewer system	Sewer pipe segments, man holes, valves, service taps, lateral lines
Electric distribution network	Primary and secondary above and under ground electric lines, poles, transformers, switches, Fuses, substations, streetlights
Gas distribution system	Gas pipe segments, valves, service taps, service lines, cathodic protection device
Storm drainage system	Aboveground drainage channels, underground drainage lines, culvert openings, catch basins
Telephone network	Centerlines of telephone conductors, switching centers, poles, service lines, other point objects
Topography	Contour lines, height points

Considering geometry of real objects, we can distinguish among objects with: 1) complete geometric description, i.e. position, size and shape, or 2) only position, or 3) without any physical characteristics. In this respect, we propose four groups of real objects to be considered for urban administration: *juridical* object (e.g. people, institutions, companies), *topographic* objects (e.g. buildings, streets, utilities), *fictional* objects (e.g. boundaries) and *abstract* objects (e.g. incomes, taxes, deeds).

- The first group of objects has a number of non-spatial characteristics such as name, age, status, occupation. Geometric description, i.e. shape or size is not required, however, the location (e.g. permanent address) is essential.
- The second group comprises all the unmovable real objects with detectable boundaries. The members of the group have complete geometric representation and thematic characteristics.
- The third group has thematic and geometric characteristics, however, the objects existence is fictive. Typical examples are neighborhoods or regions with special status (a center, industrial areas, residential areas, etc) or areas with different population or districts with various level of pollution.
- The fourth group is abstract objects such as deeds and documents, which do not have geometric representation.

The groups of real objects introduced delineate clearly *spatial* objects, i.e. *topographic* and *fictional*, which are maintained in 2D GIS systems. An important observation is related to *fictional* objects. Although the *fictional* objects are created to serve tasks mostly in 2D environment, they still have functions in 3D, as well as, they can change their dimensionality. For example, districts with a different level of air pollution can be maintained as 3D surfaces instead of areas. Therefore, we recommend their preservation in a 3D GIS, as well.

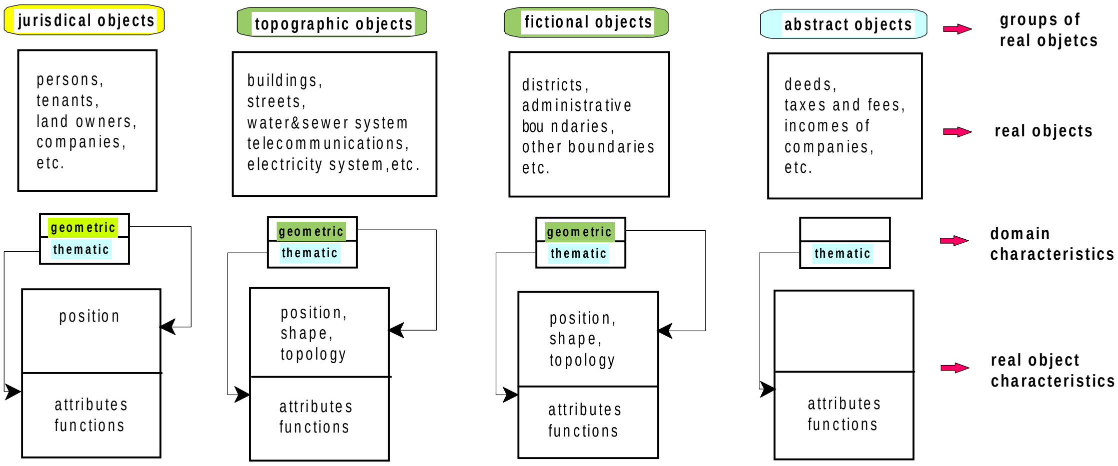

Figure 1: Groups of real objects, real objects and their properties

The other two groups, i.e. *juridical* and *abstract* objects do not have geometric description, however, their status can change. Recent developments in computer graphics and virtual reality supply techniques to represent a human body (*avatar*), capable to move in virtual worlds, speak and interact with other virtual persons or objects. *Abstract* objects might be represented by virtual sheets, stored in a drawer etc. This is to say that objects, which are represented and maintained as *non-spatial*, nowadays, could be transformed in *spatial* ones in a nearest future. In this context, we advocate an integrated approach for a 3D object identification. 3D GIS should be able to maintain not only thematic and geometric characteristics of spatial objects but *spatial* and *non-spatial* objects.

4. Resolution

Resolution, here, refers the smallest detail, which has to be represented geometrically. Although familiar from 2D, e.g. the smallest building to represent on the map, the issue is much more complex in 3D. For example, a building can be associated with a simple rectangular box, or with a composite of several boxes with indication about windows, doors, etc. Either all the ornaments on a facade might be considered or only outlines of the wall. A tree might be constructed by several solid primitives indicating thumb, leaves, and branches or by a 3D symbol.

Most of the 3D city models constructed are based on very simple (low-resolution) geometric description. Usually buildings are represented only by their walls and roofs (Wizard Solutions, 1999). More rarely windows, doors, small balconies, leveled streets and pavements are reconstructed in broad urban environments (Arena2000, 1999). Instead quite many models are mapped with photo images. Detail models including stairs, columns, rooms, furniture, etc. are modeled only for individual buildings, e.g. Congress Center, Graz, Music center, Enschede. Fuch C. 1996 reports high interest in roofs as the size of the smallest element is critical for representation of front and overhanging elements. The floors are some of the components where the demand is very low that, however, contrasts the results of the questionnaire (see Appendix3, Table4). Internal constructive parts, e.g. rooms, corridors are not investigated in the study. Our questionnaire aimed more detailed exploration on the issue, however, the results were a bit unexpected: most of the answers in the questionnaire refer instructions and users requirements (see Appendix, Table 4). Anyhow, this is again an indication for 3D GIS developers that resolution available in 3D should not drop beneath the resolution used in 2D.

The investigation among the firms has exposed several factors, which have impact on the resolution maintained: 1) the application (the wish of the user), 2) the chosen method for geometry description, 3) complexity of data acquisition procedure, 4) software and hardware for maintenance and 5) accuracy of the source data. The application is the crucial factor for the resolution, e.g. a mobile telephone company may be satisfied with a box as an abstraction of a building, while a utility company would prefer to think of a building as a composite object with boxes for each room. The method for geometry description (simplex, solid) influences the detail when one has to stick rigidly to predefined method due to some reason (e.g. the most of the data are already in this format). In that case some details could be impossible to represent and the resolution of the model will be reduced. In many cases the application demands for higher levels of detail but existing methods cannot provide at all or can provide on a very high cost data. Then the user is restricted due to lack of effective technologies for data acquisition. Software and hardware availability appears to be an essential consideration for the resolution maintained. For example, the produces of information can obtain easily complete information about the building elements (doors, windows, corridors, rooms, etc.) from constructive plans but still maintenance of such information is quite difficult process, due to large amounts of information, low speed of visualization and interaction.

Ability to operate with different geometric representations as *complexes* of objects is indicated as an important consideration for a GIS (Frank 1991, Flick 1996). Different activities may require different views: a simple box or complex geometry, or geometry with texture containing geometric details. The questionnaire has performed a producer's opinion in support of different representations (see Appendix, Table 5). Thus the issue about storage (or not), maintenance and control (switch) of the representations arises and should be considered for 3D GIS.

5. Relationships

To our experience, a systematized study on demand for 3D spatial relationships is not available. Therefore quite many efforts were spent to clarify the subject. The strategy followed has to: 1) study the software used by the firms in order to gain information about the relationships currently maintained and 2) detect the most often analysis applied daily and 3) investigate possible analysis for 3D. The software used by the firms is mostly 2D GIS with 3D extensions (or CAD) for visualization (see Appendix, Table 1) as the GIS software (e.g. ArcView, ArcInfo, AutoCAD, AutoCAD Map) is a typical example of 2D topology maintained per layer. The exploration of 3D spatial analysis has appeared the most difficult task. Some of the reasons are listed below:

- The user has strong tendency to think in 2 or 2.5 D concerning spatial analysis. For example, a query "how many meters of pipes are necessary from the street to the 5th floor" is modified to 1. "how many meters of pipes are necessary from the street to the footprint of the building" and 2."how many meters pipes are necessary for 5 floors each 3.50 m high".
- The user does not have examples of a functional 3D GIS. In many cases, he/she hardly can picture spatial operations performed in 3D.
- The user is highly influenced by the level of functionality offered by the software in use.

Table 2 (see Appendix) contains summary of the results in 2D and 2.5D. As it can be seen, priorities to metric, thematic and mixed (spatial and thematic) analysis are given. Mixed analysis, here, means query of spatial data regarding a thematic condition, e.g. "show all the administrative building". Majority of the firms considers buffering analysis quite important, as well. The results very much reflect the 2D analysis carried out presently in the offices, e.g. the often ran operation is buffering of a railway. Although 50% of the firms have found neighborhood and network analysis important, they are still not aware of benefits of 3D solutions. One argumentation refers preferences of non-GIS users (i.e. citizens) to paper maps with results rather than digital copies or screen displays. Another argumentation is still quite high demand for 2D digital maps (about 50%). An analog observation is reported in Fuchs, 1996: 10% of producers and 10% of users operate only on digital maps.

In conclusion, the exploration of user experience in spatial analysis has supplied information about the set of operations, which has to be preserved in 3D. Considering the results discussed above, the objects and resolution of interest, a meaningful set of 3D relationships can be delineated for urban applications. The objects of electricity, water and sewage, and telecommunication networks are combined in a group *utilities* for simplicity as some specific objects are explicitly mentioned (e.g. transmitters, lamp posts)

- Buildings – building *adjacent* (common wall, edge, roof facet) to building; building *adjacent* (common edge, common point) to pavement, street, park, parcel, parking lot; floor, wall *part of* building; window, door *part of* wall; window, door, floor, wall *inside* building; building *inside* building (e.g. garage *inside* house); building *around* park, building;
- Bridges – bridge *adjacent* (common surfaces) to park, pavement, street, path; bridge *over* street, pavement, park, parcel; bridge *over* building, bridge;
- Streets – street *adjacent* (common boundaries, points) to pavement, park, parcel; street *under* bridge;
- Underground – underground *under* pavement, street, park; underground *under* building, underground;
- Parcels – parcel *adjacent* (common boundaries, points) parcel, pavement, street, park; building *inside* parcel; tree *inside* parcel
- Parks – park *adjacent* (common boundaries, points) to pavement, street, parcel, path; tree, lamp post *inside* park, building *inside* park
- Utilities – utility *adjacent* (common point) to utility; utility *adjacent* to wall, terrain, floor; utility *inside* building; lamp post *part of* electricity network, utility *over* street parcel; utility *under* street, parcel; connection *part of* utility; connection *part of* wall, floor; connection *inside* building; connection *under* street, pavement; transmitter *on* building;
- Others – man-hole, monument *inside* pavement, parking lots, parks; tree *inside* man-hole;

- Vegetation – tree *inside* parcel, pavement, street, parking lot, parks;
- Districts – building, parcel, street, park, utility, monuments *inside* district
- Terrain – surface analysis;

6. Realism

Without doubts, 3D visualization needs extended means for displaying. Depending on the balance between the main components of a 3D *scene* (see Figure 2), various levels of realism can be achieved. Motivated by the high complexity of urban data, many authors (Kofler et al 1998, Raper et al 1998, Tempfli et al, 1996) recommend utilization of real images to texture the model instead of comprehensive methods for illumination and shading (see Figure 3). Urban models can benefit of texture mapping in several directions: 1) representation of details skipped by geometric modeling, 2) improvements in the orientation while interacting with the model, 3) facilitation of the user perception of sizes and shapes (Gruber et al 1995). However, texture acquisition and texture mapping processes are still far way from automation that, indeed, increases the price of the final product. As a result, complete 3D city textured models are still luxury. Our study on texture needs has exhibited high percentages in support of photo texturing (see Appendix, Table 5). Even those who prefer 2D and/or wire frame visualization have found only photo texturing meaningful.

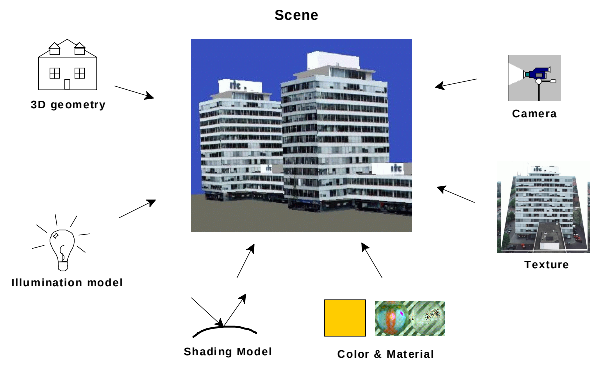

Figure 2: Components of a 3D scene

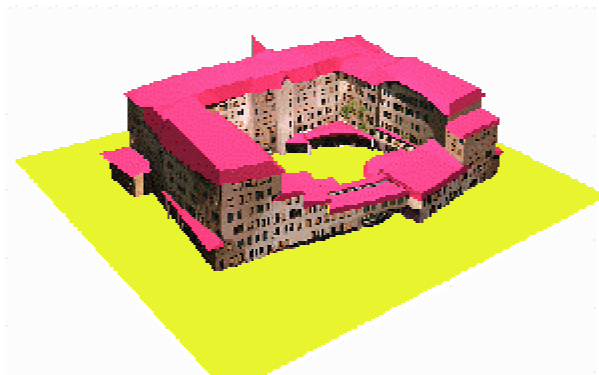

Figure 3: Textured model: ITC, Enschede

Apart from the pursued realism, most of the methods for visualization (wire frame, shaded, texture draping and texture mapping) can be successfully applied to display and (or) emphasizes on important characteristics of the objects or to control geometric representations:

- point clouds - a method not convenient for common visualization but adaptable for performance of results of thematic queries and analysis, e.g. “density of buildings”, “density of shops”, “distribution of vegetation”.
- wire frame graphics – in combination with algorithms for hidden line (face) removal might be appropriate to control the re-construction of the model, e.g. for consistency check like “sinking” and “flying” objects (see Figure 4).
- illumination and shading - a suitable method for interactive manipulation (allows working with solid objects and still the amount of data for visualization is relatively little). Shaded models ensure consistency check of ordering and orientation of shaded polygons (see Figure 5).
- texture wrapping – the method is appropriate for draping an image over large surfaces (terrain), when texture mapping is not relevant or not possible.

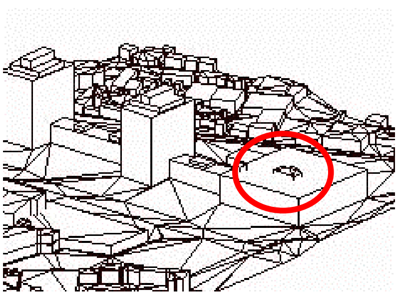

Figure 4: Wire frame: sinking objects

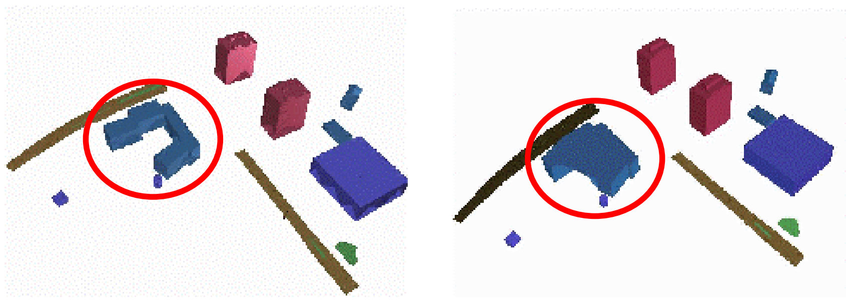

Figure 5: Shaded model: correct and incorrect ordering of faces

Almost all the firms interviewed have found 3D symbolization essential for 3D models. The producers were challenged with questions regarding traffic, public and information signs and marks. The majority of them accept the idea of additional guiding information on streets of a 3D model (see Appendix, Table 7). The 3D symbols can be divided in several groups with respect to user's needs (Bandrova ???). 3D symbols may show position, shape and size, as well as, qualitative and quantitative characteristics of real objects. Indeed, the fundamental question is which objects should be represented by symbols but not by geometry. The user is not oblige to find the answer by himself. We have proposed a library of symbols, which can facilitate the decision how to model the real world. A small set of symbols can be seen on Figure 6.

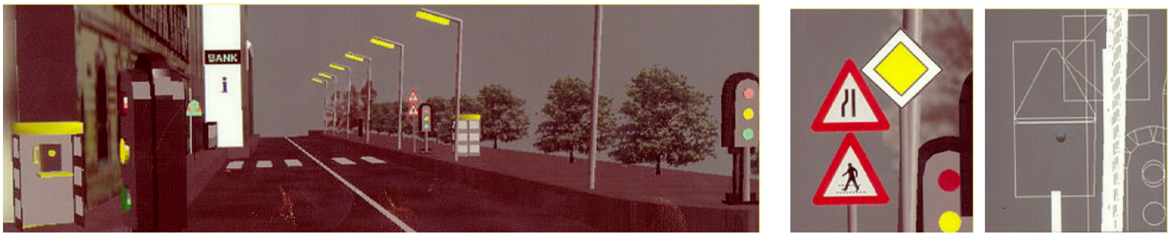

Figure 6: 3D symbols: on a scene, textured and wire frame

7. Graphic user interface

The last aspect in our investigations tries to determine requirements for GUI. Analysis of the results has revealed that GUI depends in large extend on responsibilities of the institution (firm, company, organization). An organization dealing with data acquisition and frequent update of data demands extended means to operate on smallest constructive element (*point*, *line*, and *facet*). All the firms' participants in the investigations belong to the group of producers. Table 6 (see Appendix) illustrates the most updated elements (i.e. *points*, *lines* and *facets*) and, respectively, the strong preferences to wire frame graphics. VR modelers are not mentioned by any of the firms (see Appendix, Table 5), which could be an explanation for the higher interest to wire frame. Moreover, a 3D GIS for a producer may have a standalone or Intranet realization, with no direct connection to other companies.

Completely different requirements for GUI can be drawn for a municipality 3D GIS. The municipality usually has contacts with variety of users from different organizations, which are equipped with different hardware and software. The common way to exchange data, nowadays, is a digital or paper copy (e-mailed or post-mailed) of needed information. To shorter this process, i.e. safe time, efforts and money, the municipality has to be able to offer a basic set of operations and data to all organizations needed their service. For example, the members of a telephone company have be able to check on-line the owners of buildings or ask for statistics about suburbs (i.e. information not available in the company) any time during a discussion on a new project. Many of the municipality customers are regular citizens asking some information. Although, hard copy outcomes will still be popular for quite long time, the importance of on-line services increases every day. The day when the counters in the municipality will be replaced with computer corners for self-service is coming. Hence, the municipality has to be capable to supply information to remote and local users. Accordingly, the municipality system has to be prepared for a wide range of users with diverse backgrounds. This imposes also GUI and security requirements. The interface has to be user friendly, flexible enough to cover large spectrum of questions (in both thematic and geometric domain), to offer sufficient tools for understanding the results and exploration of the model. The system must have a reliable protection against crackers or unintentional mistakes.

Virtual reality (VR) techniques have become quite popular tool for visualization of 3D models (see Appendix, Table1): 40% of the firms use software providing real-time navigation and exploration as some of them operate already with the Virtual Reality Modeling Language (VRML). We expect larger utilization of VRML in near future for both visualization and query of remote data (Zlatanova 1999). The language offers means for real-time navigation (*fly-over*, *walk-trough*, *explore)*, Internet access, realism as the conventional input devices (see Appendix, Table 6) are employed.

8. Summary

The paper presents a commentary on user requirements for a 3D GIS as cardinal real objects, their geometric details and spatial relationships important for the urban 3D models are delineated. A questionnaire among several production companies with urban specialization has provided valuable information on importance of real urban objects, demand for spatial analysis and required resolution. Questions related to preferences for 3D visualization have revealed some expectations for GUI and realism of urban models. Analyzing the results, we have suggested a classification regarding the spatial extend, which distributes the objects into four groups. Besides the group of *topographic* objects, we consider a second group with spatial extend, i.e. *fictional* object. Furthermore, we argue for integration of *non-spatial* objects into 3D GIS object considerations. Motivations are based on: 1) technologic developments permitting new geometric expressions and 2) increased complexity of tasks in many urban applications incorporating interrelations between spatial and non-spatial entities.

Requirements for user interface to manipulate of 3D data may vary with respect of the operations performed as the popularity of virtual reality techniques increases. Users realize the importance of extended means for 3D visualization and interaction with 3D models. An agreement on high realistic photo textured models was shown despite the problems in texture acquisition, processing and mapping. 3D symbols are expected to have an stretched meaning. First, they preserve the function of representing real objects and phenomenon. Second, they guide and help the user in navigation trough and orientation in the 3D model, which remains to their function in real world.

Finally, we can conclude that the user is prepared to work (produce, maintain, analyze, etc.) in three dimensions and expects appropriate software to be developed.

Acknowledgements

The authors would like to acknowledge Y. Zaharieva for sharing her experience on municipality organization and all the firms for their contribution to this study.

References

Arena 2000 project, 1999, Virtual Helsinki, http://www.helsinkiarena2000.fi/3dhelsinki/

Bandrova, T. 1997, Creation of 3D Symbols, International symposium "Modern technologies of Cadastre", 19-20 November, Sofia, Bulgaria, pp.132-138

Coad, P. and E. Yourdon, 1991, Object-oriented analysis, Prentice Hall

Croswell, P., Y. Zaharieva and R. Pantaziev, 1994, GIS Implementation Plan for the Municipality of Blagoevgrad, Bulgaria, SAID, Project No. 180-0034 - report, ICMA, International Municipal Programs, September, 65 p.

Danahy, J., 1997, A set of visualization data needs in urban environmental planning&design for photogrammetric data, Proceedings of the Ascona Workshop'97, Automatic Extraction of Man-Made Objects from Aerial and Space Images, Monte Verita, Switzerland, pp. 357-365

Gruber, M., M. Pasko and F. Leberl, 1995, Geometric versus Texture Detail in 3D Models of Real World Buildings, Automatic Extraction of Man-made Objects from Aerial and Space Images, Birkhauser Verlag, Basel, pp. 189-198

Grazer Congress Centrum, 1999, Graz, Austria, http://www.gcongress.com

Grün, A. and H. Dan, 1997, TOBAGO - a topology builder for the automated generation of building models, Proceedings of the Ascona Workshop'97, Automatic extraction of man-made objects from aerial and space images, Monte Verita, Switzerland, pp.149-160

Flick, S., 1996, An object-oriented framework for the realization of 3D Geographic Information Systems, Second Joint European Conference & Exhibition on Geographical Information, Barcelona, Spain, pp. 187-196

Frank, A., 1991, Properties of Geographic Data: Requirements for Spatial Access Methods, ???, pp. 225-234

Fuchs, C., 1996, OEEPE-Study on 3D City Models, Report Institute for Photogrammetry, University of Bonn, October, 45 p.

Kofler, M. and M. Gruber, 1997, Toward a 3D GIS Database, GIM, Vol. 11, No. 5, pp. 55-57

Leberl, F. and M. Gruber, 1996, Modeling a French Village in the Alps Proceedings of the 12th Spring Conference, Budmerice

Norman, R.J., 1996, Object-Oriented Systems Analysis and Design, Prentice Hall International, Inc., New York, 431 p.

Pilouk, M., 1996, Integrated Modeling for 3D GIS, PhD thesis, ITC, The Netherlands, 200 p.

Ranzinger, M and G. Gleixner, 1995, Changing the City: Datasets and Applications for 3D Urban Planning GIS Europe, March, pp.28-30

Raper, J., T. McCarthy and D. Unwin, 1998, Multi Dimensional Virtual Reality Geographic Information System (VRGIS): Research Guidelines, Proceedings GISRUK 98, Edinbugrh, UK

Tempfli, K., 1998, Urban 3D topologic data and texture by digital photogrammetry, ASPRS, ISBN-1-57083-054-1, March-April, Tempa, Florida, USA, CD-ROM

Tempfli, K. and M. Pilouk, 1996, Practical Photogrammetry for 3D-GIS, ISPRS Vol. XXXI, Part B4, Vienna, Austria, pp. 859-867

Twente Music Centrum, Enschede, the Netherlands, http://wwwseti.cs.utwente.nl/Parlevink/Projects/Muziekcentrum/codecompressed/vmc_zonderschisma.html

Wizard Solutions, 1999, Real cities in Virtual Reality, http://www.intoronto.com/

Zlatanova, S., 1999, Urban 3D GIS on the Web, http://barley.itc.nl

Appendix: Questionnaire on 3D

Table 1: Current status: 2D, 2.5D, 3D

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Orientation	2	2	2	2	2	2	2	2	2	2	2,3	2	2,3	1,2	3
Stored data	1,2,3	1,2,3	1,2	1,2	1,2	1,2,3	1	1,2,3	2	1,2	2	2	1,2	1,2	1
Used data	1,2,3	1,2,3	1,2	1,2	1,2	1,2,3	1	1,2,3	1,2	1,2	1	1	1,2	1,2	1
Output	1,2,3	1,2,3	1,2	1	1	1,2,3	1	1,2,3	1	1	2	2	1	1	1
Data type	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1	1,2	1,2	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1
Software: storage	1,2,3	1	1,2,3	1	1,2	2	1,2	1,3	1,2	1,2	1,2	1,2	1,2	1,2	2
Software: display	1,2	1,4	1,2,4	1	2	2,4	1,2	1	1,2	1,2	1	1,4	2,4	1,4	2

Orientation:1-Urban areas, 2-combined (urban + something else), 3-others

Geometry: stored, used data, output: 1-2D, 2-2.5D,3-3D

Data type: 1-geometry, 2-attributes, 3-relationships

Software for data storage: 1-GIS, 2-CAD, 3-DBMS, 4-VR

Table 2: Analysis in 2D and 2.5D

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Metric	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	✓
Positional	✓	-	✓	-	✓	-	-	✓	✓	✓	✓	-	✓	-	-
Network Analysis	✓	-	✓	-	✓	-	-	✓	-	-	-	✓	-	-	-
Proximity	✓	✓	✓	✓	✓	-	✓	✓	✓	✓	✓	-	-	-	-
Neighborhood	✓	✓	✓	-	✓	-	-	-	✓	✓	-	-	-	-	-
Visibility	✓	-	-	-	-	✓	-	✓	-	-	✓	✓	-	-	-
Thematic	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	✓
Mixed	✓	✓	✓	✓	-	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

✓ yes, -no

Table 3: Objects of interest: 2D, 2.5D

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Buildings	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Other Constructions	✓	-	✓	✓	-	✓	✓	✓	✓	✓	✓	-	-	✓	✓
Streets	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-
Paths	-	✓	✓	✓	-	✓	✓	✓	✓	✓	-	✓	✓	✓	-
Parks	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-
Utilities	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	-
Telecommunications	✓	✓	-	✓	-	✓	✓	✓	✓	✓	-	✓	-	✓	-
Vegetation	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

✓ yes, -no

Table 4: Resolution: 2D

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Buildings	1,6,7	1,9	1,5	1,5	1	r	1,2, 5,6,8	1	1,5	1,5	1	1	1	1	1
Streets	1,2	1,2	1,2	1,2,3	1,2,3	1	1,2,3	2	2	2	2	2	2	2	2
Paths (min width)	0.2	in	r	in	-	r	-	-	-	r	r	in	r	In	-
Parks (min area)	0.6	in	0.5	in	0,5	r	-	-	-	r	r	in	r	In	-
Utilities (min area)	0.6	in	r	in	in	r	-	-	-	r	r	in	r	In	-
Telecommunications (min area)	0.6	-	-	-	-	r	-	-	-	-	-	in	-	In	-

Buildings: 1-footprints, 2-roofs, 3-roof facets, 4-chimneys, 5-floors, 6-rooms, 7-room elements, 8-facades, 9-height

Streets: 1-pedestrian areas, 2-car tracks, 3-gardens

r – on request; in – instructions

Table 5: Visualization: 3D preferences

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Dimensions	3	1	1	3	3	3	3	1,2,3	3	3	1,2,3	2	1	1	1
Screens	✓	✓	✓	-	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Methods	1,3	1	1,2,3	1,2	1	1,2,3	1,3	1,2	1	1	1	1,2	1,2	1	1
Photo texture	✓	✓	-	-	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Texture instead of geometry	✓	✓	-	-	✓	✓	-	✓	✓	✓	-	-	✓	✓	✓
Sources	1,2,3	1,2,3	-	-	2	1,2,3	1,3	1,2,3	1	1	1,2	1	1,2,3	1	1
Software	1	2,3	4	5	1	1,5	-	1,5	1	1	-	1,5	1	1	-
Different resolution	✓	✓	✓	-	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Preferable dimensions: 1-2D, 2-3D, 3-both

Screen spiting with several views: ✓ yes, -no

Methods for geometry display: 1-frame, 2-shading, 3-photo texture
Utilization of photo texture:✓ yes,-no
Available source images for photo textures : 1-aerial, 2-terrestrial, 3-conventional camera
Known software for texture mapping: 1-3D Studio, 2-VRML, 3-OpenGL, 4-ArcView, 5-Others
Possibility to visualize geometry with texture: ✓ yes, -no
Necessity of different resolution: ✓ yes, -no

Table 6: Interaction: 2D, 2.5D

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Elements	1,2,3	1,2,3	1,2,3	1,2,3	1,2, 3	3,4	1,2,4	1,2,3	1,2, 3	1,2,3	1,2,3	1,2,3	1,2,3	1,2	1.2
Updating	1,2	1,2,3	1	2,3	1	3	2,3	1,2	2,3	2	2	2	2,3	1,2	2,3
Means for manipulation	1,2	1,2	1	1	1	1	1,2	1	1	1	1,2	1	1,2	1,2	1
Preferable environment	1	1	1	1	1	1,2	1	1	1	1	1,3	1	2,3	1	1

Mostly manipulated elements: 1-points, 2-lines, 3-faces, 4-bodies
Current manner of updating: 1-automatic, 2-semiautomatic, 3-manual
Means for manipulation: 1-mouse, 2-keyboard, 3-other (what)
Preferable visualization methods for manipulation: 1-wire frame, 2-shaded, 3-textured

Table 7: Symbolization: 3D

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Geometric domain	✓	✓	-	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Thematic domain	✓	✓	-	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	✓
Geodetic network	✓	✓	-	r	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	✓
Utilities	✓	✓	-	r	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	✓
Transport network	✓	✓	-	r	✓	✓	-	✓	✓	✓	-	-	✓	✓	✓
Information signs	✓	✓	-	r	✓	✓	-	✓	✓	✓	✓	✓	✓	✓	✓
Signs on public buildings	✓	✓	-	r	✓	✓	-	✓	✓	✓	-	✓	✓	✓	✓
Others	i	-	-	r	✓	✓	-	✓	✓	✓	-	✓	✓	r	✓

✓ yes, -no, r- on request, i -instructions