Architectural, Urban Digital Design and Spatial Simulation Tools in Digital Cities Cartography: Contribution in Spatial Design and Perception

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Abstract

The need of the ever-evolving modern society for a holistic approach to the description and understanding of space, is one of the main reasons that the tools of digital architectural, urban design and spatial simulation penetrate more and more in the field of digital cartography forming core theoretical and practical study. The simulation architecture town planning and urban environment through digital cities offer a high degree of information analysis and presentation of data by creating a modern structure and complexity in multimedia digital cartography. The scope of this study is the analysis of use of penetration and influence of architectural urban design and simulation of digital tools in Digital Cartography through analysis and categorization of digital mapping in digital cities on the Internet (architectural, town planning, thematic, multimedia, scenarios, etc.). The work deals with the contribution of these custom tools in Digital Cartography, in urban and spatial planning and the impact on the spatial perception and analysis.

Keywords: Digital cities cartography, Digital design, Spatial simulation, CAD, Digital tools contribution

1. Introduction

Tools and methodologies for the design and architecture of digital spatial simulation become necessary today for the analysis and presentation of the space. The rapid technological development and the number of processed information have developed new technologies that adapt number of tools and scientific sectors. Thus, the technological convergence of computing, telecommunications, telematics and GIS facilitate the integration of these technologies, which are components of the digital city (Couclelis, 2004). In recent years the integration and the combination of all of these technologies has created conditions for creation of websites through interactive 3D digital multimedia mapping for tourist, social, cultural, scientific and other purposes. Smaller-scale tools such as those of architectural digital design, image synthesis, animation, interactive multimedia data representation, virtual reality, photo editing, etc, are now not only complementary tools of basic tools to create digital cartography such as GIS, but increasingly essential components of digital mapping creation and analysis.

Three basic categories of digital cities exist on the Internet: (a) The “mirror cities” that use maps of cities or buildings simulating the physical area of a city through panorama visualizations, interactive maps, real-time cameras, photographs of various dimensions, thus providing greater accuracy and realism. (Dodge et al., 1997), (b) The “tool cities”, using computer tools for the transfer of functions of the city into the digital space, offering a range of tools and services. (Tarani, 2006) and (c) The “portal cities” that use Internet pages with on-line guides, lists, images, graphics, texts, hypertexts for advertising reasons (Bogenberger et al., 2003) (Fig 1).

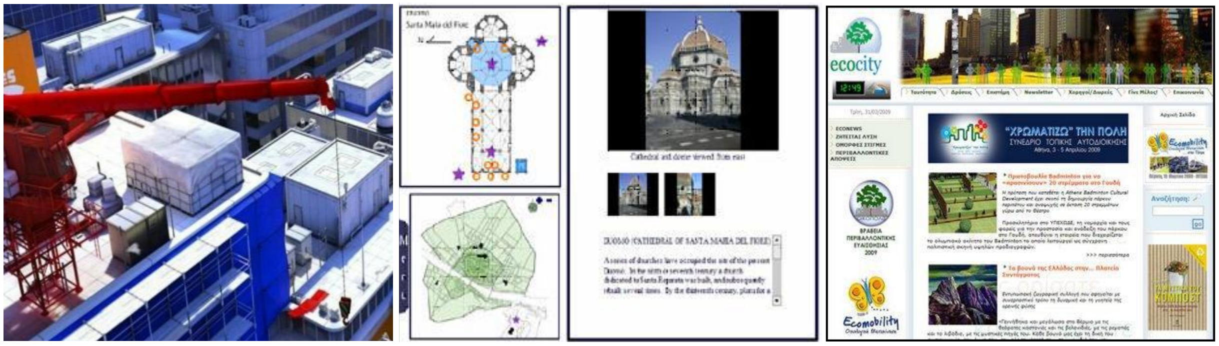

Figure 1: Examples of digital cities classification: Mirror city – Berlin (left) (Berlin home page, 2009), Tool city – Florence (middle) (Hopkins, 2006), Portal city – Korinthos (right) (korinthos, 2009).

Multiple scientific terms have been used for the characterization of digital cities, among other things: virtual city (Martin, 1978), information city (Castells, 1989), invisible city (Batty, 1990), wired city (Dutton et al., 1987), telicity/teletopia (Fathy, 1991), intelligent city (Laterasse, 1992), city in the electronic age (Harris, 1987) cybercity (Gipson, 1984) (Batten, 1995), (Campagna & De Montis, 2001) (Atkinson, 1998), etc. The term virtual city is directly related to systems, methodologies and ways of digital simulation and design. It is widely used in the World Wide Web (www) to describe an area of diverse information, environment and content as an environment that conveys information and services on the Internet. “It provides online database services, activities, information, and users in a single location on your computer as well as the actual cities are a focus in the geographical area” (Dodge et al., 1997). This term could refer to digital, non-existing production environments such as those established in the context of an electronic game (Simcity, Alphaville) (Long, 2007) a movie or a research application. However, the virtual city is information on the Internet which is planned from experts on the urban planning or on the Internet in order to present a real physical space (Atkinson, 1998). This paper discusses the type, the structure and the way of representing digital maps to digital cities with emphasis on systems design techniques and digital methods, simulation and representation information of maps and how these processes affect the spatial design and concept without an in-depth analysis of the mapping accuracy and the cartographical methods nor of the scientific data resulting from this.

The task in the next chapter presents a brief historical background and evolution of digital simulation methods and, to some extent, of Digital Cartography and continues with thoughts and discussions about digital mapping (modern techniques, readability, web cartographic data problems, perception, presentation and publishing methods, etc). Next, it continues with representations of maps to digital cities with relevant examples on the Internet and ends with reflections contribution and influence of digital design and spatial simulation tools used on digital Internet cities cartography in the spatial design and perception through a theoretical and practical approach of questionnaire procedure.

2. Digital methods of design, simulation and digital mapping: A brief historical overview and evolution

In the mid 1940s, the pioneers Turing and von Neumann predicted that computers will revolt in science while Vannevar Bush foresaw the development of multimedia (Batty, 1995). "By 2050, everything around us would have been a form of computing" (Batty, 1995). Software such as SYMUV, CALFORM and SYMAP were among the first software used for managing spatial data and the preparation of maps (Fung et al., 2004). The development of cartography was accompanied by the parallel evolution of computers and the multimedia, which were introduced in digital cartography. In 1976, Hurrion conceived and applied the term "Visual Interactive Simulation” which influenced deeply the visualizations, pointing out that the difference of simulations of the animation is that in the first one there is interaction with the user and not mere illustration (Bell & O'Keefe, 1987). In the early 1980s, CAD (Computer Aided Design) systems were developed; these systems, which were part of computing systems technology, aimed at strengthening the realisation of projects enabling the user to design in graphical environment (Sendler & Wawer, 2008). Initially the software for these systems was developed with languages such as FORTRAN, but in the late 1980s, rapid development has provided the possibility for use in personal computers (Panagiotopoulos et al., 2001).

Within this period the development of geographical information systems (GIS) and information technology, opened a new road in cartography, providing new design tools, greater flexibility and greater focus on spatial database. While the number of digital maps grew, they began to incorporate other instruments such as images, video, sound, animation since 1986 with Apple and INTEL processors with the graphical interface of Windows shortly afterward, where the real history of multimedia began. Since the early 1990s, new algorithms have stored and efficiently retrieved digitized map images (Southarda, 1992). GIS have given its users the ability to edit and select data on maps while the Internet established their universal use. The improvement and introduction of GIS offered high-resolution mapping, visualization and online interactive maps to design space (Batty, 1995). This dynamic visualization has the authority for further investigation in mapping with animation. In the early 90s, when the first steps in digital cartography and the simultaneous introduction of multimedia appeared, scientists, such as Andries Van Dam (Hypertext Intermedia), Randy Trigg and Tom Moran (Notecards), Ben Shneiderman (TIES), and Bill Atkinson (Hypercard) (Cartwright, 2007), have developed various tools and software that contributed actively in the development of computer systems and multimedia applications (Pantano Rokou, 2002).

The instruments used were black and white text, graphics, cartographic images and animation. In the middle of the past decade, the development of all these tools resulted in the introduction of virtual reality technology in regional planning and GIS, which led to the creation of Virtual Geographic Environment (VGE) allowing users to query, navigate and model the space (Fung et al., 2004). Virtual reality was a new language in the area of computing and design, more precisely simultaneously combining a layer text, 2D or 3D graphics, and geographic information. In 1996, the E.U. launched a four-year program of European digital cities (EDC) under the auspices of the Telematics Programme (Mino, 2000). Then, in 1997, the digital cities began to experiment on three-dimensional virtual reality level in an effort to attract other users and stay fully competitive on the Internet online market (Beckers & Van den Besselaar, 1998). In 2000 decade, multimedia, virtual reality, the speed of the Internet, the development of computer systems and telecommunications, have created a digital city-social information infrastructure (Van den Besselaar et al., 2002), where the complexity and the resourcefulness of digital mapping enables processing of vector and raster data in OpenData Environment with interactive elaboration from multiple users who are primarily interested in accessing information in rain, timely and concise way.

3. Digital cartography: Thoughts, debates

New web mapping technologies over the last decade bring innovate cartographic techniques by using plethora of geographic data. Many applications and developers build complex mapping applications, consuming data from multiple sources, using contemporary technologies and making the result publically available. Technologies as telecommunications, multimedia and augmented reality, make their entrance to digital cartography dynamically. Despite the increasing availability of various forms of digital maps and guides, the paper still prevails today as the main information medium used by tourists during city visits; recent technologies for digitally augmented paper maps can be used to develop interactive paper maps that provide value-added services for tourists through digital overlays (Moira Norrie & Beat Signer, 2005). Innovated tools, such as dynamic programming environments, adequally adapted and recommended by the World Wide Web (e.g. eXtensible Markup Languag – XML) facilitate, among other operations, the sharing of structured data across different information systems, encode documents and serialize data (Bray et al., 2006). Many applications for dissemination and presentation of digitized information on the Web have been developed. Applications interfaces for information introduction, web query allowing to users to search, consult and make changes in real-time (Gomez & Gonzales, 2008).

However with the advantages of the digital cartography there are many problems to be solved due to the representation, publishing methods, human perception and readability, etc. The representation of cartographic typology corresponding to different levels of accuracy and details such as DTM and city modelling require very advanced and outstanding techniques, such as digital photogrammetry, laser scanning, DTM adaptation and terrestrial survey. However, many problems still remain in relation to significant modelling three-dimensional data of architectural characteristics and natural 3D space of geographic area object of the survey, their management in complex databases (GIS 3D) and transmission and use of the cartographic data elaborated in the web service (Adami & Guerra, 2006).

The plethora of data information cartography in web services recommend advanced publishing methods which must fulfill many requirements such as: (α) fast and comfortable viewers available, (b) Maximum integration of published maps with existing systems (e.g. GIS software), (c) presentation in 3D viewers such as Google Earth, Microsoft Virtual Earth, NASA WorldWind should be possible, (d) Libraries and archives should be able to publish raster maps without the need to install and configure new software or hardware systems, (e) the whole publishing process should use more existing Open-Source tools with expandable and open solution and not depend on one product or one company, (f) the necessary software tools need to be available for a reasonable price or preferably for free (Přidal & Žabička, 2008). Another vital problem, which is not technical and depends on human perception and cognition and concerns the study of maps, is the readability of originally analogical maps when they are transformed into digital copies.

There are many discussions on the criteria by which one reads a digital rendition of an analogical work of a complex cartography which involves information such as orientation, distances, areas, scale, meaning of contour lines, etc. The complexity of an issue that involves: (a) technology during the production, distribution and employing of the map, (b) administrative and legal matters concerning the protection of intellectual copyright, (c) cultural and political questions in access and limitation definitions of the information and finally (d) processes of human perception and cognition (Falchetta, 2006) makes this issue extremely difficult or almost impossible to study, analyse and present in an complete and holistic way. Maps on the internet and especially in digital cities are represented very often only with graphical elements and no explicit information about the map's scale, extension, etc. Nevertheless, humans are able to (a) extract this information and interpret maps by distinguishing areas only by looking at the object geometry, (b) identify and group similar maps, and (c) identify the type, scale and extension of the map under certain conditions (Walter & Luoa, 2011).

In any case, taking into account the advantages of the cyber cartography and the problems to be resolved, its potential to combine multiple media, art, technologies, and perspectives into maps is very important. Informing map-users of the constructed dimension of maps is particularly vital given the exponential production of digital maps via the Internet (Caquarda & Taylor, 2005).

4. Representation cartography in digital cities

4.1 Digital cartography and data base

The representation and the types of digital cartography in digital cities on the Internet leads to a basic categorization of these cities in relation to (a) simulation of maps with databases providing data on spatial and urban planning interest for further analysis of the region by competent bodies and (b) simulation of maps without databases showing the space for serving mainly tourist purposes, seeking display points of digital cities with intense tourist interest to the public, as well as presentation of service operations of the local community. Therefore, displayed maps vary based on the architecture of the region, according to the reference levels (2D, 2.5D, 3D, virtual reality), thematic maps showing city data, maps with data graphics, maps of estimates – scenarios that depict the city on the basis of forecasts for future proposals – rehabilitation and scenarios envisaged during the construction phase of the proposed projects or after implementation of the proposals (Fig. 2).

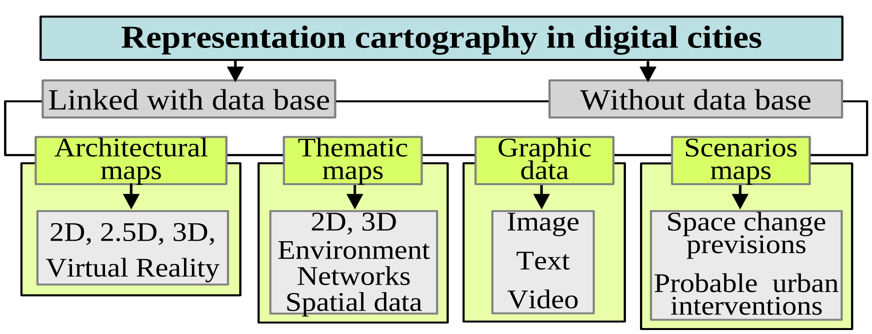

Figure 2: Diagram showing applications of simulation methods in digital cities

The enrichment of a virtual city model with data which is associated with geographical locations and points of space is one of the most modern information tools that contribute to a better perception of space and tourist promotion. A spatial database stores objects described by the spatial characteristics in a multi-dimensional space. The information stored can be associated either with two-dimensional spatial attributes such as roads, municipal boundaries, lakes etc., or with 3D features such as meteorological data (Elmasri & Navathe, 1998). Based on a bibliographic and Web-based survey conducted, it was observed that most Internet cities are "Golden guides" which provide descriptive or cartographic information for city services (police, pharmacies, shops, etc) or corresponding information for areas or buildings of particular importance serving mainly tourist requirements.

The simulation of digital cities and digital cartography with lack of databases is the most frequent form of graphic representation and descriptive data for spatial and urban planning interest. Typically network cities with lack of databases from the overall presentation and in particular from the digital cartography are addressed primarily to bodies aimed at tourist viewing and less at collecting data for further scientific analysis of the region. The combination of physical model with steadfastness of databases would be ideal but is still at experimental level due to the large amount of data that require high Internet speeds and advanced technological systems. The number of displayable data categorized by the level of detail (LOD), as well as by the type of items that are entered (e.g., economic, social, environmental, historical, etc.) as shown in the following representative examples of digital space.

The following are representative examples of digital cities in both categories in order to make clear their distinction related to the input data, the exported results and the digital simulation and design approach. The choice of towns took place after extensive bibliographical and online research of the digital space, on the basis of more representative presentation, description and technical analysis tools and their results through digital mapping as well as contribution and impact on spatial planning and concept.

4.2 Architectural maps

The term describes the presentation of cartographic data in digital cities based on their different architectural scale of design. Depending on the level of detail and design digital cities simulate the world with great diversity. In digital space, it is rare to find cities which use all the three levels (2D, 2, 5 d, 3D) and virtual reality functions to represent them because these are applications that require large computational power and lightning-fast Internet connection. Most cities that are accompanied with databases showing one of the existing levels or a combination of two and three dimensions, while rarely online digital cities have individual vector maps, urban planning, town planning or aero-photographic maps without databases.

The digital city of Prague which is the capital of the Czech Republic, is a typical example 2D simulation with mapping databases. Google map gives the possibility to navigate in vector map, satellite image and hybrid that combines the two most previous information on selected coordinates (longitude and latitude) (Visitprague, 2008). The specific application uses technology Google map with ability to create maps using ready-made software (e.g. Google map maker, GPS visualizer, etc) or by using the programming language (e.g. JavaScript, XML). Creating maps enables finding coordinates, adding point, linear and surface topology as in CAD and GIS systems, as well as enriching embeded photos and videos with html language. The possibility of also exchanging digital information content via "Really Simple Syndication" method (RSS) offers updates with full geodata, metadata, etc. In addition, this 2D mapping allows you to import files KML which is a file format used to display geographic data and vector CAD features in an Earth browser such as Google Earth (Fig. 3). The 2D digital mapping allows the direct access to the desired spatial information, while the ability of change scale and different cartographic visualization maximizes the spatial conception of the user.

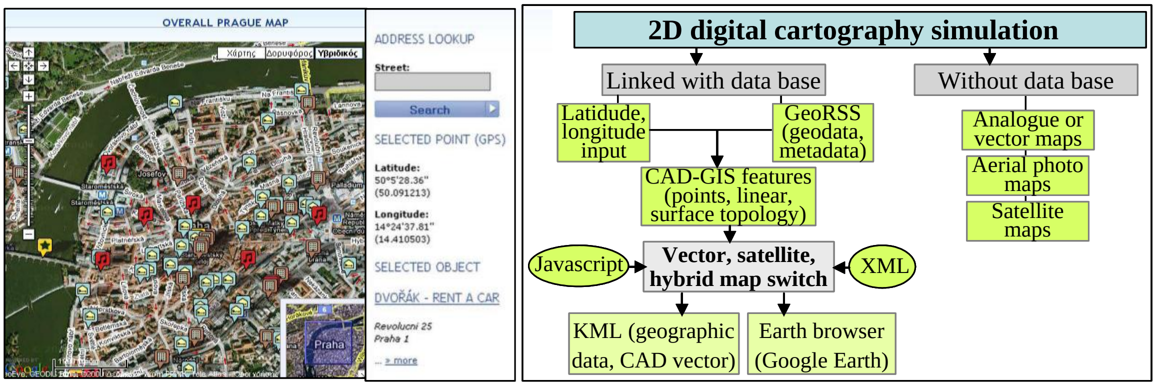

Figure 3: Hybrid map of Prague with autofocus function (left). Schematic process of 2D digital cartography simulation (right).

The informal term "2.5 D" is used to describe models while in reality it is 2D, using various techniques like 3D and called pseudo 3D. A typical example of such mapping digital city without database but with interactive programming is Tallinn of Estonia which stands out for the aesthetics of "user-interface" of the website of the area via virtual tour with panoramic images and spatial organization of points of interest with descriptive information (Fig. 4) (Tallinn, 2009). This digital mapping enables the use of interactive access to optics and descriptive information through virtual tour to major attractions with a direct spatial reference without focusing on map accuracy and cartographic data analysis. The 2.5 D digital multimedia simulation-type mapping uses multimedia platforms only to link and not to include databases (eg. Flash, Director, etc) in order to organize multimedia materials (e.g. text, images, videos, panoramas, etc) in conjunction with vector maps application results with digital accuracy and rendered CAD models. The cartographical background comes from either georeferenced satellite image or design CAD system or even from art design Desktop Publishing (DTP) system without the required, intentional map accuracy, etc. The multimedia platform is widely used for simulation, presentation of architectural and urban space and interactive web applications. It also allow you to connect any multimedia content in databases using programming language (eg, ActionScript, JavaScript) and creating applications in PDA, mobile phones, etc. (Fig. 4).

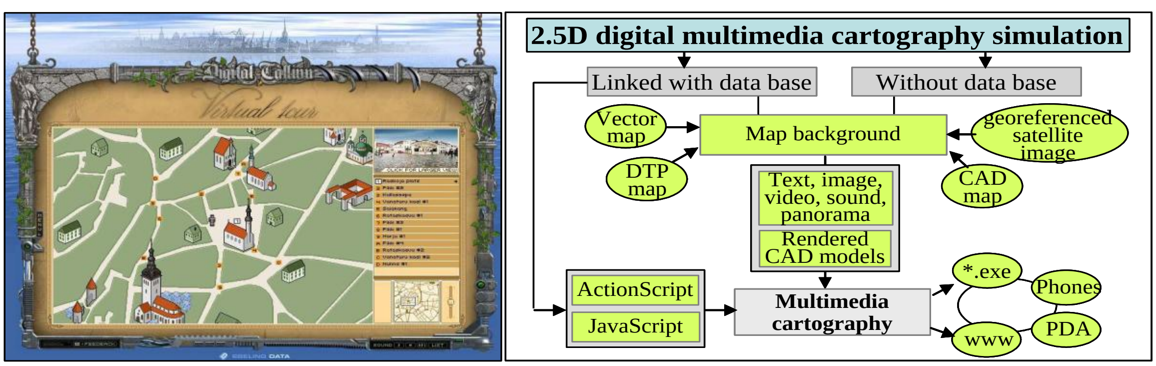

Figure 4: Interactive virtual tour map of historic center of Tallinn (left). Schematic process of 2.5D digital multimedia cartography simulation (right).

In recent years many examples of 3D digital mapping using 3D photorealistic models and virtual reality environments bloom on the Internet with impressive 3D platforms with or without databases. The application "3D Paris" combines a three-dimensional photorealistic city model based on cartography of satellite images with a gold operations guide (Paris, 2009) (Fig. 5). Designers of application is the company Cyber city 3D, an innovative enterprise modelling three-dimensional geospatial data that specializes in the production, analysis and visualization of reality through the creation of 3D models and subsequent publication on the Internet (CyberCity, 2009). For the three-dimensional model were more than 75,000 buildings with navigation capability in 2000 registered items of interest by typing location coordinates, site name, you can browse to photorealistic models in 360 degrees. The digital cities of Berlin (Berlin, 2007) and London (CASA, 2009) provide an integrated photorealistic 3D model based on high-resolution satellite images taking advantage of CAD and rendering techniques, GIS and photogrammetry through Google Earth without being supported by the database.

Nevertheless, for the creation of the model in the city of Berlin, aerial photographs of 500,000 buildings were taken on an area 890 km2 with scanning laser technology roofing and completing touring in 80 major tourist destinations. In virtual London, ways of user access and his/her virtual tour as Avatar in online participation were licensed; this participation was mainly for professional use from engineers, planners and researchers and it also concerned citizen participation in online consultation procedures (Fig. 5). The city of Philadelphia “Virtual Philadelphia” designed by the company GeoSim Philly (GeoSimPHILLY, 2009) is one of the few examples of Internet digital cities applying virtual reality features while you enter data into a pre-existing base. The application allows complete realistic simulation of the city and provides virtual tours, 2D and 3D interactive maps, local search services, future town planning view, on-line communication and markets, etc. (Fig. 5). The applications of digital 3D cities provide an innovative 3D digital mapping that approximates very realistically the actual physical space from different angles (view realistic navigation, floor plans, facades, etc.). The 3D virtual reality and digital type mapping with or without databases utilize modern techniques of remote sensing, geoinformatics, high-precision photogrammetry measurements, (10-15cm), 3D CAD systems modelling, rendering and image synthesis technologies, GIS, into multi-user production multimedia customized environment supported by programming development usually in C, Java and SQL language.

In essence it is a 3D-modeling solution optimized for effective production of large-scale 3D-city models with complex integration of ground-based aerial orthomaps photography and satellite images with auxiliary 3D data (e.g. architectural details, elevations, urban and statistical features, etc). The 3D-polylines models very often derived from 1:6000 scale base on aerial and stereo-pairs photography with an accurate modelling process in a CAD environment. The 3D specific geo-referenced models geometry is rendered by materials textures or photographic textures derived from aerial, laser scanning and street-level photographs in a CAD or rendered environment. A data processing using SQL language or adequate statistics, database, GIS and spreadsheet software involves, among others, vectors rates, elevations, distances, different qualitative and quantitative data as well as intricate data of image processing (Fig. 5).

The type of 3D digital virtual reality multimedia-cartographic modelling enables a user realistic spatial concept, a combination of free access to information with spatial data and spatial reference while creating vector models with photorealistic visualization and database let you retrieve and analyze data (e.g., measure distances, heights, etc.) to professional, scientific and research purposes (e.g. adaptation of architectural and urban studies, planning studies, comparison and analysis of spatial and statistical data, forecast scenarios, public consultation proposals and land strategies, adjustment scenarios, policy-space, etc).

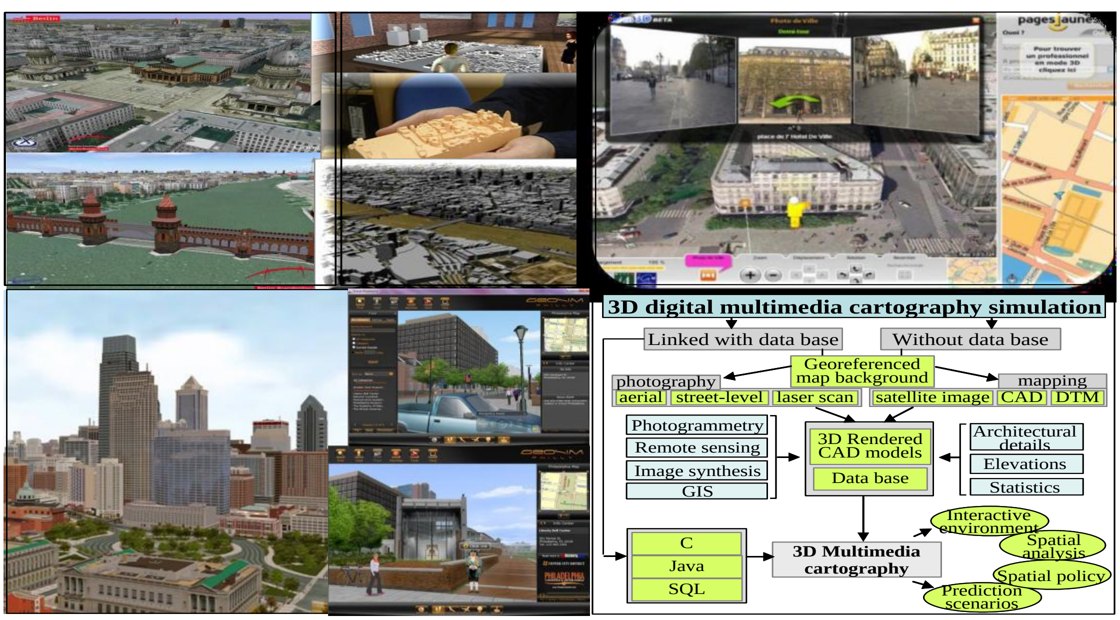

Figure 5: 3D model of Berlin city in Google Earth environment and virtual London project with avatars navigation (up-left). 3D model of Paris with avatars and yellow pages search of interesting points (up-right). Virtual city of Philadelphia with research functions (down-left).). Schematic process of 3D multimedia cartography simulation (down-right).

4.3 Thematic maps

Thematic maps are a key tool in 2D representation of digital cities and depict themes defined geographical area enabling visualization of natural, social, political, cultural, economic, sociological and other aspects of the urban fabric, state, region, etc. (Washington, 2008). A typical example is the city of Miami, where 2D digital thematic mapping with database, relates, inter alia, through existing and future land use, flood zones, initial zoning areas, special protected areas, etc. (Miami, 2004) (Fig 6) with additional operations such as customizing map representation, transfer to selected address, real estate assessment functions, etc. This kind of applications is based on an SQL server database which supports a data warehouse of vector layers, raster, property, style and views data. The editing of the database is maintained on a regular basis via extraction – transformation - modelBuilder batches routines which create or update spatial layers which are readily available via desktop and web-based applications. Bibliographical research notes lack of digital cities with 3D cartographic thematic data simulation. In a “3D Geneva” digital city project, whose aim was the involvement of users in available GIS geographic data, six areas were studied such as: (a) architecture, Urbanism and space design, (b) urban transport (cars, trains, planes), (c) environment and energy, (d) walks and biking, (e) security and emergency management and (f) territorial Information (Carneiro, 2008). For the construction of models and thematic noise maps (volume representation with colours on facades of buildings), environment and energy (daily sun exposure with corresponding colorization per hours of exposure) multiple data were used, such as 2D vector data, 2.5 D graphics data, elevation buildings data, terrain information, orthophotographs and satellite territorial images (Fig 6).

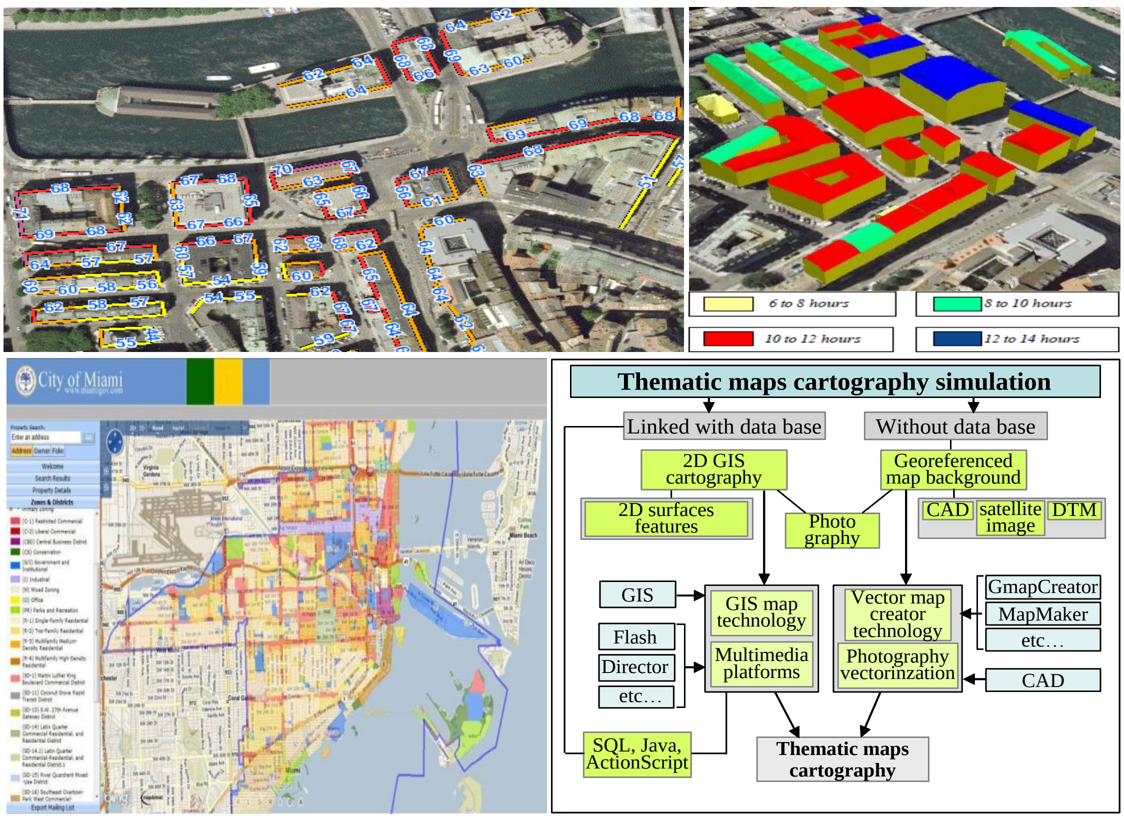

Figure 6: Examples of 2D traffic noise pollution simulation (up-left), and daily sun exposure 3D modeling on roof buildings (up-right) in Genova. Thematic map of Miami city with actual zoning visualization (down-left). Schematic process of thematic maps cartography simulation (down-right).

Construction and display of thematic maps in the context of the digital city will not allow only viewing but also managing and analyzing problems such as noise pollution of urban transport and intensity of sunshine for photovoltaic future investment (Carneiro, 2008). Most digital cities on the Internet use vector or 2D aerial maps with databases for the representation of the city, finding addresses, information on existing road network, etc. Rarest, digital online cities present their vector, urban or planning map with lack of databases such as the city of Vienna through GmapCreator technology (Vienna, 2007).

4.4 Maps of graphical data

The graphics data is perhaps the most common way of representing urban and spatial network. Digital cities widely use various types of graphic data in order to be promoted, such as pictures, panoramas, diagrams etc. Often this graphics data comprises maps incorporating 3D city models with graphical information such as the example of virtual Canberra which stands out for its innovative user interface of the 3D model of the city (Canberra, 2009) (Fig. 7). The 3D graphical map area of 3,811 hectares enables an attractive and easy access to spatial and descriptive information (interactive panoramas with automatic sliding towards the direction of movement, update of the 3D model, reviews, tips, photos, change scale, etc).

Digital mapping with graphical data allows a minimalist graphic design of major points of interest in avoiding cartographical features or accuracy which cause confusion of spatial perception. For creating maps with data graphics, multimedia applications are mainly used, such as Flash, Director, etc., which allow not only the autonomous design and interaction of objects and information but also permit inserting objects generating from the application tools of architectural, urban design and spatial digital simulation, such as CAD, GIS, vector and pixel information, special edited images, etc. Usually the background of graphical data on maps consists of no georeferenced 3D or 2D rendered images from CAD and image synthesis systems. In rarer cases, the background is aerial photograph, satellite image or even 2D vector graphics

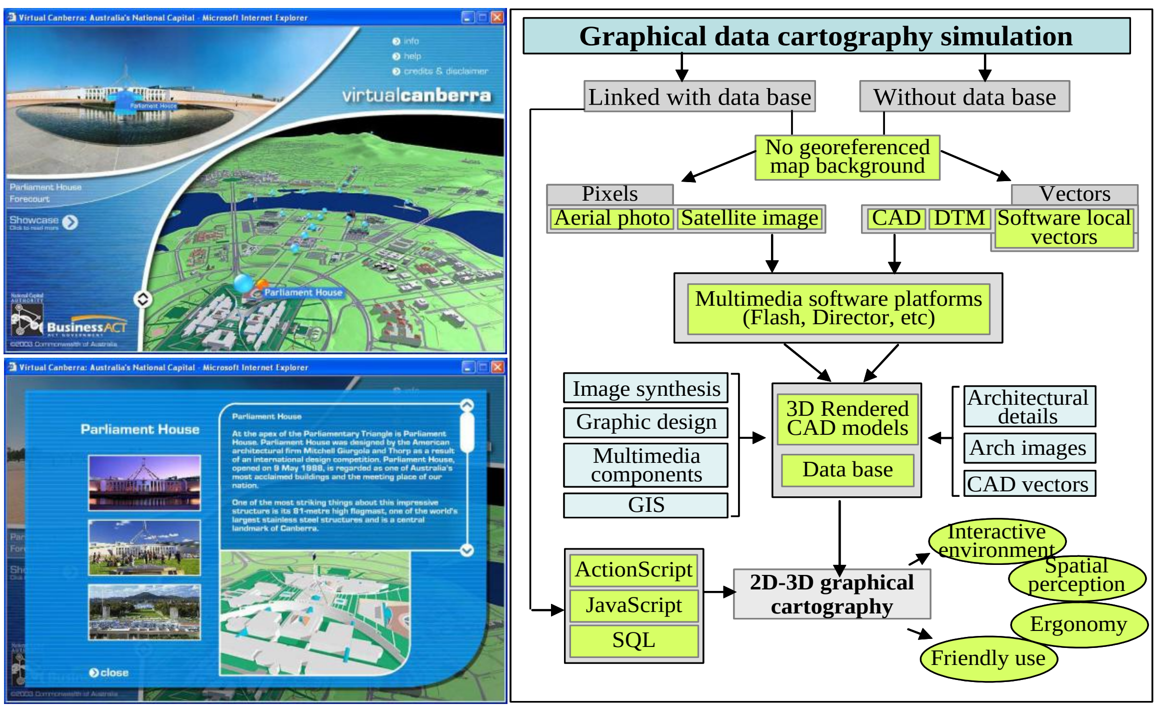

Figure 7: 3D cartography simulation with graphical data of Canberra city with labeling points interest (left). Schematic process of graphical data cartography simulation (right).

created by multimedia platform type Flash, Director, etc. The enrichment and the creation of graphical cartography is implemented through the introduction of multimedia components (eg. hypertexts, video, images, sound, animation, etc) with links, architectural details, GIS features and organized in a way that the derived graphic renders the map particularly sharp, comprehensible, and ergonomic. Import database using mainly on embedded multimedia platforms, programming languages, such as ActionScript, JavaScript, etc with the help of programming object components (Fig 7). The use of colour, the hospitality function, ergonomics, aesthetics, contact user-server feature, the information search through database and the clear goal, create sharper relation of volumes, distances and dimensions, directly assisting in the overall perception of space and making it so such virtual spatial environment suitable for consultation proposals with a wide audience.

4.5 Scenario – prediction maps

Scenario - prediction maps are associated with the representation of data in digital space depicting future interventions in the urban fabric or possible scenarios for the impact of these proposals during the implementation phase. The website of Barcelona presents the typical “portal” form of digital cities, but the virtual presentation of the city is a dynamic geographical application with actual experience digital flight (Geoshow 3D), (Barcelona, 2005) (Fig 8). The cartographical background city consists of three layers whose appearance is manageable: (a) the Digital Terrain Model (DTM), (b) the basic mapping with aerial photos of the city and (c) thematic cartography of urban fabric and filled with digital representations of future proposals, relevant actors or under construction projects. The realistic superimposed mapping with parallel information cartographic accuracy data (e.g. latitude and longitude, altitude, azimuth, inclination, flight speed, taking pictures, etc.) and the combination of database with the function of finding and retrieving data makes this mapping an important tool for the understanding and simulation of space.

The study for the city of Stuttgart was held under a programme known as VEPs (Virtual Environmental Planning Project), which was aimed at an alternative approach to the design process without the existence of active databases, combining 2D and 3D simulations, while allowing the public to observe and comment on the developments and changes in the urban fabric through a tour of the city in three dimensions (Richman & Boghdan, 2008). The project “Stuggart 21” includes basic buildings 3D modelling, 2D multimedia maps with hyperlinks to text and image data, environmental 3D models with rates data of noise and flood simulations during the elaboration phase tasks with online tools for user participation in design decisions (Fig 8).

These simulations are based on statistical weather information (wind), traffic estimates, traffic rails forecasts, historic data overflow of rivers and flood areas, flood risk maps, etc. The objective of this approach is to encourage the public to understand the environmental impact of design decisions on areas in which changes and rehabilitations will occur (Boghdan & Richman, 2008). A typical example of digital city with integrated maps forecast is the city of Detroit in Michigan that was implemented with the help of, inter alia, the UrbanSim software of the University of Washington (CUSPA, 2008) which is a simulation model for integrated design and analysis of urban development, integrating interactions between land use, transport networks, investments and public policies with environmental, social and economic dimensions and examination, and comparison of multiple scenarios (Waddell et al., 2006). In the context of creating a digital city with the aim of spatial growth projections to 2035, Detroit introduced information transport and land use estimates based on the above software. For this “pilot model”, 132516 buildings, 117408 parcels, 132453 dwellings and 183522 professionals from different specialties were designed and studied. The digital mapping and simulation of the model allows you to export the results of the total number of households and professions as well as the creation of new buildings and demolish older ones (Fig 8).

The approach of the scenarios-prediction maps creation involves the implementation of rich web applications supported by digital 3D models and various concepts and techniques of Web with very often separated components (eg. 3D view, 2D maps, etc) which communicate through Application Programming Interfaces (APIs) based in Windows API or standard template libraries in C++ and Java API language. The connection and communication between datasets and 3D models or quantitative – qualitative rates are managed by different data providers. The flexible data access is very important and vital for the function of such a system; therefore, the use of open standards data such as OGC database is very common. In this kind of cartography standard protocols and interfaces are used in order to allow requests for geographical features across the web and to provide other interfaces for requesting geo-registered map images from one or more distributed geospatial databases such a Web Map Service, Web Feature Service, Web 3D Service, etc.

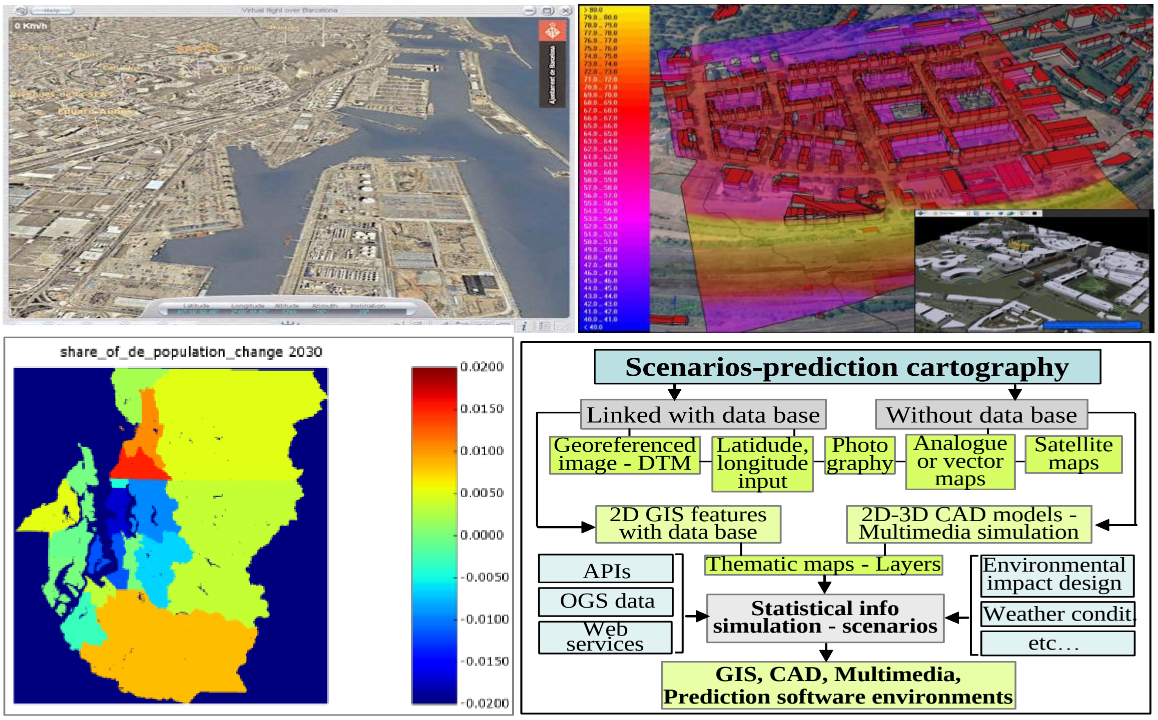

Figure 8: 3D cartography simulation of Barcelona city with superimposed thematic layers background (up-left). Prediction cartography of 3D sound map and 3D innodation animation of Stuttgart city (up-right). Example of UrbanSim indicators (down-lef). Schematic process of scenarios-prediction cartography simulation (down-right).

5. Contribution of architectural and urban simulation cartography to spatial design and perception

5.1 Theoretical approach

The term "urban and planning design" means not only creating physical projects such as a map, but all the phases in the design process of spatial units, which include planning and analysis and presentation with the use of supervisory instruments. Supervisory instruments vary in each case depending on the input data and the desired results. The method of architecture and urban cartographic simulation comes to meet the needs for representation of the provided information using a variety of ways and technologies servicing the requirements of either the actors of the citizens. The present study examines the role and value of cartographic simulation in the design and perception generally of the space and particularly of the digital space, an emerging field of study constantly evolving and placed in a high priority in the context of spatial and urban network study.

The possibility of involvement and adaptation of digital design tools and cartographic simulation during the design conception, intervention or visiting the space, varies and depends significantly on the conception process itself and also on the spatial perception. The architectural and urban design conception or intervention operation is a very complex process whose main actor, the designer, is faced with constraints and specific requirements each time in order to communicate his ideas and propose a "new behaviour" that responds to human needs and at a different level of life at a time. These constraints are imposed by different standards or rules that prevent and determine both the action of the designer. Based on his personal sensitivity, intuitiveness, way of thinking, talent and several individual criteria, the designer filters constraints in his/her own way through a process of design that makes him/her "free" to operate and intervene. He tries to invent through all these requirements and limitations, its "own limits freedom of action" and to extend or define them so that he can “reject” “sort” and “propose”. However, each process adapted by the designer during the design phase of conception must be able to expand or establish precisely “the limits of own freedom of action”. In this spirit, the use of digital tools can contribute to the design conception and process. The use of architectural, urban digital design and spatial simulation tools in digital cartography creation, as part of a help tool to design process or to spatial perception process, requires an essential pre-adaptation so that it influences these processes.

This adaptation depends on (a) the purpose of cartographic simulation, (b) the spatial data to highlight, (c) how to use digital tools, (d) the user's ability to interpret spatial relationships, etc. The design and conception process in its turn requires a critical approach adapted to the use of digital tools even if the designer must "protect" and "adapt" this design process from the requirements of such a use of digital tools (Fig. 9).

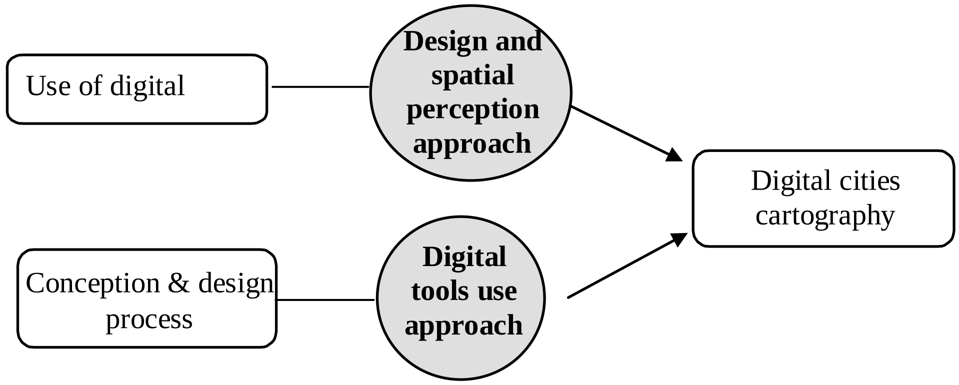

Figure 9: Schematic presentation of approaches to using digital tools and conception design process

Tools of digital design and spatial simulation are incorporated into digital space mapping either for tourist reasons, viewing and simple presentation of spatial units or for reasons of subsequent analyses and participate design based or not on database through a digital architecture-urban, thematic, graphical or scenarios-prediction cartography (Fig. 10).

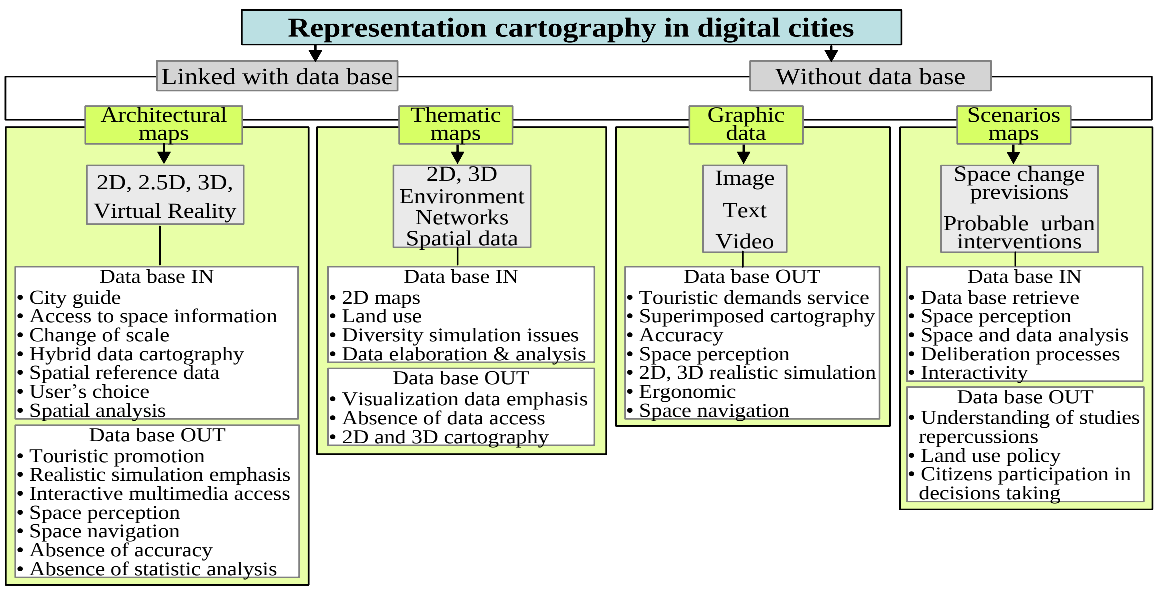

Figure 10: Contribution of digital cities simulation cartography to spatial design and perception according to data base

The first basic classification of digital cities includes cities that simulate the space with techniques for representation of information associated with parts of the city with intense tourist interest and services of the local community. Simulation of this type aims at simple browsing-representation of the city, where the user has the possibility to search and find sites through a posted online database. Concerning the second basic classification of urban simulations, space is represented in dependence on the input data in each case. The purpose of this type of simulation is the provision of data and their representation in such a way that the end user has the ability to use this data for further analyses, for possible corrections and alterations to a virtual environment. This data which forms the object of study of spatial units is related to areas calculations, vector distances illustration, elevations information etc.

Cities in this format, in most cases, provide the tools for user participation in planning, through either publication comments either storage potential interventions. In the scientific field of spatial and urban planning, this new relationship between the special and the general public is the “participate design”.

The development of urban and regional planning towards participate design involves the use of supervisory instruments and supporting mechanisms which would organize how and where to incorporate public opinion. It is clear that the necessary information should be provided to the public with the simplest possible and illustrative way so as to be realistic, clear and detailed. Worth at this point to clarify how approaches the term spatial analysis and how this is accomplished through cartographic applications of spatial simulation. The spatial analysis, in every scale of design, concerns data analysis, part of which is the spatial information in the form of geographical location, proximity, or geometry of spatial entities. It aims at an in-depth knowledge of the structure of the physical, social and economic dimensions of the space and their relations of interdependences. The analysis of spatial units therefore (a) urges the engineer or the user to approach differently the space excluding the limitation that design offers and (b) helps to identify problems, determine causes, sort them in separate dimensions, evaluate, find connections between problems and territorial units, and increase its ability to predict and control events.

Thus, the analysis of space is a complex process which involves people from different scientific fields assuming the study of different types of information that should be synthesized in a comprehensive overall perspective. The correlation of all those items of provided information necessitates the use of all kinds of cartographic simulation for their representation and understanding because processing only with written words even, detailed ones, is impractical. The cartographic simulation gives the possibility of correlation of multiple information and its representation so as to show the spatial dimension. In this way, the export of more complex results is achieved by creating a different, more complete view of the space and the proposed interventions. A typical example of correlation of information is the study of development of a settlement through the representation of the economic and social data such as income distribution or migratory movement respectively, information that can be linked with a geographical reference. Specifically, the display of quantitative and qualitative data mapping is a typical example of simulation for representation and analysis of space. As clearly shown above, the cartographical simulation is not simply an aid, but an important tool for the study and design of the site, an information tool that allows better and comprehensive spatial analysis and representation of data, simultaneously strengthening the participatory nature of the design and contributing to an integrated approach of the space through the view of the virtual and physical environment.

The architectural design representation cartography in two or three dimensions provides the user with realistic representation of space, allowing -in this digital way- a potential visitor to better understand the city. The possibility of this "first visit" varies with the level of detail of the maps and also with all the represented data. Thus, a city that simulates with great accuracy level regardless to its connection with data base creates the impression that the user is interacting with the city (avatar), and cities with little accuracy provide other functionalities such as locating position, advertising operations, etc. The city which is related to data base in architectural scale simulation facilitates the access to space information and reference data, can represent a hybrid data cartography of satellite and urban graphic map with change of scale because of the nature of architectural scale which permits the penetration in spatial entities details. The recovery of data with spatial reference can create different spatial analysis which is not possible when there is no database. In this case, taking into account the easier management of the memory due to the spatial data correlations, a realistic simulation emphasis with space navigation gives the user a more complete space perception which is not mandatory associated with spatial accuracy or statistic analysis. In the case of analog cartography, the perception of the user is limited to 2 graphic dimensions without realistic rendering of the site or link of spatial entities with geographical reference and without the possibility of participatory design, while the design and adaptation of new proposals on existing space do not take into account several parameters such as volume relations, architectural details, aesthetic and functional spatial approach, etc.

The spatial planning process involves much information and species of processing; thus the functional and technological environment must be characterised by flexibility and adaptability to a range of needs and requirements. The simulation cartography in digital cities with thematic maps responds to these requirements. The thematic maps representation cartography allows the user usually a 2D simulation of varied issues permitting data elaboration & analysis in the event of a database, but otherwise the emphasis is on visualization data and rarely in 3D simulation cartography.

The simulation of web-based thematic maps in digital cities can contribute significantly to decision-making on matters arising in relation to activities location with proposed interventions but also consequences during the implementation phase. In addition, data relating to real estate prices can be entered, promoting and facilitating the user – assessor in buy and sell matters. The introduction also of environmental information may contribute to the awareness and strengthen understanding of the user about the environmental impact of design decisions in existing areas situation or in areas where changes occur. Therefore, the thematic maps cartography in digital cities is a tool for communication among scientists and between them and citizens.

Graphics data cartography in digital cities is not supported by database and with the display of photographs, text, diagrams, panorama, multimedia methods etc, it completes and enhances the mapping spatial simulation aiming at a more complete representation of space and its elements. That data is used primarily for reasons of realistic visualization of a town and also as a tourism product to promote. The ergonomic space navigation, the high 2D and 3D realistic simulation, the superimposed cartography of spatial attributes, the accurate targeting of spatial entities to emergence permit a unique space perception. A representative example is the panoramic visualizations for servicing real estate assessment procedures, where external and internal spaces with navigation possibility are presented, through virtual reality functions so that the property can be assessed based on its characteristics and its surroundings.

Finally, the scenarios maps cartography, based or not on databases, enforces (a) participatory design, (b) deliberation processes, (c) interactivity, (d) citizens' participation in decisions taking, (e) space and data analysis, (f) space perception and finally (g) understanding of studies repercussion and land use policy via web interactive multimedia simulation prediction mapping.

Consequently, the contribution of architectural and urban simulation cartography to spatial design and perception appears angled. This cartography is used as (a) a programming tool (e.g. understanding of development, complex factors influencing growth, etc), (b) a decision-making tool (e.g. activities location, land use, environmental data management, etc.), and (c) a planning and space analysis tool in many activities (e.g. commercial applications, educational processes, market research, etc.). These advantages can lead to a reduction of compatibility problems in terms of spatial reasoning approach, and more realistic, innovative and functional interface, through ever-changing technologies, complementing and multiplying the abilities and the thoughts of designers and users.

5.2 Practical approach

5.2.1 Context

In the context of the first and second year studies of the Department of Urban-Regional planning and development engineering of the Aristotle University of Thessaloniki in Greece, the students have attended both introduction courses in architecture and urban design techniques and in computer aided architectural and urban design applying theoretical and practical issues. In traditional design courses, the students relate to both aspects of architectural design such as plans, elevations, sections, topographical solutions, street issues such as urban planning and design, change and adaptation at different spatial scales, suggestions, etc. In digital design courses, an educational process is developed multi-dimensionally in three equally important, related Pedagogical Thematic Entities concerning: (a) theoretical approach and analysis of a global system of digital, architectural and urban design with related parameters, (b) preparation of the model, presentation and knowledge transfer of the adequate software and (c) final modelling and simulation of the architectural and urban space using innovate techniques and integrating results of computational design researches (Kouzeleas, 2011).

5.2.2 Participants

A total of almost seventy student-volunteers (36 students of the first year and 33 students of the second year of studies) aged between 18 and 23 participated in this experiment. These students were asked to answer a series of targeted questions concerning the contribution of the digital environment and the corresponding tools in digital design and spatial perception. The questionnaire aimed at people who have the same small experience on both traditional and digital design so that the data be equitable and the results comparable.

5.2.3 Procedure

The questions concern the advantages and disadvantages of digital design and simulation compared to the corresponding traditional design and focus on six areas: (a) use, ergonomics and interactivity in design environment (b) spatial perception in 2D and 3D, (c) revision, correction and changes of spatial planning and their impacts, (d) conception process of design, (e) analysis of spatial features and data, (f) public participation procedures in design decisions (Table 1). In each question corresponds six statements of response: "No, Equal, A little, Enough, Significantly, Absolutely" and relate the benefits of the digital environment in relation to the traditional-analog one. The level "No" means that the digital is not superior to traditional, while the corresponding levels "A little" to "Absolutely" the superiority of digital is manifest. The questionnaire responses show generally that the digital environment affects both the design and the conception and spatial perception.

	Questionnaire
1	**Use, ergonomy and interactivity in design environment**
a	When you started to design, was it easier for you to design in a digital design environment compared to the analog design environment on paper ?
b	Is the use and navigation in a digital environment of a map easier and more intuitive than with the use & navigation in an analog map ?
c	Do you think that the user interaction with a digital map of the city is more than an analog city map ?
d	Does a complex integrated digital city guide (digital map) advise and help more a user in relation to a corresponding analog integrated city guide map?
2	**Spatial perception in 2D and 3D**
a	Does the 2D simulation of a digital map allow you to understand better space than a 2D analogue map ?
b	Does the 3D simulation of a digital map allow you to understand better space than a 3D analogue map ?
3	**Revision, correction and changes of spatial planning and their impacts**
a	Are the revision, correction elements of spatial planning and the perception of the space after changes easier in a digital simulation environment than the analog?
b	Does the understanding of impacts of changes and interventions in a space become more perceived and visible on a digital simulation environment of space than in an analog environment?
4	**Conception process of design**
a	During the conception process of design, does the digital design and simulation of space help more than conception & design on paper ?
5	**Analysis of spatial feautures and data**
a	Are the analysis of spatial feautures and data more adequate, integrated and complete in a digital map than in an analog map?
6	**Public participation procedures in design decisions**
a	Are the procedures for consultation and public participation in design decisions easier in a digital simulation environment city in relation to the public participation around an analog map?

Table 1: Questionnaire focusing on six areas concerning the contribution of the digital environment and the corresponding tools in digital design and spatial perception.

5.2.4 Results

Starting with the areas that mostly the digital environment affects on the conception and the spatial perception, according to the answers, the opportunity offered by digital cartography for revision, correction and changes of spatial features and perception of their impacts revision, are much greater than the corresponding ability of the traditional map and it is at high levels by 15% to 29% in every high positive statement of response (from “enough” to “absolutely”). The ability to create scenarios and their effects into a digital simulation environment becomes more familiar to the respondents at "Enough" statement by 28% (average in the questions of this area), in relation to the potential changes and corrections which rise at the rate of 22% at "Significantly" statement and 22% at "Absolutely" statement (Table 2) (Fig. 11).

	Questions	No	Equal	A little	Enough	Significantly	Absolutely
1	**Use, ergonomy and interactivity in design environment**						
a	Easier design for beginners	24%	8%	10%	25%	20%	13%
b	Easier and more intuitive use & navigation	4%	10%	6%	23%	29%	29%
c	More user interaction capabilities	6%	17%	4%	19%	34%	21%
d	Fuller orientation by digital city guide	8%	21%	8%	21%	26%	17%
2	**Spatial perception in 2D and 3D**						
a	Space perception in 2D	4%	30%	12%	22%	18%	14%
b	Space perception in 3D		13%	6%	30%	23%	28%
3	**Revision, correction and changes of spatial planning and their impacts**						
a	Easier environment to review, correct, change & understanding	2%	10%	6%	27%	25%	29%
b	Better understanding of scenarios & changes repercussions	8%	26%	4%	28%	19%	15%
4	**Conception process of design**						
a	Help during the design concept	19%	32%	19%	13%	9%	8%
5	**Analysis of spatial feautures and data**						
a	More adequate & complete spatial feautures & data analysis		25%	6%	31%	19%	19%
6	**Public participation procedures in design decisions**						
a	Easier deliberation processes & citizens participation in decisions		17%	17%	26%	21%	19%

Table 2: Responses in pourcentage in six statements on digital environment contribution questionnaire

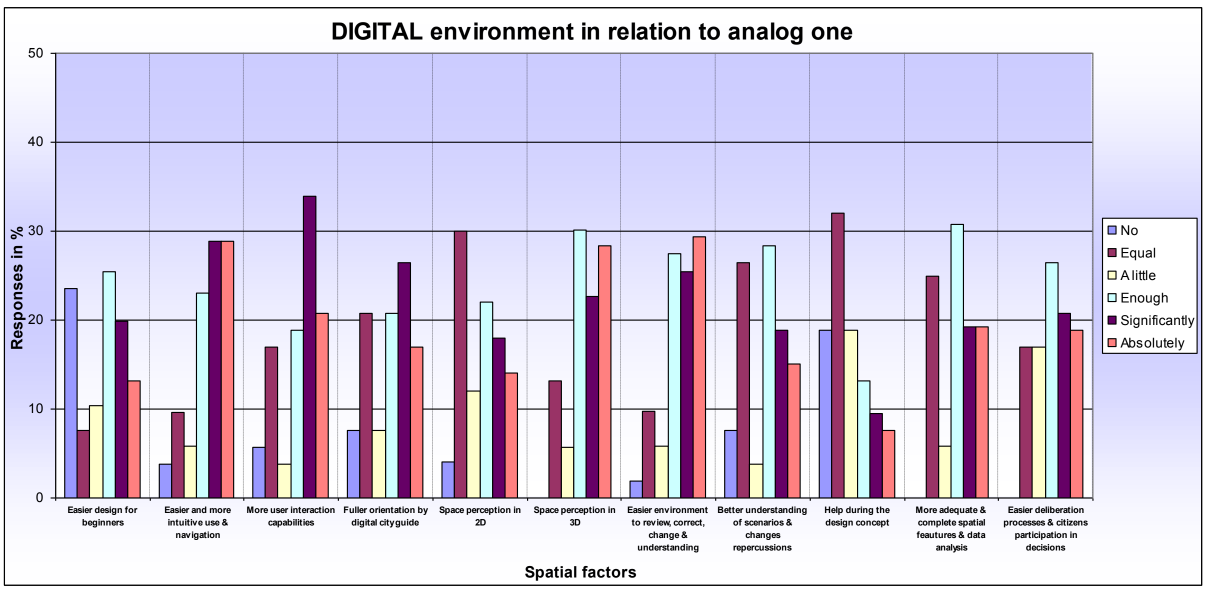

Figure 11: Chart schematic responses results of digital environment contribution to digital design and spatial perception

The average of the positive statements (from "enough" to "absolutely") of the two questions of the above area ("*Easier environment to review, correct, change & understanding*" and "*Better understanding of scenarios & changes repercussions*") is 72% (against 28% of the negative statements from "No" to "A little") (Fig. 12).

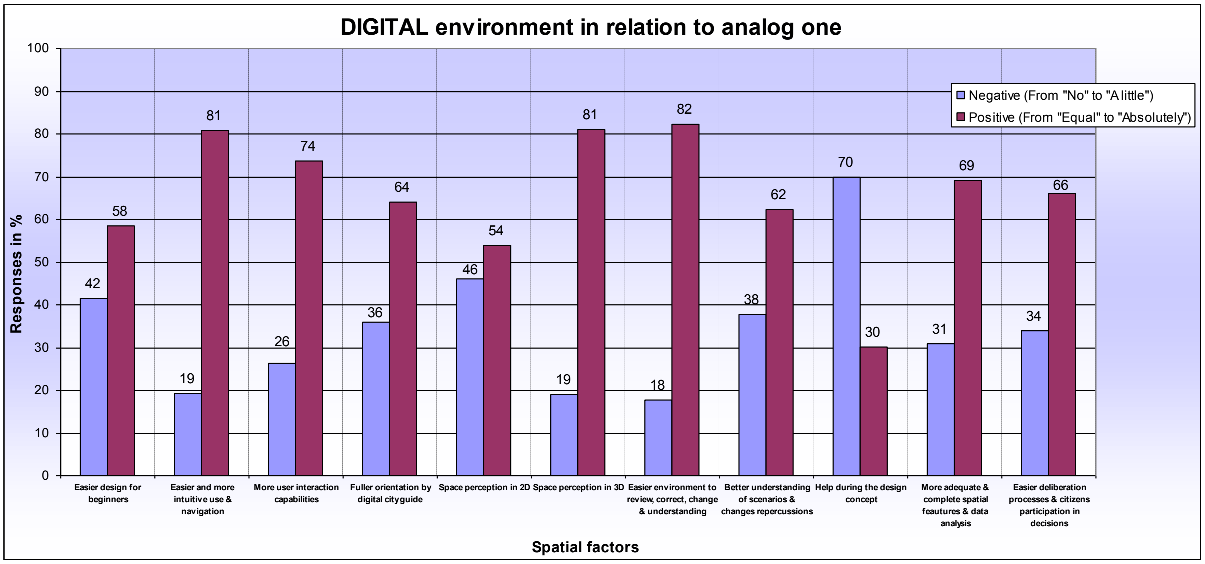

Figure 12: Chart schematic responses results of digital environment contribution to digital design and spatial perception by positive and negative grouping of responses statements

In the second area that mostly the digital environment affects on the spatial perception, the use, the ergonomics and the interactivity of digital tools in web cartography are better and more effective than the traditional-analog cartography from 13% to 34% in every high positive statement of response (from “enough” to “absolutely”) (Table 2) but for the beginners the design in analog environment is about as easy and ergonomic with 42% (“No”+“Equal”+“A little”) as in the digital environment with 58% (“Enough”+“Significantly”+“Absolutely”) (Fig. 12). This indicates inter alia, the relationship and comfort that a novice designer develops with the traditional-analog design and simulation as well as the reluctance or difficulty adapting to a digital environment.

In the third area that mostly the digital environment affects on the spatial perception, digital cartography and tools enabling significantly and absolutely better analysis of spatial data from 19% to 31% and public participation procedures in design decisions from 19% to 26% respectively, in every high positive statement of response (from “enough” to “absolutely”) (Table 2) (Fig. 11). The effect of digital cartography in the analysis of spatial data through thematic maps, databases, etc., is obvious to the respondents in "Enough" statement to 31% in relation to the other positive statements “Significantly” and “Absolutely” with 19%, while public participation in planning decisions through a digital platform indicates in 26% in “enough” statement and 21% and 19% in the others positive statements the understanding by the respondents, the power of digital space for "a common language", communication, better information, reduced distance and cost, time saving, etc. (Table 2) (Fig. 12). The average of the positive statements (from “enough” to “absolutely”) of the “Analysis of spatial features and data” is 69% (against 31% of the negative statements from “No” to “A little”), while the corresponding average of the positive statements of the “Public participation procedures in design decisions” area is 66% (against 34% of the negative statements) (Fig. 12).

In the fourth area, the digital environment obviously affects more the spatial perception in 3D at 23% to 30% in every high positive statement of response (from “enough” to “absolutely”) in contrast to spatial perception in 2D where a large proportion of 34% (“No”+“A little”) suggests that it is not affected by the digital environment only, but also by the traditional environment which plays a very important role (Table 2). The average of the positive statements (from “enough” to “absolutely”) of the “Space perception in 3D” is 81% (against 19% of the negative statements from “No” to “A little”), while the corresponding average of the positive statements of the “Space perception in 2D is only 54% (against 46% of the negative statements) (Fig. 12). In the fifth and final area of influence of the digital environment in the design and spatial concept is the conception design process. A sizable percentage of respondents 32% (“Equal”) states that the conception process is affected equally by the digital and the traditional-analog environment, while a 19% states that the conception process is not affected at all by the digital environment. The average of the positive statements (from “enough” to “absolutely”) of the “Conception process of design” area is only 30% (against 70% of the negative statements from “No” to “A little”).

Finally, the graphic representation of responses also shows that 73% of "spatial factors" (questions of digital environment) (8 questions to 11) affects in more than 60% (positive versus negative statements) the spatial design and perception (Fig. 12).

6. Conclusions

The digital map simulation has become an important tool that is widely used in all types of digital cities. Simulation of maps with databases allows spatial analysis and further processing and simulation maps without database are used more for tourist browsing and viewing of local community service. The categorization of digital mapping in digital cities on the Internet involves architecture maps of all levels scale (2D, 2.5D, 3D, virtual reality), thematic maps, graphic data maps with graphical information and scenarios-prediction maps.

Contemporary architectural, urban digital design and spatial simulation tools are increasingly involved in digital cities cartography. Technologies such as CAD, Multimedia platforms, DTP and GIS systems based on (a) virtual reality, rendering, animation and photogrammetry techniques, (b) programming languages such as LISP, Action-JavaScript, XML, SQL, C++, etc, (c) multimedia materials and (d) graphics, ergonomics and contact user-server functions, create, provide and retrieve important cartographical elements that permit an holistic cartographical interactive simulation and analysis, such as georeferenced satellite or aerial images, vectors rates, elevations, distances, different qualitative and quantitative data, intricate data of image processing, etc. In addition, technologies such as geoinformatics, data processing using SQL language or adequate statistics and APIs communication, complete the accuracy and the interactivity of the digital cartography on Internet by offering geodata, metadata for professional, scientific and research purposes.

The contribution of web digital cartographic simulation in spatial planning and spatial perception is huge either in viewing and simple presentation of spatial units issues or analyses and participate design issues, in particular:

- Tourism promotion and development: techniques for integrated and realistic representation of space, better spatial perception in identifying locations of cities, routes to be followed, addresses, panoramic images for tourist service, social and business processes, etc.
- Access and information collection tool: (e.g. areas measures, vector distance, altitude, urban and other technical information, etc) for further corrections, alterations and analyses in a virtual environment, providing media planning and analysis of the space in many applications (commercial, educational, social service, market research, business cooperation and contact, etc
- Participatory design: It creates conditions for solving problems relating to decision-making by citizens and political leaders (location, land use, rehabilitation, environmental data, spatial development, agricultural and economic policy, etc), shaping opinions, topics concept and approach of the space through processes of consultation, virtual presentation proposals – assistance, navigation functions, civic participation during planning to publish comments and proposed possible intervention storage, etc.
- Scientific analysis: It allows and detects problematic spatial units, and identifying its causes, classification, evaluation, and their association interface, highlighting the spatial dimension. It assists the analysis of natural and artificial features of space (architectural details, volumes, materials, buildings, identify "bad" or "troublesome" areas or volumes, etc.). It provides comprehensive and qualitative this spatial planning by increasing the ability to predict, control, and the impact of design decisions in future architectures, environmental planning, social, economic and energy studies.
- A questionnaire procedure addressed to young designers with a small, on purpose, experience in digital and analogical design (Engineers student-volunteers) shows that the digital environment affects both the design and the conception and spatial perception. The areas that mostly the digital design affect on the conception and the spatial perception, in the average of positive statement of response (from “enough” to “absolutely”), are:
  - (a) the opportunity offered by digital cartography for revision, correction and changes of spatial planning and their impacts which rise at the rate of 71%,
  - (b) the use, the ergonomics and the interactivity of digital tools in web cartography with 69%,
  - (c) the better analysis of spatial data with 69% and the public participation procedures in design decisions with 66%,
  - (d) the spatial perception in 2D and 3D with 57% and finally
  - (e) the conception process of design with 30%.

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