MUVIS: a PUBLIC participatory urban planning and multidimensional visualization ONLINE SYSTEM

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Abstract:

MUVIS (Multidimensional Urban Visions) is an applied research project aimed to create an extensible platform for online participatory urban planning and multidimensional visualization. In the Virtual Petržalka case study we facilitate model creation and visualization as well as support discussion of urban planning and its visions from any creative author. We describe selected problems in Bratislava urban planning in the past and we discuss our approach, its usability, acceptance, and estimation of its future impact.

Keywords:

Virtual worlds software, Geographic visualization, Visualization toolkits

Abstrakt:

MUVIS (Multidimensional Urban Visions) je rozširovateľná platforma na internetovú podporu tvorby mesta pomocou verejnej diskusie. Pre ľudí, miestne samosprávy a investorov umožní dialóg všetkých zúčastnených a na príklade virtuálnej Petržalky poskytne nástroj na tvorbu, vizualizáciu a diskusiu o víziách a plánoch na podporu čo najlepších rozhodnutí o budúcnosti našich miest. Opíšeme vybrané problémy urbánneho rozvoja Bratislavy z minulosti a vyhodnotíme náš prístup, jeho použiteľnosť a prijateľnosť aj možný budúci význam.

Kľúčové slová:

Softvér pre virtuálne svety, Geografická vizualizácia, Vizualizačné nástroje

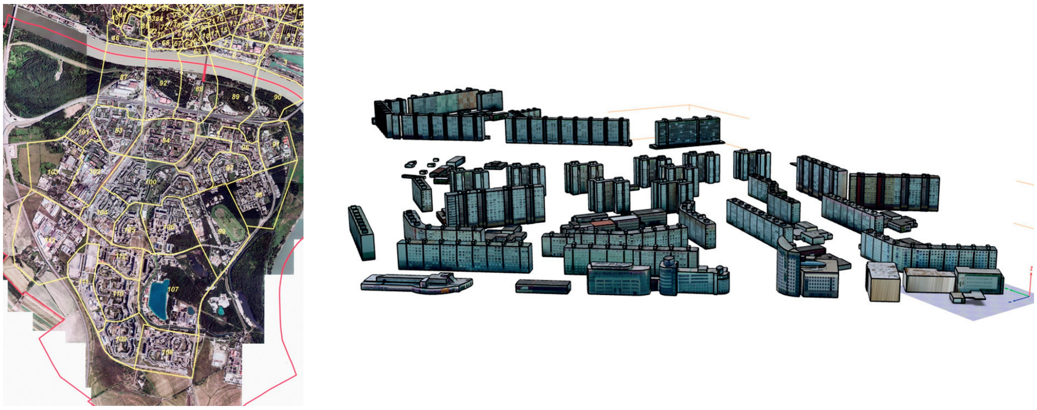


Figure 1: *(a) Left: Bratislava historic center is separated from Petržalka (encircled by the red border) by the Danube river. The whole area was subdivided into smaller parts (yellow borders) for the purpose of model creation. Aerial photo courtesy of Eurosense Slovakia. (b) Right: Petržalka is a controversial urban area with miserable architecture, infrastructure, and many unsolved problems. Building MUVIS database starts with aerial images, rooflines, and building footprints from Cadaster Portal of Slovakia. Initial Petržalka dataset without terrain and vegetation rendered by Martin Samuelčík illustrates the urban problem, where the people have to live in.*

INTRODUCTION

MUVIS offers a recent technology solution, transfers the ideas from academy to practice and attempts to affect – in the best possible way – the future of our cities. MUVIS, finishing in March 2013 will offer the people, local authorities, and investors a dialogue of all participants. In this paper we overview the methodology, technology, and both digital content creation and presentation. In the rest of the paper we introduce Bratislava and Petržalka motivation, the previous work, methodology and technology. In more detail, we present our project decisions and achievements. Finally, we conclude and discuss the future work.

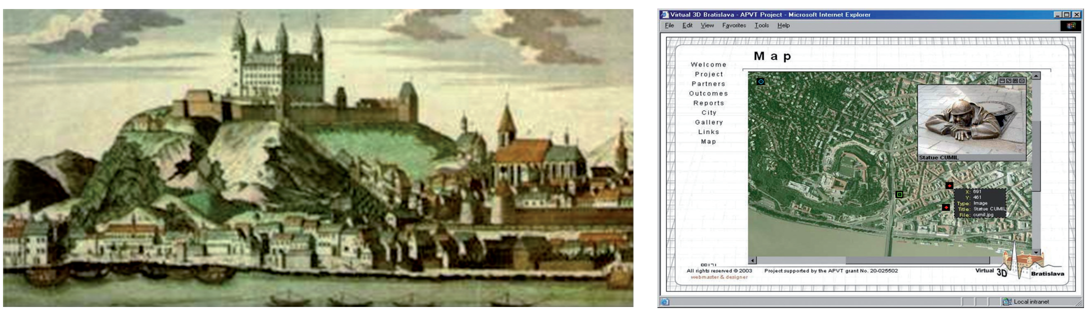


Figure 2: *Historic discontinuity visualization: (a) Left, a painted veduta from 18th century serves as a symbol for the old city, (b) Right, a screenshot from Virtual 3D Bratislava Navigation Tool by Stanislav Stanek. Aerial photo courtesy of Eurosense Slovakia, terrestrial photo by Matej Zeman. The popular statue symbolically wonders the higway damaging old city beauty.*

BRATISLAVA AND PETRŽALKA MOTIVATION

Bratislava (Pressburg, Posonium, Istropolis) urban development and phenomenon of genius loci [Norb00] suffered a lot from many historical and ideological discontinuities. One of the victims of such deformations was the Bratislava Castle vicinity, visible in Fig. 2(a) left in its original organic urban context and today, Fig. 2(b). In the year 2009, the archaeological research discovered an old Celtic castle underneath the current Bratislava Castle. Probably, it is – according to Austrian professor Werner Jobst [Mus10] – the lost Carnuntum the capital of the Noricum province, mentioned by in written history – in the year 6. The castle was destructed by fire in 1811, however, being considered as a symbol of feudalism, this ruined memorial without a roof and surrounding prominent urban area was not renovated until about 150 years later the fire. Next to the castle we can find probably the top anti-cultural damage of a historic old town – a highway between the Castle and the Coronation Church Fig. 2(b). The valuable historic urban area, an original place of history and local atmosphere, was cut by modernistic and noisy transport route built as a prolongation of a postmodern bridge.

Despite these and others urban atrocities, the biggest urban area under permanent public discussion is Petržalka, illustrated in Figure 1. Petržalka is a giant habitat built from the cheapest housing alternative – panel buildings. The biggest and longest blocks of them are nicknamed the Chinese Wall. Its 150 000 population makes Petržalka, so to say, the third biggest city in Slovakia (the second one Kosice (eastern Slovakia) is the European Cultural Capital 2013) with the highest divorce rate, remarkable crime problems and other poor indicators of the quality of life. One of the general solutions for the future urban development seems to be the public participation in decision making. As the current urban disaster cannot simply be replaced, we have opened a new communication channel for public participation in its current and future urban development and improvement. The abovementioned context motivated our decision to choose Petržalka as the first case study for the MUVIS project. Virtual model of Petržalka extends the existing virtual model of historic Bratislava southwards and MUVIS was verified, tested, and evaluated using this urban database.

PREVIOUS WORK

Many authors identified the alienation of modern architecture and urbanism. A public participation GIS (PP GIS) is often proposed as a promising alternative [Kyem09]. MUVIS is an extensible platform for online participatory urban planning and multidimensional visualization. Exploiting a layered multidimensional content structure, aware of time and space in the virtual city, MUVIS users will share and co-author "The City as a Process in Time and Space" [Fers02], at least virtually. Urban planners search for shapes and functions on multiple scales, forming a new version of "urban text", but there is no complex vocabulary of scales, shapes and functions, they are discovered and created ad hoc. The valuable old cities – among others Graz, Prague, Vienna, Bardejov (eastern Slovakia) – were included into the UNESCO's World Cultural and Natural Heritage List. The unlucky ones, like Petržalka, heavily influenced by the unqualified past decisions, especially inorganic changes, suffer from alienation, anonymity, missing infrastructure and another miserable phenomena.

The organicity of change and proportionality of shapes can be approximately measured using fractal geometry [Sali03]. We guess the famous Waterfall by Wright induces a largely different measure compared to the Bratislava highway cut through the heart of the old town – placing the Coronation Church facade right next to everyday pressure of trucks, cars, and buses. The collective imagination in this case is not formed, but deformed. The first experiments with Bratislava fractal measurements arose in a PhD thesis [Mesz10] at the Slovak University of Technology. The PP GIS approach studied Viera Joklova [Jokl07]. She identifies urban area as being influenced by an intersection of a professional and a public approach, sharing multiple modalities of maps, models, and metadata, Fig. 3.

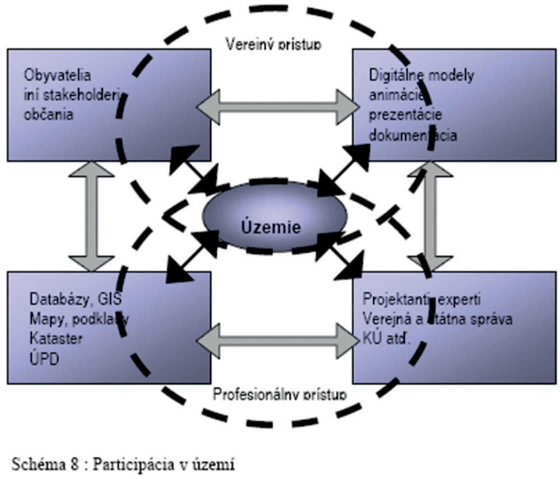
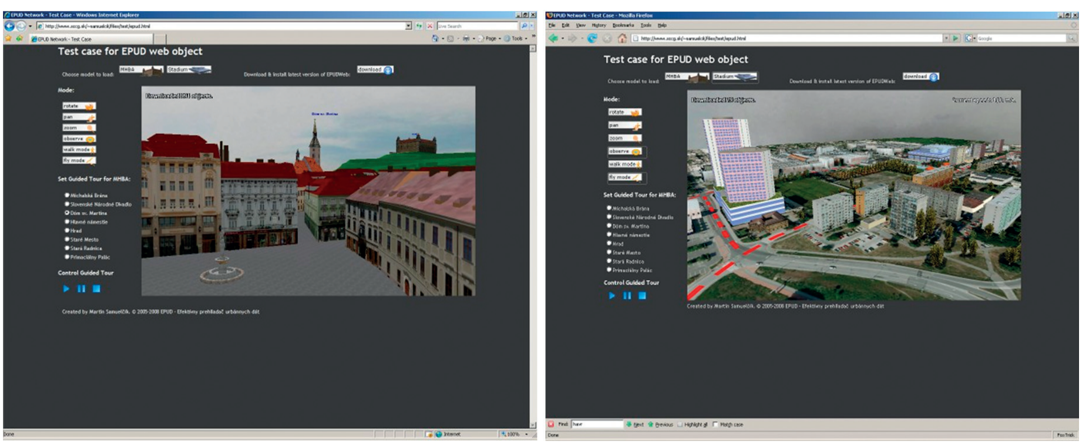


Figure 3: *Multiple intersections of interests and needs in urban area. Image courtesy by Viera Joklova.*

1.1 A Few Urban Planning Notions

The city has, among other places (squares, riversides, streets, quarters), the *city verticals*, given by towers, memorials, silhouettes, rivers and wells (old water sources). The oldest known ancient algorithm for founding a new city has been preserved in Latin books. The founders of Rome were the Etruscans – "engineers" invited by the rural Romans who had no knowledge in the field that time. The Etruscans computed the city location, ploughed the city border around, erected the city tower to transcend the city to the sky and – nearby – they dug a *mundus*. The mundus was not necessarily a well, but it meant the symbolic root of the city, transcending the city downwards, into the earth and into the depth. (One can see in erecting and rooting the male and female principles.) The Etruscan language, being isolated from Indo-European ones, did not survive up to now. Despite the fact we use two fundamental Etruscan words. This cultural heritage preserved Latin for us – *urbs* (the city) and *mundus* (the world, the meaning was



changed by the Latin users in ancient Roman Empire).

Figure 4: *(a) Left, one of the first experiments to fly over virtual Bratislava using Microsoft Internet Explorer. The screenshot displays Bratislava Castle Hill without vegetation and the Coronation Church tower as seen from the Old City Hall. EPUD software tool was*

used as web object here. (b) A model of a part of Petržalka in Mozilla Firefox using our EPUDWeb object.

There are several well-known urban thinking milestones, for city creation the famous Ten Books on Architecture by Vitruv [Vitr09], for city perception Lynch's Image of the City [Lync60]. His perceptual notions – especially **imageability** – express the **readability, areas, squares, borders**... Individual perception of a particular place, **genius loci**, has phenomenological explanation in [Norb81]. **The place** is, after Forte, the author of virtual museum definition [Qvor01], the opposite of an alienated **space** (e.g. hypermarket). The architectural alienation is discussed e.g. in [Bang07], the alienation of architecture and urbanism was studied e.g. by Rem Koolhaas, and socio-psychological problems of urbanism in [Mits69]. Bangs judges that the architecture missed classic craft in mastering proportions and preserving archetypes like cave, glade... The habitat (flat, house) should balance the needs for privacy and public space, which is not possible in noisy panel houses. Nowadays, nobody has a legal way to coordinate investor's egoisms, which would lead [Mits69] to unthinkable limitation of private property rights. Therefore, long-term **public participation (PP)** is one of the experiments to overcome the alienation. **The Aarhus Convention** [Aarh98] is a new sort of an environmental deal, trying to harmonize both human and environmental rights [Jokl07, p. 73]. PP can be characterized as a forum for exchange of opinions, experiences, knowledge, organized to support communication of all segments, solving the specific problems in given area [Renn95]. PP can support social inclusion, better concurrency, social cohesion, environmental balance and public feedback for decision making [Gave98]. PP classification and its computerized support is offered in [Jokl07, p. 73n] and PP is mandatory in Germany by law [Jokl07, p. 79]. The risky aspect of PP is that the public is not prepared for it. Therefore, MUVIS mission includes the technology enlightenment/evangelization part, as well. We distinguish **GIS** as a professional planning tool used for decision-making [Jokl07] from **PPGIS (Public Participation Geographical System)**, combining methods and technologies, conveying interactive presentation of various alternatives of geospatial data, based on problem-oriented selection. A relatively recent survey of PPGIS projects and dilemmas offers [Kyem09]. Another alternatives represent **geobrowsers** (Google Earth [GooE09], MS Virtual Earth [MSVE09]), compared e.g. in [Lebe07], and **VEPS (Virtual Environment Planning Systems)** [Jokl07]. The functionality of each of the above alternatives necessarily covers file and database management, search and navigation in space, time, or semantics, calibrating, filtering and storage, versioning, urban database editing, multimedia presentation of ideas, feedback, comments, forum and voting subsystems. Since all of them are VR systems, their architecture can be broadly subdivided into four categories: scene graph, semantic database, generic system, or distributed system [Guti07].

1.2 Cyber Cities

The vision of future internet outlines the Semantic Web [Bern01], requiring autonomous agents and globally built ontologies like CIDOC CRM [Crof05] for cultural heritage and INSPIRE [Jan09] for geodata. The cyber cities [VirC09] methodology started with a few chapters in [Leon00]. Work-flow issues for automation are analyzed by F. Leberl et al. [Lebe00] into three parts: 1. Aerial photogrammetry, 2. Digital canopy elevation model, and 3. Building geometry extraction. The Model building pipeline is characterized by G. Roth [Roth00] as: 1. Calibration, 2. Acquisition, 3. Registration, 4. Point Creation, 5. Model Creation, 6. Model (Mesh) Compression, and 7. Texture creation. Multiple modifications were elaborated in [Ferk04], [Lebe07], [Klei09], where even "ontological scales" appear and from where the evaluation [Mose08] for virtual Berlin [VirB09] is inspired. MS Virtual Earth (renamed to Bing Maps later) workflow was described in [Lebe07] as: 1. Surface Point Cloud, 2. Orthorectified Image, 3. Classification Map, 4. Bare Earth Topography, 5. 2.5D Textured Buildings. There are also experiments with procedural cyber city creation which can be used for less important city parts or in computer games where the exact model is not necessary. The goal of virtualization can be formulated as converting space into places, where place is defined by Christian Norberg-Schulz as "dynamic unity of architecture, population, and interactions among them". There are three levels of quality for virtual places [Came07, s. 337]: 1. Visualization virtual places, 2. Activity-based virtual places, and 3. Hermeneutic virtual places – culturally coded places where one can hide himself, identify with, own or collect cultural objects (in our case visions, presentations, opinions). The fundamental double-book on semiotics for virtual reality is Virtual Space [Qvor01] and Virtual Interaction [Qvor02], whereas the VR technology seems to be best taught in [Guti08]. The alternatives for W3C Semantic Web initiative are represented by digital libraries, e.g. Europeana [Euro09]. The quality measure for virtual museums visits formalizing the interestingness by time spent can be found in [Came07], but a specialized cyber city reference and a generally accepted measure of the quality of virtual museums is still missing. Obviously, the (low-level) geometric and radiometric errors in subspaces of a standard 8D ($x,y,z,t,r,g,b,alpha$) state space can be evaluated using standard measurement or estimation methods. The complexity in the field is discussed e.g. in [Zara02]. The cyber city initiative resulted into a fast growing international network around the CityGML portal [City12] and one of the first CityGML modeling tools was Toposcopy [Gron08]. *"CityGML is a common information model and XML-based encoding for the representation, storage, and exchange of virtual 3D city and landscape models. CityGML provides a standard model and mechanism for describing 3D objects with respect to their geometry, topology, semantics and appearance, and defines five different levels of detail. Included are also generalization hierarchies between thematic classes, aggregations, relations between objects, and spatial properties. CityGML is highly scalable and* datasets *can include different urban entities supporting the general trend toward modeling not only individual buildings but also whole sites, districts, cities, regions, and countries"* [City12]. This seems to be complete enough, but a city has a heritage layer, consisting of tangible and intangible parts, for their complete interoperability vocabulary refer to ISO standard [Crof05]. Recently, the heritage layer of Adelaide was released in May 2012, including: 1. heritage listed properties (State and local listings) and 2. 77 properties proposed for heritage listing as part of the City Heritage Development Plan Amendment. We discuss this layer later for the case of Bratislava and metadata semantics in MUVIS project.

1.3 Virtual Bratislava

Chronologically, the development of Virtual Bratislava model and related methods can be traced back in time through multiple academic projects over a time span of more than 10 years: MUVIS, Multidimensional urban visions (OPVaV-2008/4.2/01-SORO; 26240220009), Geometry Processing for Virtual Reality (VEGA 1/0763/09), Complexity of Geometric Algorithms for Realtime Rendering in VR (VEGA 1/3083/06), PM3Donline (AV 4/0023/05), EPUD (APVT-20-P05105), Natural Phenomena Visualization using Unstructured Grid (ASO SK-04-BA-010), STRAPAMO 18: MetropoVis, Virtual Heart of Central Europe (www.vhce.info, Culture 2000 n. 2003 – 1467/001/001 CLT CA12), Virtual Environments for WWW (VEGA 1/0174/03), Navigation and Cooperation in Virtual Environments – Virtual Bratislava (APVT 20-025502), Advanced Methods for Virtual Habitat (Aktion AT-SK No. 323-6/2003), Computer Graphics and Image Processing Applications (VEGA 1/7666/20), and Multimedia Historic Bratislava DVD (MDPT 456/131/2005). These group projects were solved in accordance with tens of dissertations, master and bachelor theses [Beha08], [Dušk09], [Feki07], [Majo09], [Varh09]. The complete list of all coauthors includes up to 200 names.

In this paragraph we recall selected experience and/or results from the above projects, described more in [AMVH03], [Ftac07], [PMZA08], [Ferk09]. The first online 3D Bratislava models were cultural heritage highlights at [VHCE09], optimized for IE (2004) [Ferk04], namely the Bratislava Castle, a National Cultural Monument and the well-known landmark or St.

Martin's Cathedral (also known as Coronation Church), a three-ships gothic church where 11 kings and 8 queens (including Mary Therese) were crowned between 1563-1830. Both memorials can be seen in Figure 2. The first Slovak virtual museum is specified in [Mrva07], [Ferk09] and published online [PMZA09]. As the real museum is in an old castle surrounded by a historic park, we also developed a method of park reconstruction using, to a certain extent, dendrologic data [SmHe08], [Ferk09]. Laser measurements were needed for the Bratislava castle well reconstruction. Combining real data and hypothetic lighting scenario, we reconstructed the interior of Chatam Sofer Memorial, presented at [VHCE09]. For Multimedia Historic Bratislava DVD [Ftac07], [Boro08] we experimented with sound gallery for presenting the emotional history highlights and with a matrix-like organization of digital assets – in one direction the memorials, city sights or themes and in the second direction, orthogonally to the first one, the output multimedia – photographs, videos, interactive 3D models. The navigation thus becomes intuitive and idiomatic in sense of [Coop95] and even elderly people just learning how to operate our novel multimedia kiosks can navigate quickly. The ideas from applied research project were combined with basic research findings – geometry processing using data-dependency [Toth06], mesh refinement [Noci07], specialized triangulations, false fundamental matrices for speeding-up epipolar reconstruction, extracting semantics from pictorial data [Šiku03], [Šiku06a], [Šiku06b], information visualization [Novo07], encrypting multimedia data, video segmentation [Čern06], image-based and real-time rendering methods, reconstruction quality [Samu08], [Lack09], streaming, guided tours planning, and empathic avatars [Stan09]. For presenting the past, we experimented with digital storytelling, which resulted into the discovery of LOD-stories [Pato10]. However, some problems remain open and the vision of a 3D Xerox, i.e. an automatic conversion of input data into a cyber-city or museum, requires much more efforts, ideas, and future work. For cyber-city internet presentation the real-time rendering in an online environment seems to be the crucial one.

OUR APPROACH

We define our approach as **a cooperative creation and evaluation of possibilities in geometric-semantic domain**. It might seem natural to just adopt one of the existing PP GIS solutions, but the financial and legal situation in transforming countries differs heavily from established market economies. For short, there is neither legislative nor market prepared for cyber cities, virtual cultural heritage, digital libraries, or digitization of museum collections. The complete initiative in this segment comes from academy and EU funding. This is the reason behind the obvious gap between functional virtual Berlin, Graz, or Vienna, already possible as everyday professional tool of respective divisions at city municipalities, and the striving virtual Prague, Bratislava, Budapest, Warsaw, Petersburg or Moscow, depending on academic projects and their (usually underfed) budget.

We identify three major target groups in the MUVIS project – authors, specialists, and public. Each of these groups comes with a different motivation, different skills and different information technology available. For example the latter are not well prepared for using modern information technology tools (e.g. we had to develop special urban reconstruction tutorials in Slovak for our own students [Ona07]). Wide public audience will share the MUVIS visualization and in given cases it will participate on urban planning forum. No special education is assumed and we can't count on a powerful hardware being used on their side either. These factors limit the amount of their active participation on creating or modifying the virtual space. The authors, on the other side, have the full access (passive and active) to the digital content and provide both the virtual working ground for the other two target groups and the administration of the project itself. They also maintain the database and develop future MUVIS version. The last group – the specialists – represent a force in the urban planning, coming either from the municipal administration domain or from the professional domain, such as e.g. architects, real estate developers etc. This group has a presumably higher level of experience than the general public yet still has not a limited access to the underlying digital content.

MUVIS cross-platform functionality necessarily covers file and database management, search and navigation in space, time, or semantics, calibrating, filtering and storage, versioning, urban database editing, multimedia presentation of ideas, feedback, comments, forum and voting subsystems for given localities. We combine two architectures – scene graph and semantic database to certain extent. Scene graph architecture supports the geometric criterion for visualization part. On the other hand, the urban database has to be constructed with respect to semantics. For possibly distributed memory system for preservation and storage of enormous datasets we take into account Bigtable [Chan06], proven in multiple similar projects, e.g. web indexing or Google Earth [GooE09].

The project development is subdivided into the design and development of three conceptually separate fields of functionality – a server-side application handling the storage, index and retrieval of digital content, an active-access providing client application (editor), and a passive-access client application (viewer).

The digital content used in our project is rooted in a 4D domain and extended by semantic relations between objects, by multidimensional object attributes and by multimedia content documenting the modeled places from an empathic point of view. The created database offers creating arbitrary and abstract relations through semantic triplets, thus supporting a higher-level knowledge built above the raw city model. The client-server protocol is open and platform-independent which creates opportunities for future extensions and involvement of other domain experts, such as statisticians, sociologists, ecologists and many others.

The editor is partly built upon our previous works on effective presentation of urban data and is being extended to facilitate both technological improvement, e.g. in the form of forming relations and higher-level semantics, and technical improvement, e.g. by introducing vegetation or variable lighting conditions.

The viewer development forks into producing a high-quality viewer oriented on the specialists and technically experienced public and a medium-quality viewer offering less options in both interaction and visualization but being more accessible to the wide audience. Thus, in the end, each of the user groups will be provided with tools to satisfy their needs without being bothered with excessive or overwhelming options or requirements. Each of them uses its own conveying technology; the high-quality viewer is based around our Effective Presenter for Urban Data [Samu08] and uses a GPU-accelerated client-side web object, while the medium-quality viewer uses Adobe FLASH technology which is available to the wider audience for the price of simpler and less detailed visualization.

As the specification of these modules is not open for public yet, we hope to present them in detail in one of our future publications.

We cooperate with EUROSENSE Slovakia, contributing with preprocessed aerial photos in the urban area shown in Figure 2. The detailed project requirements and functional specification take into account recent findings and they will be tested both with the full urban model and respective target groups within the case study Petržalka.

RESULTS

Since the project start in September 2009, we built the geometric model first. Data, tools, and methods from previous projects [Ferk04], [Boro07], [Boro08] were either adopted or under development to meet new requirements. Thinking about MUVIS in terms of cooperative creation and evaluation of possibilities in geometric-semantic domain, neither geometric nor semantic aspect was not significantly reduced in given application area. This is why we required multidimensional attributes or metadata beyond the 3D/4D spatial domain. Previous version of Virtual Bratislava model represented a cyber-city heavy model, available on DVD only. Microsoft® Virtual Earth™ is a geospatial mapping platform for layered data for given location [MSVE08], [WiVE08]. Google Maps is both service and technology [WiGM08], related to the virtual globe of Google Earth [GooE08], [WiGE08] and even extending to the outer space. Both global projects have limited use and precision and they simulate mainly flyover options and exploit satellite and aerial photos of Earth. Our previous project [Ftac07] can be considered as an analogy to Google Earth. The challenging task of online browsing or even editing higher precision urban models is done in Virtual Old Prague [VirP09] or Virtual Berlin [VirB09] by downloading data and/or viewer. MUVIS aims to offer an acceptable online solution like Virtual Adelaide [Adel12]. The model already includes the virtual vegetation and an inserted urban vision – visualization of one of multiple not really built alternatives of the ice hockey stadium for the World Hockey Championship in Bratislava 2011.

1.4 MUVIS DATABASE SERVER

MUVIS Database Server is the database backend for all MUVIS clients. We have developed client-server network protocol independent of internal client graphics and data file formats. At the moment of writing, MUVIS clients use COLLADA format as a 3D models carrier together with appropriate file formats for multimedia (e.g. JPEGs for pictures). Administrator of the database is able to manage these file formats. Data are then obtained accordingly to their purpose: any entity that can be time- and geo-referenced (3D building models, panoramas, photographs taken by tourists, etc.) is handled via its reference (point in time and space) and a set of attributes. Attribute list is maintained by administrator, who assigns privileges for reading/writing the attribute values (e.g. users can name owners of house models they built). Database entities are organized in four ways:

1) entity can be georeferenced, thus accessible by its space/time reference,
2) entities can be organized into separate layers (e.g. layer for terrain, buildings, vegetation, traffic or other infrastructure),
3) two or more entities can be assigned into “relation” (e.g. all buildings in student campus can form one relation),
4) there is a semantic hierarchy of entities available. Entities are organized into semantic tree, which usually represents administrative division of the underlying city (city is divided into districts, districts are divided into streets, streets are divided into lots, etc.), however the exact semantics is precisely defined by the administrator.

MUVIS Server is able to retrieve information based on search criteria combined from geo-referencing intervals (axis-aligned bounding boxes), layers, relations, semantics and attribute values. Only users authorized by administrator are allowed to write new or edit existing entities.

1.5 MUVIS DATA

We divide data into three main categories: 3D data (ortho and terrestrial textured buildings), multimedia (text, videos, images, panoramas) and attributes. In the layer of 3D data we have obtained original data from Eurosense company. These data need to be refined and retextured due to consistency. After these steps 3D data from center of model and some of the most important objects were retextured by terrestrial textures. We need to photograph about 2500 photographs for selected 105 objects, and we prepared about 460 textures. We also prepared semitransparent images for vegetation objects and 4 3D models of buildings, which user can add into the system.

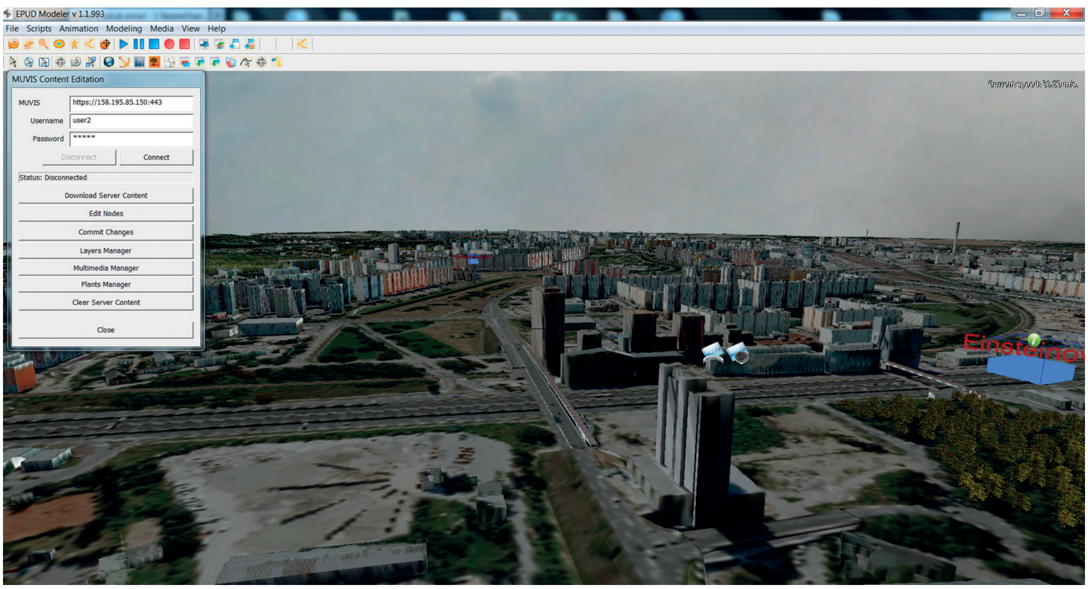
We also prepared the multimedia files consist of about 10 text files, 200 photographs, 4 audio files, 20 panoramas and 9 videos.

We present attributes in the 3D model via text information based on INSPIRE attributes model, which consist from different categories assigned to 3D objects in the scene. We present them as the information in the table.

1.6 MUVIS EDITOR

We were working on the complex application (Figure 5) for viewing and editing content of the MUVIS project. Therefore our work consists of two major parts, modeling system and viewing application.

These parts have some common parts, like communication system with server and rendering system. In the modeling part of project, we created standalone application that is capable of preparing data, storing data and rendering data. In the preparation phase, user can use external object model and import it inside system, the do some minor transformation with object. Special tools are dedicated to work with objects representing vegetation, buildings and terrain, and also for preparation of all data for easy and fast rendering. As additional information inside virtual world, modeler application can insert several types of multimedia like texts, picture, panoramas or sounds into scene attached to several objects. Prepared data are then uploaded in efficient way to MUVIS server. Viewer application is mainly used for efficient obtaining data from MUVIS server and for its displaying. We prepared caching system for optimization of download process. Objects are displayed on the screen immediately after download and processing of the object is finished. We implemented fast rendering system for displaying large virtual scenes with many objects. We also include several image enhancing effects. As additional form of rendering, this application can show multimedia data.



Viewer application can be used as standalone application as well as plugin inside web browser, where plugin can cooperate with browser layer.

Figure 3: *MUVIS editor with 3D model of Petržalka and Multimedia assets.*

We have developed an easy to use graphical user interface (GUI) to insert (and interact with) 3D models in a virtual urban environment. It has capability to add a high resolution 3D model and also its low resolution alternative, which is used in the Flash version of EPUD viewer. This GUI also allows to edit multiple objects at once.

Another GUI we developed for EPUD modeler is for quickly planting a big number of trees, plants, etc.. Even any 3D model can be used instead of vegetation. User have to just draw an arbitrary polygon to mark the area where he wants the vegetation (even non-convex one) then set a vegetation type (e.g. a type of tree, or plant) and finally set a height and density (how dense these trees should be placed to each other) and then the EPUD modeler places 3D models of the vegetation on the marked area.

Framework used for GUI is wxWidgets, which is multiplatform, so all the user interfaces can be easily ported to other platforms like Linux.

1.7 MUVIS VIEWER

Both web based solutions, the EPUD viewer and Flash based player, are embedded in a operating web page to use our solution on Internet. The user can choose which version of player he wants. The page is responsible for common parts as for user login, registration, working with layers etc., which are independent of the player. Therefore it provides one interface for the client no matter which player is presented. However it uses two different protocols to communicate with the EPUD viewer and the Flash player. On one hand the operating web page have to control the player and transfer the requests from the user to the player. And on the other hand he page is also responsible for responses on player requests. If the player requests to show multimedia in external environment, the operating page will process the request and present the external media as part of the HTML.

The purpose of the implemented Flash-based viewer is to bridge the technological gap between general public and usual GIS systems. Our goal was to introduce a solution that establishes a reasonable trade-off between ease of use and functionality. The choice of Adobe Flash technology as the platform for the viewer stems from the combination of the high percentage of Flash player installations across personal computers and the availability of hardware-accelerated 3D graphics. Introduced in Flash Player 11, the Stage3D API largely erased the former abysmal difference between 3D performance of desktop applications and rich internet applications. The older competing technologies (VRML, X3D) are now obsolete and the upcoming web-standard WebGL was not mature enough yet for a reliable implementation of the functionality required by MUVIS.

The final implementation takes advantage of the Away3D library that supports Stage3D and provides sufficient support for data import in form of Collada files. We considered other available solutions (e.g. Alternativa3D) for Stage3D implementations but no other provided the necessary functionality and support.

Despite the high performance of Flash's Stage3D, extensive optimization still has to be made. Mostly on the memory part, where a combination of local storage, CPU RAM and GPU RAM was devised that balances the RAM limitations against the user-unfriendly object download. The displayed objects are also chosen from a limited surrounding of the camera position to further decrease the memory demands (Our full test case model counts for as much as 4GB of Flash data.) A portion of the unused data is locally cached to prevent repetitive HTTP requests and to shorten the download time during the operation of the Flash viewer.

CONCLUSION AND FUTURE WORK

MUVIS (Multidimensional Urban Visions) is a three-year applied research project for creating an extensible platform that will support online participatory urban planning and related multidimensional visualization. MUVIS will support and initiate public discussion and dialogue between the people, the local authorities, and the real estate investors. We use Virtual Petržalka as a place to demonstrate our efforts in a real-world case study, a place to support creation and visualization of the current state and the future visions. MUVIS offers a state-of-the-art technology solution, transfers the ideas from academy to practice and attempts to influence the future development of our cities in the best was possible.

We plan to experiment using MUVIS with MARS [Mars12], a multi-touch augmented reality system that uses two displays – one with multi-touch capability and second with augmented reality display. We especially devised the combination of these two visual spaces in a way that is seamless for the user when shifting the attention between them. Joint presentation of 2D and 3D data is a frequent situation in architecture, urban development or real estate business. Our experience shows that building a mental model which merges two-dimensional floor plans and three-dimensional visualizations is not an easy task for the average user. The interactivity and the feel of direct manipulation improve this situation. We propose a usage scenario where the table holds the neighborhood map, floor plans or geometry plans from the land register. The focused 3D model of the building is added to the augmented view. Basic user interaction such as panning and zooming can easily be performed in the table space.

This scenario can also be adapted for similar needs where the ground plans are combined with a 3D object geo-located within the 2D environment. These include: archaeology, geology or crime investigation.

All of them can also benefit from the secondary context where a different view of the ground plane can be displayed: satellite map, weather map, etc...

From the point of view of the widest target group, our intention is to enable people not only in poor Petržalka to be consciously and interactively participating with their contribution to the future of their own environment. We hope that our model of cooperation, our workflow, and project results might be inspiring within the arising information society.

The public and experts were involved into the process of application design through the usability testing and in the future, they will use the application as the participatory tool for enhancing the process of decision making in city development.

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