Visualization of Documented 3D Cities

Clément Chagnaud, John Samuel Samuel, Sylvie Servigne, Gilles Gesquière

Eurographics Workshop on Urban Data Modelling and Visualisation (2016)
F. Biljecki and V. Tourre (Editors)

Visualization of Documented 3D Cities

Clément Chagnaud, John Samuel, Sylvie Servigne, and Gilles Gesquière

Université de Lyon, LIRIS, CNRS, UMR-CNRS 5205, France
clement.chagnaud@cpe.fr,{john.samuel,sylvie.servigne,gilles.gesquiere}@liris.cnrs.fr

Abstract

Documents whether historical photographs or urban regulations are important for understanding the urban past as well as for urban planning. CityGML is an open standard used to represent 3D structure and thematic information of the cities. In this article, we briefly present how the recent extension to CityGML to represent documents has been integrated to the 4D virtual urban environment. We will then focus on different visualization techniques of documents in this environment and the various metrics used to evaluate them.

Categories and Subject Descriptors (according to ACM CCS): I.3.6 [Computer Graphics]: Standards— I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism— I.3.8 [Computer Graphics]: Applications—

1. Introduction

Documents play a very important role in understanding the urban past and in urban planning. Panoramic city photographs, cadastral plans, aerial images, paintings, postal cards found in municipal and private archives on one hand can give (artistic) impression of the historical past of a city and on the other hand can also be used to build and verify 4D (spatial and temporal) mockups. Urban planners and historians use 4D mockups for testing various hypotheses and to visualize urban history and evolution. Spatially and temporally located textual documents like regulations and construction permits alongside new proposed plans help urban planners make appropriate decisions. Similarly, historical documents alongside proposed hypotheses help historians to quickly comprehend and even verify them.

Handling of documents, especially photographs is becoming an integral part of GIS (Geographical Information System). In particular, we can see their usage in online services like Google Maps, where the user can navigate a 2D or 3D (satellite) view and several labels or pins are shown related to user queries or important points of interest. When a user clicks on these labels, additional information like photographs, business contact details etc. are shown as an overlay or a pop-up. Yet users do not have options to simultaneously navigate spatially as well as temporally through a multitude of documents. Visualization of documents, especially over city objects of interest in a virtual urban environment is a challenging research area.

Open urban data, particularly CityGML data [GKCKH12] are being used for several urban research studies, e.g., detection of changes in city [PMG15], understanding of urban changes in the past [PGG15] etc. City evolution or regulations can be explained by using additional data such as documents obtained from diverse sources. Much recently, the missing link between various city objects and urban documents in CityGML has been resolved by a proposition in the form of an ADE (Application Domain Extension) [SPS*16]. With this extension, it is now possible to represent and share urban documents and their references to city objects during various periods of time. In this article, we go further with this extension and discuss how documents are visualized in a 4D virtual urban environment. We propose various visualization metrics and use them to evaluate four proposed visualization techniques. Finally, we will quickly present how temporal metadata of documents like publication date are utilized in our proposed visualization.

Section 2 presents the role of documents to understand the urban past, present and future and the growing requirement to visualize them. In section 3, we present related works. Various visualization techniques, visualization metrics, associated development are detailed in section 4 and the results obtained so far have been described in section 5. Finally section 6 presents our future course of work and concludes the article.

2. Visualization of Documented 3D Cities

GIS is being used in diverse fields like navigation, traffic management, urban planning, historical studies. Web mapping services like Google Maps providing two dimensional and three dimensional models of existing urban environments are now very common. Softwares like Google Earth have shifted the demand from 2D mapping to 3D mapping services. Much lately, thanks to various research works namely Nantes 1900 project [QHLK15], reconstitution of the medieval town of Cluny [RHPM*14], the virtual Leodium project [PCD*13], the shift has now focused towards 4D

GIS, i.e., including the temporal aspect in addition to the already supported spatial (2D, 3D) features.

Documents like textual sources, plans [AL15, Sim12] are commonly used to study the evolution of historical elements of the city. [Sim12] considered non-existence, hypothetical existence, verified existence, hypothetical removal and verified non-existence of historical city objects based on documents. Similarly [AL15] studied the evolution of historical objects in urban landscape considering the evolution of their functional and constitutional aspects taking into account material sources and documents. Documents are spatially localized based on the locations, buildings that they refer to or even the location of their publishers. Furthermore the granularity or level of detail of the referred location must also be known. Aerial images or panoramic city photographs may span over an entire city or a particular city sector whereas building images concern part of the city at a much granular level. Other metadata like the publication date of a document, or exact date or period of a location the document refers to are used to temporally localize a document. Old postal cards for example, give various panoramic views of city at different periods in time.

Cities continue to evolve and new projects are proposed from time to time. With mockups, urban planners project the city at any given instant in the future and study the impact of concurrent projects on the city. Planners use various types of documents like plans, images, construction permits, textual rules and regulation etc. Hence they need to consult them along with their projected plans. They study the impact of new buildings or new schools that may appear in the coming years, the details of which may only be found in some documents including newspaper articles.

Hence documents form an integral part of urban landscape. Urban planners and historians look for solutions that can integrate both city objects as well as the associated documents that refer them on a 3D/4D urban environment. Considering both their perspectives, we require a solution that allows the users to upload documents related to their locations of interest to test their hypotheses as well as to share them with other experts in an interoperable manner. They require options to navigate spatially as well as temporally through a multitude of documents at different levels of detail. Such navigation is required so that the user can compare different city objects at different points of time from the point of view of historical documents or future project plans. Simultaneous visualization of multiple documents also permits the user to quickly find desired document.

3. Related Work

Virtual environments [BNC*03, BD15, cLZ16, BFH01] like 3D navigation maps, virtual reality, augmented reality are used to provide an *information-rich sensory environments* to the end users. One of the key requirements in this context is to guide the user in different scenarios. Text, for example is commonly used to display names of buildings, roads, villages, cities etc. It can be placed anywhere around the object and lines or arrows may also be used to show the precise object(s) referred to by it. Such an environment may also involve displaying multiple textual labels simultaneously and their positioning for user-friendly view is a key research area.

Open Locast project [BC12] overlays 2D map environment with textual content over points of interest. An almost similar approach can be found in several mapping services like Google Maps. [ZTM14, GLK*12, MD06, VFW13, SMHW15] explore displaying textual-based information in 3D urban environment and focus on displaying multiple labels without much occlusion in a manner that the users can read them. Four perspective factors (text size, text color, text transparency and text resolution) were tested and evaluated in [ZTM14]. [GLK*12] analyses the underlying image by detecting the edges. It then builds an edge map and detects salient regions to build a salient map. Several label orientations like top, bottom, left, right, radial or combinations of them are chosen using the above maps and considering whether the location of interest is inside or outside a building. Textual labels are shown at the top of objects using poles like a billboard in [MD06]. [VFW13] focuses on 3D navigation maps making use of glowing roads and transparency label aura to ensure the readability of labels whereas billboards are used by [SMHW15] to display textual information for the same purpose. In all these above works, textual display has been the key focus. We want to extend 4D urban environment with the ability to simultaneously view multiple documents and focus on billboard based display to visualize documents by placing them over concerned city objects with a pole.

Urban documents have several interesting metadata like title, source, publication date, key content, tags. [GZL*14] gives an overview of various existing techniques used to visualize a multitude of documents both in 2D and 3D environment, though not specifically targeting GIS. But it focuses on how various metadata associated with the documents such as user-generated tags and categories are used to create interesting visuals like for highlighting document clusters based on topic. We make use of these metadata to highlight user search results in the urban environment. Additionally, documents like paintings, photographs and plans have additional information like the orientation or the point of view from where the concerned document was created which is also used to position the documents.

White Bastion 4D visualization project [ROS15] is a closely related work that explores various techniques to achieve 3D reconstitution of historical buildings using latest web technologies and view their evolution temporally. In our work, we want to extend the scale up to a complete city or a city sector in an interoperable manner. Therefore our proposition is based on CityGML [GKCKH12], an open standard to represent both the urban objects as well as urban documents and to stay as generic as possible.

4. Visualization of Documents

CityGML is an open standard by OGC [OGC16] that can be used to represent thematic, semantics and 3D structure of cities. CityGML data are now currently available for a number of cities like Paris, Lyon, Milan, Berlin etc. Its use permits sharing and exchange between diverse communities in an interoperable manner. Recently, [SPS*16] proposed an extension to CityGML in the form of an ADE (Application Domain Extension) in order to represent documents and associated data. Urban documents concern various city objects of different epochs. The proposed extension, inspired by the Dublin Core [Wei97] helps to represent the metadata of document

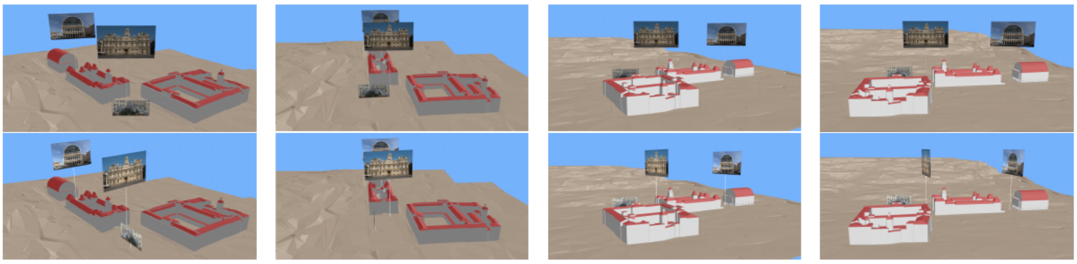

Figure 1: *Orientation of images. Top images show the thumbnails of documents facing the camera or the user while images in the bottom row show the same images but when their orientation are known or are provided by the user*

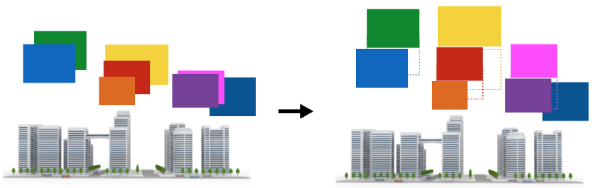

Figure 2: *Goal: Display of documents without much occlusion*

(like title, description, publication date, purpose of document, data encoding used), its key content, referenced city objects and associated date or period referred to by it. In addition, the extension also represents the semantic links between documents as well as documents and city objects. In this section, we explore visualization of documents especially photographs in the 4D urban environment built using CityGML.

We consider the following metadata for our prototype: size (height, width) of image, location (position x, position y, position z) of image where the user wishes to display, orientation of image, file path, title of image, type (e.g., jpg, png), source type (public, private), Level Of Detail (LOD, Fig 3), initial billboard pole height, priority of image, its publication date. Attributes such as size, position, orientation, axis, billboard pole height, LOD are used to decide the positioning of the image whereas others are used for searching and filtering out desired documents. Some of these information need to be provided by the user, take for example the orientation (a value between -180 to +180 degrees) of a photograph as shown in Figure 1. When the orientation is known and used for visualization as such, the user can get the view of the concerned city object from the artist's viewpoint and can even verify it with the concerned city object(s). But for this article, we will assume that all the documents face the camera and follows it as it is moved around the virtual environment.

The goal of document visualization as shown in Figure 2 is to reduce the amount of occlusion when multiple images are shown. When a user uploads a set of documents to be visualized along with the underlying 3D visual environment, the documents appear as thumbnails over the associated city objects linked with a line (hence the name billboard display). As mentioned above, the initial billboard pole height can be proposed by the user and then the system detects the percentage of occlusion to change the height to achieve maximum possible visibility of documents. The user can also navigate the 3D urban space using zoom and pan options. To decide the granularity of the image details, we initially propose four levels of detail as shown in Figure 3: (a) city for images covering entire cities like aerial views, plans, panoramic city photographs, (b) sector for images that concern only a part of the city, (c) road for images of road, statues, fountains, city furniture (e.g., traffic lights) and (d) building for images of a building or remarkable monument.

We require metrics like [ZTM14], but extended to documents for evaluating efficiency of document visualization. If for example, all the documents are displayed at the same height and the documents are viewed from the same level, we find that the documents may overlap with each other; those in the front hiding those behind. Some documents cannot be completly seen when partially culled out due to screen boundaries. Hence different visualization techniques need to be tested for different scenarios. We consider the following visualization techniques (Figure 4):

1. *Naive display (without any LOD considerations)*: All documents are displayed at the same altitude with the same scale. They are displayed by only taking into consideration their anchoring point (i.e the point on map it concerns).
2. *LOD display*: Documents are displayed according to their LOD (Level of Detail). Each LOD has its own parameters for scale and altitude. Documents fill different heights of the screen.
3. *Staired display*: Documents are sorted from the closest to the farthest to the viewer. Each document is displayed higher than the document right in front of it.
4. *Staired display by LOD*: Documents are sorted from the closest to the farthest to the viewer for every LOD. The first image of a given LOD is placed at the altitude designated to the concerned LOD and subsequent images of that LOD are displayed higher to the previous image of the same LOD.

4.1. Visualization Metrics

We consider the metrics given below for evaluating different visualization techniques and measure them for a given screen area.

- **ND**: Total number of documents to be displayed

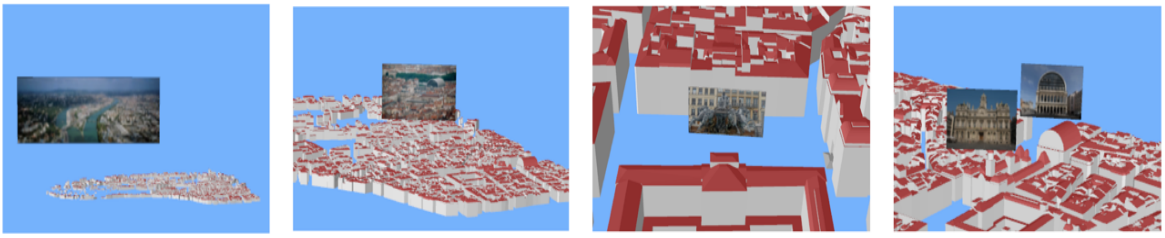

Figure 3: *Different documents at different levels of detail: (a) city, (b) sector, (c) road , (d) building*

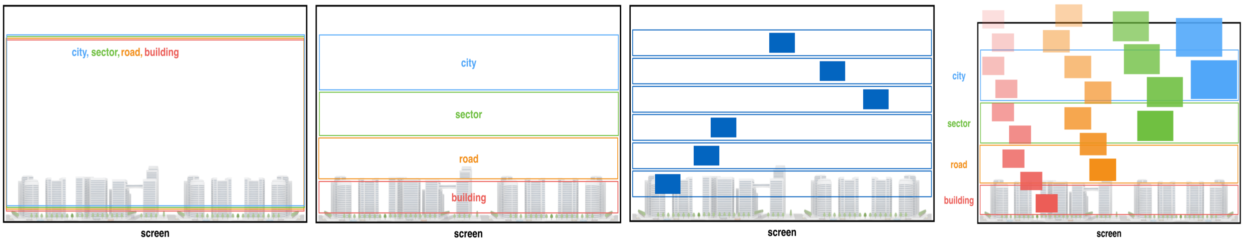

Figure 4: *(a) Naive Display, (b) LOD Display, (c) Staired Display, (d) Staired Display by LOD*

- **NDs**: Number of documents actually displayed on screen, namely not culled out
- **RNDs**: Ratio of documents displayed to total number of documents. NDs/ND
- **NDh**: Number of documents on screen but hidden (we consider a document hidden when over 30% area is overlapped)
- **RNDh**: Ratio of documents hidden to documents on screen. NDh/NDs
- **Sa**: Total screen area
- **Da**: Area on screen occupied by a document
- **TDa**: Total area on screen occupied by documents
- **OVa**: Overlapped area of a document
- **TOVa**: Total overlapped area of all the documents
- **RDS**: Ratio of all document area to screen area ((TDa-TOVa)/Sa)

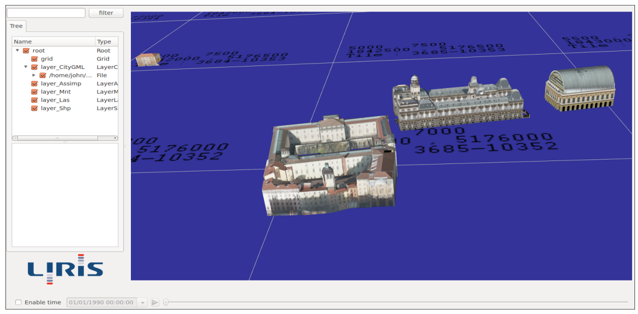

Figure 5: *3D-USE tool to interact and visualize with CityGML objects*

4.2. Development

A virtual urban scene editor called 3D-USE[†] has been developed to test and visualize both the existing CityGML objects as well as its various extensions. The editor permits the user to upload CityGML files, manipulate and explore different 3D city objects. It also lets the user to visualize the city or a group of city objects from different camera angles. 3D-USE is shown in Fig 5 after a CityGML file has been loaded.

There are several ways by which the user can interact with the tool. The contents of CityGML files loaded to the editor can be visualized in two different views. The first view shows the content in a textual tree view format (top-left under filter option) whereas the second view shows the city objects in a 3D format (right-central). For the latter, the user can make use of the zoom in/out as well as the option to change the camera angle using the mouse buttons.

Thus in this 3D view, the user can see the 3D structures of the city objects and obtain their various views from different camera angles. Also it is in this view that the user can visualize the loaded documents. There is one more view called the attributes view (bottom-left), which shows the attributes of the concerned city object when it is selected either in the textual view or in the 3D view. Finally, there is a temporal bar at the bottom, which can be configured with a start date and the ending date. When the user enables this bar and moves (or presses play button), the documents are displayed based on their publication date. In addition to the above, there is a limited search option that can be used to search and filter the desired city objects based on their names.

The 3D virtual scene is modelized with the open source 3D graphics library OpenSceneGraph. As its name says, this library has a scene graph hierarchy to manage objects in the 3D scene. Basically there are two types of objects: the nodes and the drawables. Drawables store geometric data for rendering. Displayed images and pdf are mapped onto 2D quadrilateral-shaped drawables, only 4

† http://liris.cnrs.fr/vcity/wiki/doku.php

vertices are needed to build it. These drawables are held in a group node alongside their linking line. Both of them are displayed according to their specific coordinates thanks to methods provided by the library. OSG enables billboard objects which contains geometries whose orientation is dynamically rotated around a defined axis (or point) to ensure facing the camera. Some of the group nodes can be set as switch nodes and have boolean mask to enable or disable processing of its children. This feature is used whether or not to display an image (e.g., disable images at city LOD when user is actually zoomed in to much more granular levels like buildings or road LOD).

One of the main features of OSG that we are using is callback function. Callback functions are attached to a node and are called each time a frame is rendered. These are used to perform all dynamic (run-time) computations, here namely metrics computations and switch nodes mask updates.

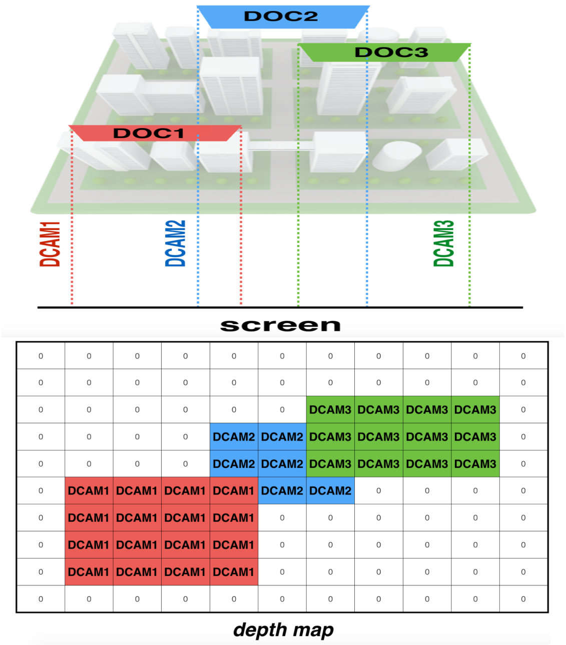

Figure 6: *Depth Map obtained after projecting the documents in 3D world to 2D space*

In order to provide various display techniques, we need to know the position of each document both in the 3D world as well in the 2D screen plane, i.e., the projection of the document in the 3D world to 2D space. That is why we introduce **DCAM** parameter, the distance between the document center and the camera position.

To compute OVa, firstly we create a depth map which is a matrix of screen dimensions that represents every pixel of the screen as shown in Fig. 6. Each pixel contains the DCAM value of the closest document it displays. If it does not display any document, the pixel value is set to zero. By doing so we have a map of the foreground documents displayed on screen. Then for each document we crop the depth map accordingly to the document screen coordinates to create its overlapping matrix. Each pixel value in the overlapping matrix that does not match document DCAM value is considered

Table 1: *Visualization Techniques and Metric values at a given position*

Technique	RNDs	RNDh	RDS
Naive Display	1	0.48	0.064
LOD Display	1	0.17	0.071
Staired Display	0.4	0	0.045
Staired Display by LOD	0.9	0.05	0.081

as an overlapped pixel. We can get its OVa by computing every unmatching pixel (Fig 7).

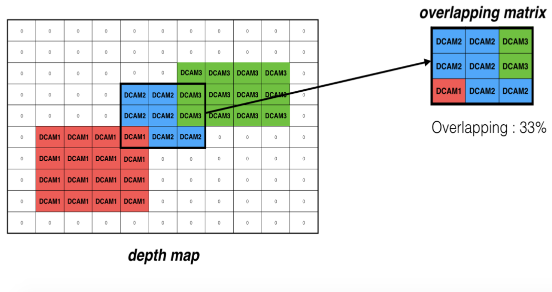

Figure 7: *Overlapping Matrix. Document 2 has 33% of overlapping*

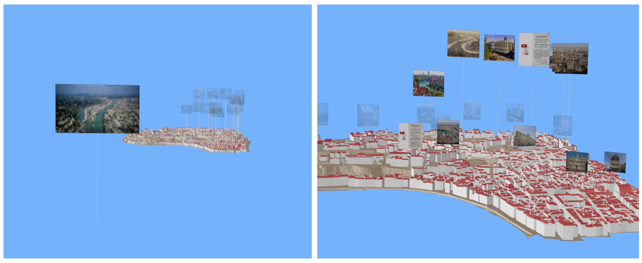

Figure 8: *Documents visualized with different transparency values. (a) Zoomed-out (Initial) View and (b) Zoomed-in View*

5. Results

Figure 8 displays the documents and makes use of transparency to differentiate between images at different LOD levels. But for our evaluation, we do not make use of transparency value. In order to correctly compare the display techniques described above we compute three metrics out of the same view for each technique. With 3D-Use we are able to move the camera to a specific position at a specific orientation. By doing so we can assure that the metrics are witnessing the same view for each experience. We also ensure that as we navigate around the 3D view, the documents always face the camera (or the viewer). The results are given in Table 1.

The results obtained at less granular level show that in naive display (Fig 9), documents are displayed at the same altitude so almost half of them are hidden. This display provides very less visible information, but none of the document we want to display is missing. In LOD Display (Fig 10), considering LOD reduces the percentage of hidden documents to 0,17 which is more appropriate to increase the visibility of information available. Staired display (Fig 11) avoids overlapping but does not fully display the group of documents. This displaying technique permits to see every document on screen, overlaping is reduced to zero. But the farthest document is very high above the map, so some documents may not even appear on the screen area. Though some are lost from human view, every single displayed one is completely visible. Staired display by LOD (Fig 12) ensures better value on the number of documents displayed compared to staired display and lesser overlapping than naive display. Even though staired display by LOD give better results in terms of reduced overlapping when compared to other approaches and also shows more number of documents than staired display, naive display and LOD display techniques are quite helpful to have an overview of available multitude of documents.

Finally with the publication date of documents and temporal bar enabled, documents only appear when the current time on the temporal bar is greater than the publication date and remain visible till the last date set for the temporal bar. Another feature that we tested was to specify a period for document visibility in order to reduce the document clutter towards the end of the temporal bar. In addition to using these metrics, the prototype has also been tested by an urban-historian.

Figure 9: *Naive display*

Figure 10: *LOD display*

There are some limitations in our current prototype. It loads the CityGML file with a limited number of pictures specified by the user. Two directions are explored towards handling cases involving a large number of pictures: providing users with search/filter options so as to limit the number of documents visualized based on priority rules and performing scalability tests to understand the limits of the platform.

Figure 11: *Staired display*

Figure 12: *Staired display by LOD*

6. Conclusion

Documents like images and textual sources play an important role in planning and understanding the urban landscape from different points of view. To the best of our knowledge, ours is the first working implementation based on CityGML that represents and visualizes the urban documents and the referenced city objects. We also proposed four visualization techniques and different metrics to evaluate them. Even though naive display and LOD display techniques involve overlapping, they are useful to get a quick overview of the available multitude of documents.

Dynamic computing of visualization metrics can also be used to dynamically reposition the images. We are currently working on such algorithms so as to achieve better visualization results and to improve the perfomance issues encountered during visualization of a large number of documents. Documents may refer to locations whose perimeters cannot be fully defined. Incertitude of information must be taken into account not only by the underlying CityGML model but also by the visual model so obtained. Visual features like transparency are already explored by us to represent uncertain information, but a much deeper study is still required.

Acknowledgements

This work‡ was performed within the framework of the LABEX IMU (ANR-10-LABX-0088) of Université de Lyon, within the program “Investissements d’Avenir” (ANR-11-IDEX-0007) operated by the French National Research Agency (ANR).

‡ http://alaric.liris.cnrs.fr

References

[AL15] AUTRAN J., LOCHARD T.: Décrire et exploiter la dimension territoriale et historique d'un patrimoine architectural et urbain. *Cybergeo: European Journal of Geography* (2015). 2

[BC12] BOGHANI A., CASALEGNO F.: Open locast: Locative media platforms for situated cultural experiences. In *UMAP Workshops* (2012). 2

[BD15] BLEISCH S., DYKES J.: Quantitative data graphics in 3d desktop-based virtual environments - an evaluation. *Int. J. Digital Earth 8*, 8 (2015), 623–639. 2

[BFH01] BELL B., FEINER S., HÖLLERER T.: View management for virtual and augmented reality. In *Proceedings of the 14th Annual ACM Symposium on User Interface Software and Technology, UIST* (2001), ACM, pp. 101–110. 2

[BNC*03] BOWMAN D. A., NORTH C., CHEN J., POLYS N. F., PYLA P. S., YILMAZ U.: Information-rich virtual environments: theory, tools, and research agenda. In *Proceedings of the ACM symposium on Virtual reality software and technology* (2003), ACM, pp. 81–90. 2

[cLZ16] ÇÖLTEKIN A., LOKKA I., ZAHNER M.: On the usability and usefulness of 3d (geo)visualizations - a focus on virtual reality environments. *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences XLI-B2* (2016), 387–392. 2

[GKCKH12] GRÖGER G., KOLBE T. H., C. N., K. H. H.: OGC city geography markup language (CityGML) encoding standard v2.0. *OGC Doc* (2012). 1, 2

[GLK*12] GRASSET R., LANGLOTZ T., KALKOFEN D., TATZGERN M., SCHMALSTIEG D.: Image-driven view management for augmented reality browsers. In *11th IEEE International Symposium on Mixed and Augmented Reality, ISMAR* (2012), IEEE Computer Society, pp. 177–186. 2

[GZL*14] GAN Q., ZHU M., LI M., LIANG T., CAO Y., ZHOU B.: Document visualization: an overview of current research. *Wiley Interdisciplinary Reviews: Computational Statistics 6*, 1 (2014), 19–36. 2

[MD06] MAASS S., DÖLLNER J.: Efficient view management for dynamic annotation placement in virtual landscapes. In *Smart Graphics, 6th International Symposium, SG Proceedings* (2006), vol. 4073 of *Lecture Notes in Computer Science*, Springer, pp. 1–12. 2

[OGC16] Open geospatial consortium, http://www.opengeospatial.org/, 2016. 2

[PCD*13] PFEIFFER M., CARRÉ C., DELFOSSE V., HALLOT P., BILLEN R.: Virtual leodium: from an historical 3d city scale model to an archeological information system. *ISRP Annals of Photogrammetry, 2-5/W1* (2013). 1

[PGG15] PÉRINAUD C., GAY G., GESQUIÈRE G.: Exploration of the changing structure of cities: Challenges for temporal city models. In *2015 Digital Heritage* (Sept 2015), vol. 2, pp. 73–76. 1

[PMG15] PÉDRINIS F., MOREL M., GESQUIÈRE G.: *Change Detection of Cities*. Springer International Publishing, Cham, 2015, pp. 123–139. 1

[QHLK15] QUANTIN M., HERVY B., LAROCHE F., KEROUANTON J.-L.: Mass customization for cultural heritage 3d models. In *Digital Heritage* (2015). 1

[RHPM*14] ROLLIER-HANSELMANN J., PETTY Z., MAZUIR A., FAUCHER S., , COULAIS J.-F.: Développement d'un sig 4d pour la ville médiévale de cluny. *Archeologia e calcolatori* (2014), 164–179. 1

[ROS15] RIZVIC S., OKANOVIC V., SADZAK A.: Visualization and multimedia presentation of cultural heritage. In *Information and Communication Technology, Electronics and Microelectronics (MIPRO), 2015 38th International Convention on* (May 2015), pp. 348–351. 2

[Sim12] SIMON G.: Modélisations multi-scalaires des dynamiques urbaines dans la longue durée: l'exemple du quartier abbatial de vendôme (41). *Cybergeo: European Journal of Geography* (2012). 2

[SMHW15] SCHWARTGES N., MORGAN B., HAUNERT J., WOLFF A.: Labeling streets along a route in interactive 3d maps using billboards. In *AGILE 2015 - Geographic Information Science as an Enabler of Smarter Cities and Communities* (2015), Lecture Notes in Geoinformation and Cartography, Springer, pp. 269–287. 2

[SPS*16] SAMUEL J., PÉRINAUD C., SERVIGNE S., GAY G., GESQUIÈRE G.: Representation and visualization of urban fabric through historical documents. In *14th EUROGRAPHICS Workshop on Graphics and Cultural Heritage* (2016). 1, 2

[VFW13] VAARANIEMI M., FREIDANK M., WESTERMANN R.: *Enhancing the Visibility of Labels in 3D Navigation Maps*. Springer Berlin Heidelberg, Berlin, Heidelberg, 2013, pp. 23–40. 2

[Wei97] WEIBEL S.: The Dublin Core: a simple content description model for electronic resources. *Bulletin of the American Society for Information Science and Technology 24*, 1 (1997), 9–11. 2

[ZTM14] ZHANG F., TOURRE V., MOREAU G.: Using metrics to evaluate and improve text-based information visualization in 3d urban environment. *22nd International Conference in Central Europe on Computer Graphics, Visualization and Computer Vision, WSCG* (2014). 2, 3