GIRAPIM. A 3D INFORMATION SYSTEM FOR SURVEYING CULTURAL HERITAGE ENVIRONMENTS

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ABSTRACT:

Several important goals for Urban GIS involve to Documentation, Information and Management Systems (DiMAS). Nowadays, there are good solutions for each one of them, but their integration poses still some non-trivial challenges. Between others, these challenges involve to a) interoperability between different tools, b) customized provision of services, and c) interactive dialogue with changing environments for different kinds of agents. In this work we describe our work in progress for the three mentioned issues which is being applied to Cultural Heritage Urban environments. The GIRAPIM solution developed in this work uses CityGML as a general semantic framework for integrating the above cited three systems, and displays some applications for interventions in public buildings and small urban districts with interest from the Cultural Heritage viewpoint. Some specific contributions of our approach concern to range-based modeling, the development of a specific Ontology common to DiMAS and the provision of web services along the life-cycle of intervention on the building or a small urban environment. The methodology is being applied for surveying interventions in isolated historic building and small urban district in several Spanish urban cities with interest from the Cultural Heritage viewpoint.

1. INTRODUCTION

1.1 General Instructions

Cultural Heritage environments, or more general AEC (Architecture, Engineering, Construction) environments, must be considered as living systems where different kinds of agents interact between them and with the environment by exchanging physical resources, functions and services to different scales. Their character as a *living system* involves to the whole life cycle relative to different stages and their corresponding *tasks* such as surveying (relative to land, urban, district and building objects), planning (relational database, updating), intervention (conservation or rehabilitation, usually), and maintenance (monitoring, tracking and validation). There are different kinds of *agents* (logical, physical) which operate to different scales going from microscopically agents for environmental issues, human agents (understood as users or technicians with different kinds of interaction involving to accessibility or interventions, e.g.), physical domain (buildings, urban district and surrounding nature) or variable environmental conditions (atmospheric conditions, unexpected events). All these tasks involve to the integration of Documentation, Information and Management Systems (DIMaS) with respect to a common geometric model, and the provision of services to different kinds of users, including technicians and citizens in general, with a special regard to disabled persons. This integration is a long-term goal; to start with, it requires an open source *semantic approach* for reusing available repositories, models and tools. A semantic approach includes a lexicon (key words), a thessaurus (definitions or descriptions which are represented as "relations") and taxonomy (set of logical rules for managing information and generating knowledge). CityGML provides a semantic framework which solves interoperability issues in AEC environments and provides a support for DIMaS. Our approach is based on an adaptation of CityGML \cite{kolbe2003towards} to Cultural Heritage buildings and small urban districts, where we are integrating Documentation, Information and Management Systems in a common software application. For developing an effective interaction in a smart monitored environment between users and 3D GIS, it is necessary to solve some issues concerning to IST infrastructure for monitoring, localization and tracking, which provides a support for interacting with the environments and providing services to different kinds of agents..

Regarding the *IST infrastructure*, the large diversity of hardware (proprietary solutions, electronic devices, etc), and software (operating systems, visualization systems) and communication protocols, requires to solve *interoperability issues* according to standards. Furthermore usual GPS systems for localization and Internet accessibility for web services provision, it is necessary to develop an environmental monitoring which can be performed from tags with different kind of sensors. A typical Services Oriented Architecture (SOA) has a modular structure with modules for environment monitoring, database management, information treatment (processing and analysis), and communications. All of them are referred to a 3D Information System which provides a logical support for the services deployment; in our case, the 3D GIS has been designed and implemented in the CityGML framework. Following the dual representation, each indoor or outdoor "space" is stored as a node with a numerical code (referred to GPS coordinates for outdoor environments, e.g.) with edges connecting nodes corresponding to adjacent spaces. For making easier the interaction with the environment, each tag with sensors for monitoring has an identifier which is referred to the nearest node. In this way, monitoring networks are constructed by reusing the low-level symbolic representation developed under the CityGML framework.

To avoid problems with proprietary solutions, it is appropriate construct *web services* for supporting advanced contents in the design and implementation of SOA. From communications viewpoint, the only technical requirement involves to the access to an external local (Intranet) or global (Internet) network. Obviously, the mid- or high-level CityGML functionalities can be used only at office or on a mobile PC at workplace. Technical details are developed in other works, and they will not be repeated here. However, to achieve low-level functionalities on small mobile devices (UMPC, PDAs or Smart Phones) it is necessary to perform a drastic reduction of range-based models which are described below. We have developed some low-level solutions which are based on an off-line extraction of dominant planes which are grouped in very low size local models which can be visualized on the display of small mobile devices; the availability of localization systems in indoor or outdoor environments and the interactive visualization of 3D contents based in Collada allows to select 3D pieces, make consults, update information and develop a dialog between technicians at workplace and office. Our solution uses the support provided by Google Inc. applications for navigating and providing additional contents which are visualized in the display of mobile device, and which can be activated following passive (detection of presence by automatic of tags containing RFID) or active (tactile display to be explored through user interaction).

CityGML [Kolbe and Groger 2003] provides the logical framework for developing applications focused towards planning and executing (conservation or rehabilitation) interventions in Cultural Heritage buildings or to provide services to citizens. CityGML is a new encoding standard, recommended by the Open Geospatial Consortium in August, 2008 [Groger et al, 2008]. In particular, we aim to provide a support for solving physical and digital accessibility issues to different kinds of users, with a special regard to technicians (in charge of solutions) and disabled persons in very restricted environments relative to indoor (Museums or Cathedrals, e.g.) and outdoor urban scenarios (urban district of Segovia, Spain). Different kinds of users (technicians, citizens, persons with some dependence or disability, e.g.) pose different requirements to perform planned tasks; hence, we have developed a multi-resolution approach based on a fusion of image- and range-based $3D$ modeling as support for DIMaS and linked services. For instance, (a) high-level resolution is adapted to office work requirements for tasks to be performed by technicians; (b) mid-level resolution is displayed on a Ultra Mobile PC (supported on a wheelchair for disabled persons, e.g.) for on-line updating information which are referred to high-resolution $3D$ models or for making easier customized queries (including access to the available database) or services (localization, additional information); (c) very low-level resolution is displayed on tactile interfaces of small mobile devices (PDAs or smart phones) with more limited functionalities which are linked to an interactive dialog with a monitored environment. Hence, the used device imposes additional conditions relative to the interaction supported by the visualization module; so, the standard Collada [Barnes, 2006] can be supported by an UMPC, but not for most small mobile devices, currently.

To provide a support for different kinds of users (technicians or disabled persons), there are typically several systems with the corresponding tasks including *Documentation Systems* -with surveying, monitoring, and modeling, as typical tasks-, *Information Systems* -with processing, analysis, data mining, visualization as typical tasks- and *Management* Systems -with planning, intervention, tracking and maintenance as typical tasks-. The above three Systems can be considered as "very large layers" which are superimposed as successive steps with an increasing complexity; in particular, Documentation System provides the support for Information System, and this one for Management System, with their corresponding geodatabase for storing, updating, processing and analyzing information which must be translated in a new knowledge about the environment and the interaction with different kinds of users. Three-dimensional Geographic Information Systems (3D GIS in the successive) include raster and vector data, with their corresponding reference systems. The design and implementation of multiple articulations between the above three systems (Documentation, Information and Management) requires a semantic approach for the knowledge management. A semantic approach provides a support for interactions between different agents in terms of ordinary language with key words which are structured according to acknowledged definitions (thesauri) and logical rules (taxonomies).

Regarding semantic aspects and following an obvious linguistic analogy with an increasing complexity, space-temporal models of interventions can be described in terms of (a) *syntactic elements* (in terms of "basic components" corresponding to morphological elements or materials), (b) *structural roles* (materials or elements, i.e. relations and basic laws for autonomous subsystems) and (c) *functional framework* (where tasks to be performed by experts are defined as paths in a space-temporal model superimposed to the architectural object). The information and knowledge management is performed in terms of a *logical structure* with the corresponding computer implementation for each specific Ontology; its structure can be defined in terms of classes, propositional, and/or descriptive logic, which is the most complex one for modeling and computer implementation. The available information is supported and managed by entity-relation diagrams which are specified in the developed ontology. Aspects related to lexicon and thessaurus with their corresponding logical structures (classes and propositional logic) are well known; the weakest aspects concern to high level taxonomies corresponding to some kind of descriptive logic for Knowledge Management Systems which are supported by different statistical tools. Regarding functional aspects, the entity-relation diagram provides the support for a space Γ of paths γ corresponding to tasks to be performed; on each path γ one can define scalar or vector functions, dynamical systems or functionals to be optimized corresponding to the management of tasks to be performed. Main tasks which are considered in our applications concern to *(i) Documentation System*: image- and range-based modeling; (*ii*) *Information System*: superposition onto the geometric model of information arising from the application of non-destructive and semi-destructive techniques in conservation and restoration tasks, including multisensor monitoring and tracking; *(iii) Management System:* including Economic Costs, feasibility, impact, and evaluation of solutions in a Multicriterion Optimization framework. A computer implementation of this scheme.

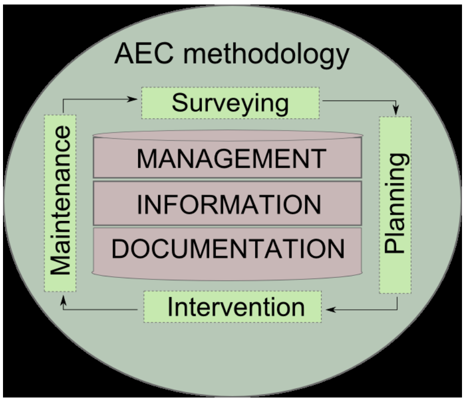

Figure 1: Overview of systems and AEC task

This work is focused towards the presentation of our contributions regarding integrated solutions for interventions to Cultural Heritage environments; these integrated solutions are designed following a typical scheme of Services Oriented Architectures (SOA) which are supported on Semantic 3D GIS and modeled in the CityGML framework. Our solutions are being applied to an indoor scenario -the Maritime Museum of Barcelona- and an outdoor scenario -a small urban district of Segovia- in Spain. The developed SOA is supported by two kinds of communication networks for indoor scenes (WiFi for the Maritime Museum in Barcelona) or outdoor scenes (Bluetooth or BT, for a historic urban district in Segovia). Localization services arises from a local integrated sensor network for indoor scenes given by tags with radio-frequency identifiers (RFID) for Museums, or outdoor scenes with Global Positioning Systems (GPS) for small urban districts; in both cases, the localization is referred to a 3D Information System in the CityGML framework. The available communication network restricts the type of dialogue, and the possibility of linked services; in particular, BT protocols (available in Segovia) support only a low-level interactivity which is based on deployment of multimedia contents, currently. An alternate solution as web service based on 3G technologies has been developed in outdoor (urban district in Segovia) and indoor scenarios (National Museum of Sculpture, Valladolid).

According to the above description, we have organized this paper as follows: We start by specifying the geometric framework

2. A GEOMETRIC FRAMEWORK AS REFERENCE

Urban or architectural environment, spatial planning and interactions simulation in complex environments have requirements that affect to an increasingly complex knowledge representation with respect to a well-defined and robust model. The robustness and accuracy is linked with geometric models: A well-defined geometry for an architectural context provides a support for advanced visualization including features such as navigation, inspection and extraction of metric information and interactive simulation of possible interventions, which are crucial for technicians. Simultaneously, the information exchange between different experts and the implicit information reuse in 3D models requires solving interoperability issues between different sources.

We use a hybrid approach to $3D$ architectural surveying arising from image- or range-based information, with georeferencing of capture devices in terms of different kinds of coordinates, including a topographic network, depending on customer requirements. Three-dimensional models of isolated buildings of small urban districts are constructed from a combination of image- and range-based information; a semi-automatic post-processing provides reduced low-resolution models which are exported to mobile devices for technicians field work or general information for citizens. An accurate georeferencing allows to provide services added to $3D$ models from the current localization of users.

The range information of our $3D$ models for isolated buildings or small urban districts has been captured with different laser scan devices extending previous work (started from [L.M.Fuentes 2006] for urban environments); these devices produce dense clouds "points" which store geometric information (spatial coordinates for the position) and radiometric (one channel for intensity in grayscale or three channels for color information). Aligning dense point clouds requires the selection of homologous points in different scans, scanning and alignment of views (with special regard to problems of relative orientation and height), cleaning of redundant information (different criteria optimization) and simplifying information. Typically, laser scanning is used for surveying individual buildings, but has also been used for scanning small urban areas (squares, streets, districts) where private or public agents are planning to perform some kind of intervention; nominal reaching of laser scan device (Ilris $3D$, Optech Inc.) is superior to one thousand meters. Some quarters of small villages have been scanned, by integrating cadastral information in the resulting 3D GIS, with some applications developed for local administrations. Scanning small urban areas generates clouds of tens or hundreds of millions of points that requires high computing power for advanced visualization with different levels of detail to include rendering, browsing, query, annotation and extraction of metric information.

There are technical solutions via hardware (requiring powerful machines in some cases for processing very large models), middleware (for connecting software components in distributed applications) or software (virtual parallel machines, for example) for intelligent compression or mesh simplification. In the same way as in CityGML and in despite of the large amount of information, we have developed solutions to different LoD which provide a remote support on office which can be updated in a remote way and for portable devices (SmartPhones and UMPC, mainly). From a geometric reference model in a remote server to two LoD, we have developed navigational tools on low resolution models allowing consultation, storing and updating from annotated images which are referred to the model. We have not still developed an automatic recognition of architectural elements and, because of this, the updating is performed in a manual way. In the same way, and following a simpler approach, from the current location our application provides multimedia services about real objects related to the scene. A crucial fact is the availability of models at different resolutions compatible with each other (common elements are present at each level of resolution) and tools for the progressive reduction of associated mesh to maintain the overall topology of the object. An automatic recognition of middleware embedded in device, allows to identify the resolution to offer depending on the device that aims to access the application remotely.

Three-dimensional modeling is usually performed in terms of meshes. The triangular meshes are very accurate but they present additional memory requirements and a very high processing power. Otherwise, quadrangular meshes provide a support for rendering on low-cost portable devices and, therefore, monitoring of processes linked to interventions and the provision of services based on highly simplified models.

A very simple case of quadrangular mesh linked to a 3D object corresponding to the collection of dominant planes (facades, roofs and floor) of a building which is represented as simple polyhedron (connected object without self-intersections). The collection of dominant planes is generated by data grouping of the unit normal map linked to a triangulation. There are different algorithms types (adjacency, "triangle soup") that allow spread "triangulation" provided the difference of unit normal vectors is below a threshold (the difference between affixes in the unit normal sphere is a vector whose length is under a threshold selected by the user). The result of this process generates a collection of regions *Ri*. which is the maximal connected region contained in a plane with a selected normal unit vector; maximality is defined with respect to the aggregation of adjacent triangles with a similar unit normal vector. An automatic selection of "nodes" (values with the highest frequency from statistical viewpoint) allow to identify the "winners" for most representative façades. The boundary of each planar maximal region is a non necessarily simple polygonal because it can contain "holes" (in other words, it is not necessarily simply connected). In the simplest case, this region is a rectangle which provides the support for matching views s maps of textures. The spatial intersection of adjacent dominant planes gives dominant edges (not necessarily visible), representing an extrusion of corners appearing usually in cartographic representations.

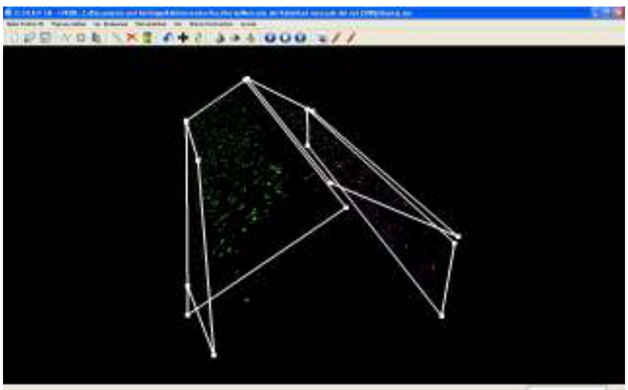

Figure 2: Example of semi-automatic dominant planes detection

The *semiautomatic extraction of dominant planes* in the software GIRAPIM application requires to identify several parameters by the user such as thresholds for maximal difference of length between affixes of vectors or the maximal number of dominant planes for the scene. However, after fixing meaningful parameters the detection and labeling of dominant planes is performed in an automatic way, allowing the automation insertion of typology (Facade, roof or floor). In this way, we obtain in an automatic way a doubly connected list given by a collection of structural elements with pointers representing the condition of sharing a common edge for two adjacent dominant planes. Finally, we obtain a reference model (Fig. 2) for supporting vector information; more details below in the section *3D Information modeling*).

3. URBAN ONTOLOGIES

According to T. R. Gruber, an Ontology is a specification of a conceptualization (see [Gruber et al., 1993] for more details). More explicitly, an ontology must show how to connect lexicon (vocabulary), thesaurus (dictionaries) and taxonomies (systems of logical rules) with the corresponding flowcharts. Given these components (lexicon, thessaurus, taxonomy), their articulation in an ontology is not unique, and this articulation can be understood as the specification of the Ontology, properly said. In the context of Cultural Interest Goods context (BIC in Spanish) we have developed a unique Ontology integrating aspects relative to domain (physical space), users (experts, disabled citizens and others) and tasks to performed. Aspects involving to the domain, users and tasks are articulated in a dynamic way by using events that occur in each context, even though the meaning may be different for each ontology. So, for example a ladder can be linked to a structural analysis (related or not with an intervention in the domain ontology) or poses an accessibility problem (for people with physical disabilities in the Ontology of Users)to be solved by technicians in relation to tasks location or movement (including within the task ontologies). In order to apply the Ontology it is necessary characterize and implement its architecture (lexicon, thesauri and taxonomies), populate and validate it. The first stage has required the participation of experts from different areas (Architecture, Linguistics, Computer Science among others), while the last two, has required the participation of different kind of entities (firms, institutions related to BICs and end users). Therefore, we have adopted a collaborative framework for the design and implementation of logical schemes and software architecture that manages assets and services in the two use cases.

The geometric support provides a framework for information which in our case is stored in relational databases. This framework makes easier the interoperability between additional tools for information processing and analysis modules which is contained in different repositories. Middleware solutions which include web servers and application servers which are distributed in different repositories. The collection of relations involving keywords of lexicon and their hierarchies is crossed with spatial relationships between building and urban elements. Relationships are of different kinds including spatial (inclusion, adjacency, intersection), functional (utility, order, value e.g.) or normative aspects (administrative norms, actuation protocols, e.g.). They involve to entities which are extracted from documents in different multimedia supports (text, image, volumes). The management of relationships between spatial entities and keywords is performed in terms of logical rules.

In our case, the specification of a semantic geometrically referenced framework facilitates the reuse of materials from a unique ontology with different knowledge fields involving the domain (physical domain, monitoring systems, equipments), users (technicians, citizens in general, dependent persons and tasks to be performed (interventions, visits, interactive dialog with the environment). The geometrical support is given by multi-resolution models supporting different functionalities or tasks. Tasks are topologically defined as paths in a physical representation of urban space (working space) or as temporal agenda in the representation of management system along the time. These models are geometrically defined by using geometric features common to different levels of detail, following CityGML methodology for urban environments or buildings. Their management is performed in terms of directed graphs associated to a dual representation of the physical space or a flow diagram of tasks. In this way, the symbolic representation of "spaces" by means of dual graphs (one node for each "cell") is extended in our work to tasks: each task represents a path which must be traveled across a subgraph of the entity-relation diagram. The formalization in terms of hypergraphs is under development, nowadays.

Taxonomies are given by systems of logical rules in charge of managing information and generating knowledge from relationships included in the entity-relation diagrams. There are different types of logical rules depending on the "expression" of the terms in the vocabulary, the glossary or the relationship. They follow an increasing order of difficulty in its formulation: logic of classes, predicates logic and other different methodologies of first-order propositional logic, second order or descriptive logic (managed by inference or bayesian schemes or fuzzy logic, e.g.). The machines usually operated with classes or propositional logic; however, in most of daily tasks humans operate with descriptive logic schemes, where heuristics or experience have a similar or higher value than in classes or propositional logic. Fuzzy logic has been applied for assisting decision making in AEC following principles of collaborative environments (see [Campbell, 2007]).

In our work, we have designed and implemented a software platform that provides a support for managing the intervention process in buildings and small urban districts. From the technicians viewpoint the application is focused towards SMEs (in charge of services, usually), cultural foundations and administration entities. Simultaneously, we have generated a documentation repository for cultural heritage in urban environments following the specified Ontology in the CityGML framework. In a more specific way, the documentation repository is focused towards assessing accessibility issues for people with some kind of psychic or physic disability (motion, hearing, visual). Hence, our application is a multi-purpose platform for documents, information and management issues having in account tasks (behaviors and actions) to be performed by different kinds of users (citizens in general or technicians).

4. 3D INFORMATION MODELING

Information Processing and Analysis are the two first stages of 3D building modeling in small urban zones. In our approach we have developed modeling techniques based on image or range information. GIRAPIM is a software application focused on hybrid modeling, CAD modeling (Fig. 3) and rendering tools for visualization. The hybrid characteristic concerns not only to the different nature of inputs (rectified images and clouds of points), but also to the reconversion of discrete digital information into a continuous one. In particular, clouds of points are grouped in dominant planes (corresponding to the ground, facades and roofs) which are grouped in bounded polytopes defined by connected polygonal of dominant planes with adjacency restrictions.

Detection of 3D primitives from discrete information (dense points cloud) follows a similar approach to the 2D case: filtering, local analysis and clustering, with two critical parameters: linearity and proximity of directional vectors. The resulting object is called an urban polytope which typically would correspond to a block bounded by a collection of streets to the ground level, and façades and roofs for the other dimensions. From the small number of polytopes we generate a volumetric segmentation for the urban model, where each building contained at each isolated urban polytope is labeled according to UTM coordinates. The subsequent urban model generation and customization is delegated to CAD modeling tools like Google SketchUp or Blender thanks to GIRAPIM DXF and Collada export facilities for features.

On the spatial model, we superimpose a layer of services which are referred to information systems for AEC environments. Traditional powerful CAD modeling tools have not incorporated semantic contents allowed by CityGML, like Kolbe et Al. showed in [Kolbe et al, 2008]. Knowledge management and semantic interoperability is a task delegated to the specified ontology in an upper layer. In this way each geometric object supports semantic information which can be independently collected for urban or architectural surveying; we have paid special attention to reporting specific Accessibility issues for disabled persons or Rehabilitation and Conservation tasks for technicians (see Fig. 3).

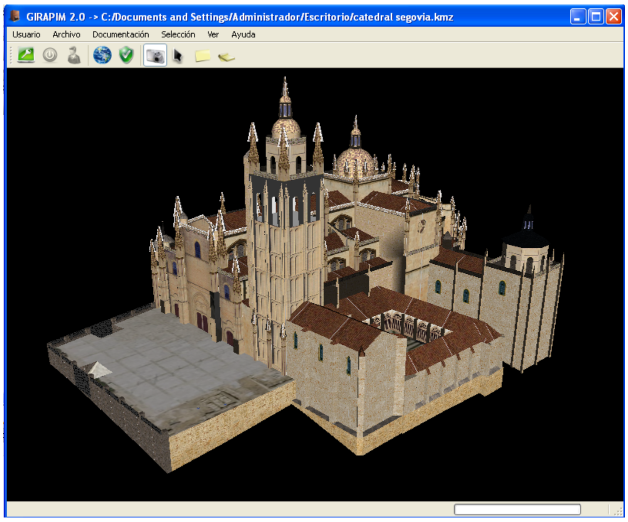

Figure 3: CAD Models for cultural heritage semantic documentation.

The generation of complex and detailed building models is not an issue managed by GIRAPIM because it is a well solved problem. But GIRAPIM allows the management of different levels of complexity at different levels of detail (LoD) suitable to user application domain, following the CityGML methodology. The resulting multi-resolution approach allows to manage models at different LoD with a variable complexity going from a simple cube model based on the detection of dominant planes to a cathedral model composed by a triangular complex mesh. Depending on the user type and their requirements, our application can display a model for urban scale contents for citizens in general, or, alternately a model for detailed information annotation for problematic aspects for technicians.

5. HERITAGE AND URBAN DOCUMENTATION

GIRAPIM has been developed as a collaborative environment for interactive 3D cultural heritage documentation. One of the most important application issue is the semantic support for 3D urban objects information provided by CityGML. GIRAPIM applies the CityGML data model for including specific aspects of cultural heritage environments based on thesaurus described by our ontology. The performed extesion is an affordable task thanks to CityGML Application Domain Extension mechanism. In our approach, we have developed the CityGML \textit{building module}, adding three new modules according to the three functional components of Ontology (users, tasks and domain), creating the Cultural Heritage ADE (see figure 4):

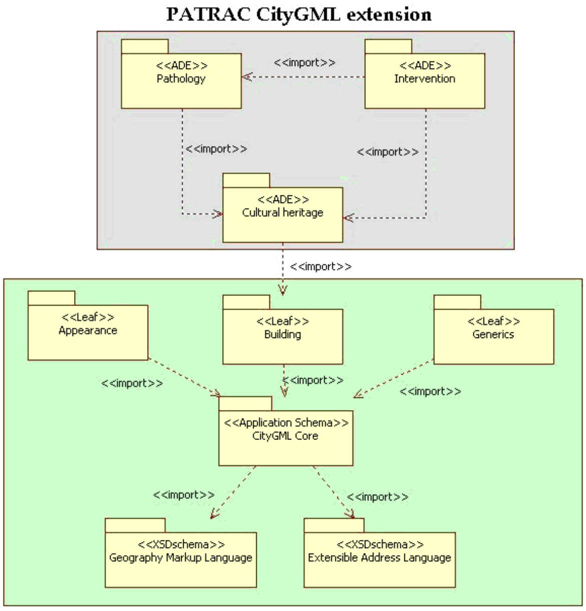

Figure 4: CityGML ADE for Cultural Heritage.

Each module can be described as follows:

- *Cultural Heritage*. It is the main module that imports CityGML building module. For us, a building is a collection of spaces (not only a room, a broader concept). Also, each space can contain a set of structural elements (like walls, arches, doors, ...). These characteristics are defined by CityGML as detailed below:

  Space = "Room"
  Constructive element = "IntBuildingInstallation"
  Monument (new entity) is a type of "AbstractBuilding"

  The Cultural Heritage ADE adds to CityGML some new entities (e.g. monument) and appropriate attributes which are specified in the thesaurus of the Ontology.
- *Pathology*. This extension for the building module is introduced for identifying accessibility problems and pathologies in buildings. An accessibility problem is defined by the space that contains it, while a pathology is associated with the corresponding constructive (structural or material) element.
- *Intervention*. This module includes new entities that represent the solution to solve pathologies and accessibility problems.

The Cultural Heritage ADE is a first step in order to provide future services such as semantic support for monitoring, context-aware information, automatic reports generation or management *agenda* for intervention process (typically in 4D models). Nowadays, we are developing several modules concerning to each one of them.

6. HERITAGE AND URBAN DOCUMENTATION

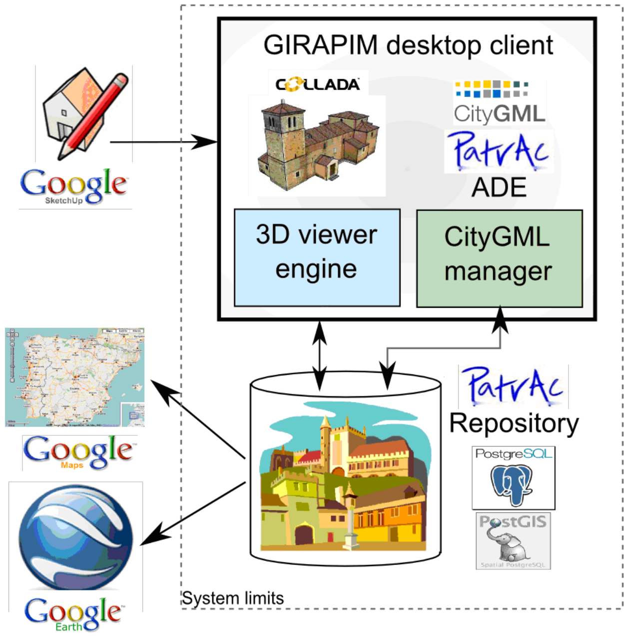

Figure 5: Overview of Girapim Architecture.

In cultural heritage domain technicians need to have an accurate model for information management. Furthermore, lower resolution models are desirable in order to provide information which can be explored by citizens in different kind of devices like Smart Phones or Mobile Internet Devices. For achieving these goals, we have designed and implemented the software application GIRAPIM as a client desktop tool. Figure \ref{fig:arch} shows some connections between different components, with emphasis on the viewer, the repository and CityGML module. Next, we shall will briefly describe each part of them:

1. *Viewer*. It is the component that enables visualization of semantic annotations and geometry 3D model. Based on OpenGL rendering technology (a Khronos Group standard), it shows the information overlaying a geometry and semantic layer. It is also responsible for picking and selection of objects in the scene with the mouse.
2. *Repository*. It is designed to provide support to CityGML and Ontology thesauri classes. It manages the central repository of contents for scenarios where accessibility problems are detected. Information is managed and showed by GIRAPIM, but it is available for other external services and applications in the semantic database supported by PostgreSQL [Momjian, 2001] database management system with PostGIS [Ramsey, 2005] extension enabled.

3. *CityGML*. This module is responsible for Cultural Heritage ADE data exportation. The set of CityGML entities extended by Cultural Heritage ADE cover completely the thesauri of the Ontology. In this way, database information contents can be exported and managed in the Web 3.0 framework, providing a support for interoperability with other services (see figure 4).

6.1 Interoperability

The main issue to solve in order to achieve semantic annotation simplification is the model interoperability. Nowadays, we have not still a complete ontology allowing modeling representation. Because of this, we have used an open standard like Collada, which is compatible with many visualization and modeling available tools, such as Google Earth or Blender respectively.
Collada (COLLAborative Design Activity) [Arnaud, 2006] is an open exchange file format for interactive 3D graphics, currently managed by the Khronos Group consortium. It defines a XML schema and vocabulary for exchanging digital graphics between applications. Originally created by Sony, today is shared between Sony and Khronos Group and it is supported by many game studios, graphic engines and modeling software (e.g. 3D Studio, Maya or Blender). GIRAPIM allows importing and visualization of Collada models (.dae) representing cultural heritage assets with up to high level of detail, especially at interior.

GIRAPIM also support Google Earth (.kmz) file import feature. KMZ is an acronym for KML [Wilson, 2008] compressed that can be easily linked with Collada graphic models. Above this models, users can include semantic tags displayable and navigable in 3D virtual globes and exportable to CityGML. For instance, data can be visualized in Google Earth, or in any web browser thanks to available plug-in. Thus, it simplifies the access and visualization of the semantic information from future Web Services, like in the work of Honda et Al. in [Honda et al., 2006]. Moreover, KMZ files can be easily exported from free version of Google Sketch Up allowing 3D surveying and reconstruction of buildings from satellite images. Semantic annotation process translates 3D geometric model data to 3D semantic model data in CityGML, which is necessary for agent reasoning capabilities. This approach takes advantage of CityGML geographic position of the semantic information in order to support task such as spatial reasoning, problem detection or 3D context-based information provision. With geometrically referenced information we can show context-aware information in 2D maps for mobile devices, allowing intelligent remote content provision. The creation of Web Services to transfer 3D semantic information between many different proposal systems is supported in this framework. GIRAPIM provides data access and management for high level tasks such as case-based reasoning and services in an Ontology and CityGML shared vocabulary.

7. CONCLUSIONS AND FUTURE WORK

Urban GIS are emerging as a new way for planning, publishing and managing building information for institutions and citizens. The addition of semantic data to geometric models and geography supports enables application interoperability and creates a common framework to develop a network of Web Services that connect people, things and local administrations. This opens an innovative common space for everyone that needs collaboration in order to create, annotate and manage the information. Our software application GIRAPIM is a prototype that supports these three tasks under the common CityGML framework. Although GIRAPIM allows semi-automatic low resolution building modeling, interventions tasks require a higher level of detail. Hence, these tasks must be performed with professional modeling tools designed for this specific purpose. Moreover, it would be desirable to have a more integrated city model, besides KML export feature, and a complete support and interoperability with focused business processes as in standard Building Information Modeling through IFC data. Following the same philosophy, we aim to include RDF publication of CityGML building data, in a way fully compatible with Web 3.0, allowing city and building reasoning and detection of risks, needs, etc, in the next future.

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