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CONSTRUCTORS OF GEOMETRIC PRIMITIVES IN DOMAIN ONTOLOGIES FOR URBAN ENVIRONMENTS

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SUMMARY: *A sustainable urban environment requires an integration of documentation and management systems in surveying and planning applications for different kinds of services involving services and processes. Traditional GIS approaches are geo-referenced to 2D information or, more recently, to a virtualized environment arising from the reprojection of textured views on 3D models. In this work, a tool for extracting dominant planes from dense 3D range information is applied for the automatic identification of structural elements (façades, ground and roofs) and their automatic labelling in terms of data of dominant planes. This tool is integrated inside the software platform UvaCad.*

The constructor of urban geometric primitives is given as a generator of 3D chains corresponding to the grouping of maximal planar quadrilaterals with "similar properties" for the normal unit vector. As a by-product, one has a semi-automatic volumetric segmentation of small urban environments as support for the development of a Domain Ontology in urban environments. Our methodology is illustrated with some examples corresponding to small villages and typical central squares (Plaza Mayor) of old Spanish cities.

KEYWORDS: *Ontologies,Urban Environments, CityGML, XML*

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1. INTRODUCTION

Urban or architectural surveying, spatial planning and simulation of interactions in complex environments present increasing requirements involving knowledge representation with respect to a well-defined and robust model. Robustness arises from geometric data and it is linked also to the automatic elimination of outliers from the computational viewpoint. An accurate geometry provides an objetive model and a robust support for advanced visualization, including functionalities such as navigation, inspection and interactive simulation of possible interventions. Simultaneously, the information exchange between different experts and reuse of implicit information on augmented 3D models require to solve interoperability issues between different resources with a large heterogeneity for data and metadata of 3D objects. Information reuse in repositories of 3D urban objects must be solved in a semantic framework relative to domain, tasks and/or users to different LoD. This issue poses general problems (see (Guarino, 1998), (Kuhn, 2001) for "old" references or (Zlatanova and Prosperi, 2006) for more recent results).

It is necessary to design a multilevel and multipurpose software platform able of integrating data of physical domain, actions or tasks to be performed and behaviours of different users with their functionalities and constraints (involving goals, roles and agents), and to solve the interoperability issues. The integration of modeling and software tools for design, simulation, execution and management of urban resources is an ambitious program which is still far from being achieved. There exists a general agreement about the need of developing a semantic framework for accomplishing this program, but there is still the need of developing software tools for processing, analyzing and exchanging information about different kinds of modeling and data treatment. The formalization of urban modeling is a relatively recent area with important contributions in the procedural framework (Parish and Muller, 2001), (Guarino, 1998) or, more recently, in the semantic framework (Teller, Keita, Roussey and Laurini, 2007), (Teller, Lee and Roussey, 2007).

An important challenge is the design and implementation of an integrated 3D information model for urban environments. The pioneering work of T.Kolbe (Kolbe and Gröger, 2003), and his collaborators is a reference work in this domain with important contributions of other R& D groups (Emgård and Zlatanova, 2006). The Open Source Software platform CityGML (`www.citygml.org/`) provides a modular approach for integrating surveying, planning and simulating interventions, and with several applications in technological domains. CityGML provides a hierarchical support for integrating every kind of spatial and non-spatial features in a common framework. CityGML is organized following a semantic approach for making easier the interoperability between different sources, tasks and knowledge domains. In this work a special attention is paid to semantic aspects related to Domain Ontologies for Urban Environments.

A *Urban Domain Ontology* concerns to the modeling of urban domains and knowledge about individuals and their relations in their spatial context. The logical support for urban modeling consists of objects and/or concepts, and their properties and relationships which are managed from a logic viewpoint involving attributes in measurable fields (geometric and radiometric properties usually, or in vector and raster data following the usual GIS terminology). Knowledge about relationships and individuals in a spatial context must be translated to interfaces used for generating and communicating knowledge following predicate or descriptive logics involving physical objects. A city is not only a set of buildings, not even can be reduced from the symbolic viewpoint to a network with nodes, paths and zones. The understanding of spatial delimitation is important for functionalities and uses which very often are historically and socially determined, and this involves to relations between different agents which must be translated in terms and logical rules.

A crucial aspect for linking objects and concepts concerns to the design and implementation of software tools for semi-automatic recognition of georeferenced data. Digital inputs arise from 2D views or 3D representations of volumetric objects. Low- and mid-level recognition from discrete data follow clustering principles with agglomerative (bottom-up, merging) and divisive (top-down, splitting) strategies. Constructors are nearer to agglomerative strategy from unstructured information, whereas descriptors would be nearer to the identification of attributes (radiometric properties, .e.g) or parameters (numerical data, .e.g) of basic elements which can be found in already available models. Constructors and descriptors are focused towards the construction of a generative grammar for urban environments. Obviously, the solution of this problem depends on the scale. For large scale, a very interested contribution for automating the generation of urban models from aerial skew photography (levels 1 and 2 in the terminology of CityGML) in terms of a constructive grammar following like-fractal models can be seen in (Lunazzi, 2006). Our work takes a different viewpoint because the inputs arise from range-based information arising from a laser scan device Ilris 3D (Optech). It is mainly focused towards a very limited class of constructors linked to piecewise-linear (PL- in the successive) modeling for boundary surface representations (BSP). Inputs for our modeling arise from merging discrete clouds of points captured with a Laser scan Ilris 3D (Optech).

Some issues regarding to computer implementation of Domain Ontologies including constructors and abstractors remain still open. Both issues are meaningful for Semi-Automatic Recognition and for management of domain ontologies, also. Constructor and abstractor operators are in some sense conjugate between them; they are strongly related to agglomerative and divisive approaches in regard to the physical support linked to a urban GIS. Traditional aspects arising from usual GIS (with their spatial hierarchies organized in different thematic layers) are semantically integrated as a physical support for the development of interactions involving similar functionalities, in despite of their morphological diversity. In this work, we restrict ourselves to specify some relations between vector data of a 3D GIS for buildings and their representation in terms of different geometric representations. Inputs arise from laser scanning and digital cartographic support for urban environments. Some cadastral applications have been developed for conservation interventions of urban neighbourhoods in small villages of Palencia (Spain). A related work can be found in (Stoter and van Oosterom, 2005).

A large number of old cities in Western Europe are articulated around squares as bounded spaces for organizing activities between individuals in a spatial context. The Plaza Mayor of Valladolid (Spain) is a paradigm because it plays an important role as institutional and political centre from 13th century, and it has been taken as model for designing a large number of squares between 16th and 18th centuries, not only in Spain, but also in Latin America; thus, we have paid some attention to this example (more details in (Finat et al., 2004) from a conventional GIS viewpoint). Irregularities in old towns are disappearing by modern urban re-design, but they are ubiquitous in smaller villages with vestiges of Renaissance style which are superimposed to an irregular network (sometimes with Arabian influence); to illustrate them, we have included some examples arising from the scanning of historical centre of several small villages of Palencia (Spain), with a semi-automatic detection of dominant planes and boundary surfaces for representing complex objects linked to larger urban spaces (squares, blocks). Our range-based method is explained in (Fuentes et al., 2006).

FIG. 1: Pasting dense point clouds

This paper is organized as follows: Section 2 is focused towards the presentation of some generalities about the application of Ontologies for urban environments. Section 3 deals with the method performed for extracting dominant planes. Section 4 involves to the construction of intermediate geometric entities (connected polygonals of dominant planes) which are meaningful for bounding urban environments (streets, blocks). Some remarks about designing schemata and populating ontologies are developed in section 5. A brief description of an experimental set-up is presented in the section 6. The paper ends with an exposition of work in progress and challenges for the next future.

2. GENERALITIES ABOUT ONTOLOGICAL APPROACH

Morphological urban diversity and the functional heterogeneity involving different agents performing complex tasks require a semantic approach with well specified ontologies for domain, agents and tasks. Following T.R.Gruber, an Ontology is a specification of a conceptualization. This specification can be formulated in different frameworks which involve knowledge fields as diverse as philosophy (a logical language for connecting different services and interaction modalities) or engineering approaches (software design and implementation).

Representations of physical space, relations between different agents and evolving complex systems provide a support for the interplay between GIS, logic and engineering approaches to Urban Ontologies. A first demarcation involves to the specification of lexicon, Thessauri and taxonomies for each Ontology. The specification of appropriate Lexicon and Thessauri for urban environments is being successfully accomplished in the framework of (www.towntology.net). Thessauri add relations between acknowledged concepts belonging to lexicon. Rules involving such relations are usually verified in an interactive way by validating logical predicates, including uncertainty aspects which are characteristic of human knowledge. Thus, Thessauri and taxonomies include functionalities (relations and operators) of a semantic approach, and must be inserted as an independent module of the database relative to the physical spatial support. The design and implementation of software tools for intelligent identification of such functionalities is a challenge for the next future.

More formally, a *semantic framework for geometric objects* appearing in *urban environments* concerns to specifying the *three levels* of an ontology for urban spaces:

- a *lexicon* given by terms involving basic geometric primitives (including dominant planes and simple quadrics, e.g.);
- *thessauri*, i.e. acknowledged vocabularies and definitions (glossary) between terms involving to different kinds of relations in buildings or urban spaces; and
- a *taxonomy*, i.e. a set of rules with the specification of logic types for management of roles played by primitives in urban spaces (streets, squares, open spaces e.g.)

The most difficult part concerns to the specification of taxonomies. Troubles arise from two sources: There are several types of logic (classes, propositional and descriptive), and we have not still a well-defined and commonly accepted formal linguistic for the logic verification of assertions in terms of relators and constructors. There are specific languages (RDF, RDF Schemata, OWL dialects) for managing taxonomies, but they are not enough flexible for describing restrictions involving the descriptive logic, which corresponds to the ordinary language. Due to this limitation for finding semi-automatic solutions and formalizing our knowledge, initial solutions introduce beacons on the scene or tags on data for solving recognition issues (manual labelling, usually).

The articulation between the above three levels must be hold in different types of ontologies involving the domain (urban typologies, mainly), tasks to be performed (surveying, planning, visualizing, modifying, consulting, extracting information) and different kinds of users (professionals, civil administration, business or services stakeholders, citizens, etc). The articulation holds at different levels and in terms of different ”events” linked to the interaction; it is symbolically represented by means of different kinds of graphs appearing in different layers which are connected between them with edges (active or not depending on events). Detection of events is a typical problem of recognition in scenes. To start with, we shall restrict ourselves to static events.

The automatic generation of Domain Ontologies requires to solve Recognition problems from digital support involving 2D views or 3D representations of volumetric objects as independent of user as possible. Recognition problems have a long history in Computer Vision with a feedback between bottom-up and top-down approaches. Query, retrieval, indexing and classification are the main stages for Recognition problems, but there is no still a satisfactory solution for complex objects such that those appearing in urban scenarios. Thus, it is necessary to restrict Recognition to a low number of (geometric or radiometric) primitives which can be grouped in more complex objects to be merged by means of clustering strategies depending on topological (adjacency, proximity, continuity), radiometric (similar grey intensity levels) or geometric (colinearity, coplanarity) constraints.

The application of segmentation and clustering techniques has allowed identify 2D zones, extract and enhance 1D boundaries and close polygonals linked to objects appearing in digital 2D cartography or aerial photography of urban zones. All these 2D data are exported to the 0th level of CityGML and labelled as meaningful data. The same techniques are applied to extract data in orthoviews of façades with a similar strategy for the automatic extraction of simple 2D primitives with their corresponding vector and raster data. These data are projected on 3D models by using the UvaCad software platform for the information insertion on 1st and 2nd levels of CityGML on a toy 3D model. Unfortunately, we have not still enough fine software tools for the automatic identification of simple geometric primitives appearing in buildings (details in façades, e.g.) in terms of their functionalities or their structural role, and labelling is manually performed, currently.

3. SEMI-AUTOMATIC DETECTION OF DOMINANT PLANES. LOCAL ASPECTS

The structural role of some components in urban scenes is better understood in terms of simple geometric 3D models, which can support higher resolution models by reprojecting views on 3D models. In this work, accurate discrete 3D models are generated from range information captured with the Ilris 3D laser scan of Optech. Color or textures arising from high resolution views are reprojected on the resulting dense cloud of points by means of simple geometric transformations between orthoviews and conveniently oriented clouds of points; this solution has been implemented in the framework of UvaCad software platform. A recent extension of this solution allows to identify dominant planes and linking them in polygonals in an automatic way. The estimation of dominant planes is performed by constructing a triangulation and by grouping adjacent triangles with a similar unit normal vector, up to a threshold which can be selected by the user.

A dominant plane is the support for a maximal connected planar region (not necessarily simply connected) with a total surface higher than a threshold fixed by the user; most of such planar regions are (unions of coplanar) quadrilaterals with holes corresponding to elements not belonging to the plane or shadows for the scanning (arising from partial occlusions, .e.g). In urban scenes, unions of coplanar quadrilaterals support the visible part of façades, roofs or ground, which are labelled with usual attributes introduced in CityGML. Currently, most of attributes are manually inserted. Only, labels relative to façades, roofs or ground are automatically generated.

The selection of the most meaningful dominant planes is performed by voting procedures for the list of normal unit vectors linked to a triangulation superimposed to the cloud of points. The distribution of normal unit vectors to the triangles is far from being uniform in the unit sphere. Indeed, there are a finite number of local maxima whose typical (modal) values correspond to dominant planes. So, a) normal unit vectors corresponding to façades are distributed along the equator; b) normal unit vectors corresponding to the ground are concentrated in the North Pole, up to streets with meaningful slopes; c) normal unit vectors corresponding to roofs are distributed along a parallel of the spherical representation whose typical slope depends on climatic or cultural aspects (including architectural solutions).

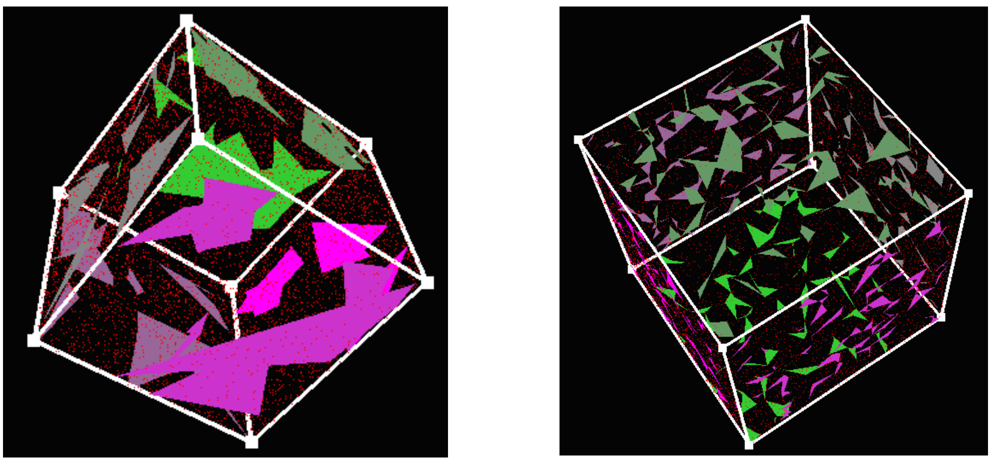

FIG. 2: Different resolution for dominant planes detection in a cube (100 pts. and 600 pts.)

Irregularities (due to the relative orientation or the reflectance variability, e.g.) or even discontinuities (due to partial occlusions, e.g.) in spatial distributions of clouds of points are a source of uncertainty for the automatic generation of 3D models. Thus, we have developed a coarse-to-fine methodology able of identifying coarse models even when one has only a ”soup of triangles” for a well-defined geometric structure. Coarse models correspond to simple geometric primitives (parallelepipeds, spherical or cylindrical components, e.g.), whereas fine models are linked to an estimation of curvatures from discrete clouds of points. For illustrating the developed method, a visualization of dominant planes corresponding to dominant planes of a cube is displayed in the next figure. Our application labels faces and draws theoretical edges corresponding to the intersection of adjacent faces by adding constraints relative to near triangles for computing intersections of dominant planes.

Dominant planes in urban environments provide a support for façades, ground and roofs, which are modelled as a union of 3D large quadrilaterals not simply connected (i.e. with holes corresponding to windows, doors, cornices, etc), whose boundaries are given as the intersection of dominant planes with nearest triangles. The visible part of the façade is not necessarily a quadrilateral. However, for the automatic identification of structural elements (in order to simplify their computer treatment), it is convenient to replace the visible part of the bounding surface by a quadrilateral Q_i. The quadrilateral Q_i can be obtained by a small modification of the algorithm based in the detection of extreme points for convex hulls. Depending on the package corresponding to the normal unit vector $\mathbf{N}_i$, each quadrilateral is automatically labelled with a superindex:

- (*f*) (façade) if the third component of $\mathbf{N}_i$ is null (up to a threshold)
- (*g*) (ground) if the first and second components of $\mathbf{N}_i$ are null (up to a threshold)
- (*r*) (roof), otherwise.

Automatic labelling is a crucial step for generating chains of elements belonging to the same type, and it allows recovering and managing street façades as a whole, e.g.. The selection of transversal sections to a cloud of points allows the automatic management in terms of 2D information. Next example is linked to a very narrow street of a small village (Paredes de Nava, Palencia, Spain), where one can select in an interactive way the allowed maximal number of dominant planes (7 in this case) for obtaining a polygonal where each segment represents the normal section of a façade (see figure 4). Small irregularities w.r.t. dominant planes are detected and displayed in order to correct the initial selection, before the final visualisation.

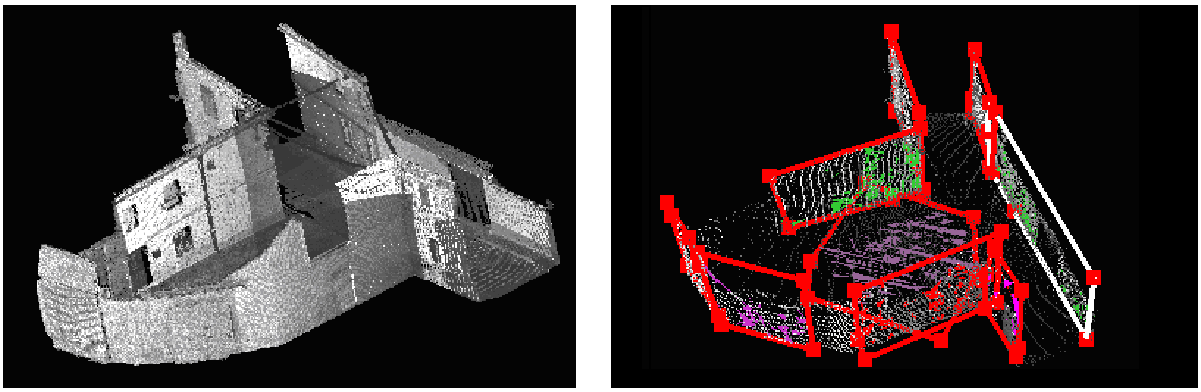

FIG. 3: Polygonal representation of a continuous facades in a Place. Becerril de Campos, Palencia, Spain

Furthermore, there exists a smart option which avoids the manual selection of the allowed maximal number of façades: it suffices to connect extreme ends of the polygonal by means of a segment $s_{0N} = \overline{\mathbf{P}_0\mathbf{P}_N}$ and evaluate the orthogonal distance of intermediate vertices $\mathbf{P}_i$ w.r.t. the added segment. If the distance $d(\mathbf{P}_i, s_{0N})$ is higher than a threshold, then replace the segment s_{0N} by the polygonal obtained connecting vertices $\mathbf{P}_0, \mathbf{P}_i, \mathbf{P}_N$. An easy iteration gives an improved polygonal.

Often, it is not possible the scan of roofs, but data arising from aerial photography can be inserted in an interactive way, by selecting an adequate number of control points. By merging maximal parallelograms linked to adjacent façades, we construct a polytope given bounded by 3D polygonal of dominant planes (including façades and roofs) which extends the usual 2D information based in digital cartography with high accuracy (error less than 2 cm for scale 1:100). This approach is compatible with multiresolution approaches. In absence of dominant planes (for open spaces, e.g.), one can choose an option for embedding a virtual bounding box which allows to generate virtual dominant planes and compute edges given lacking edges of quadrilaterals. Global management is performed in terms of octrees. This solution has been applied to a 3D Information System of 4 small villages of Palencia (Spain) with some vestiges of Civil Renaissance buildings.

4. MERGING DOMINANT PLANES. SYMBOLIC REPRESENTATIONS FOR TAXONOMIES

Automatic Detection of Dominant Planes provides a collection $\mathcal{Q}$ of quadrilaterals Q_i with adjacency relations. Hence, an adjacency graph $\mathcal{G}$ is associated to the collection $\mathcal{Q}$ of quadrilaterals. In the adjacency graph $\mathcal{G}$ each quadrilateral Q_i corresponding to a dominant plane DP_i is represented by a node $\mathbf{n}_i$; each segment $Q_i \cap Q_j \subset DP_i \cap DP_j$ of two quadrilaterals corresponds to the edge e_{ij} of the graph $\mathcal{G}$. Each edge is labelled with two superindexes of the collection (*f*), (*g*) or (*r*) depending on the label façade, ground or roof linked to labelling procedures described in the above section. A priori, the graph would contain cycles, but due to incomplete information some edges could be absent. The information can be completed by activating the option of generating a bounding box. Polygonal of planes with similar characteristics are symbolically represented by maximal connected subgraphs of the adjacency graph $\mathcal{G}$ whose nodes are labelled with the same superindex (*f*), (*g*) or (*r*). The Fig.4 displays a collection of façades belonging to the same tortuous street of Paredes de Nava (Palencia, Spain).

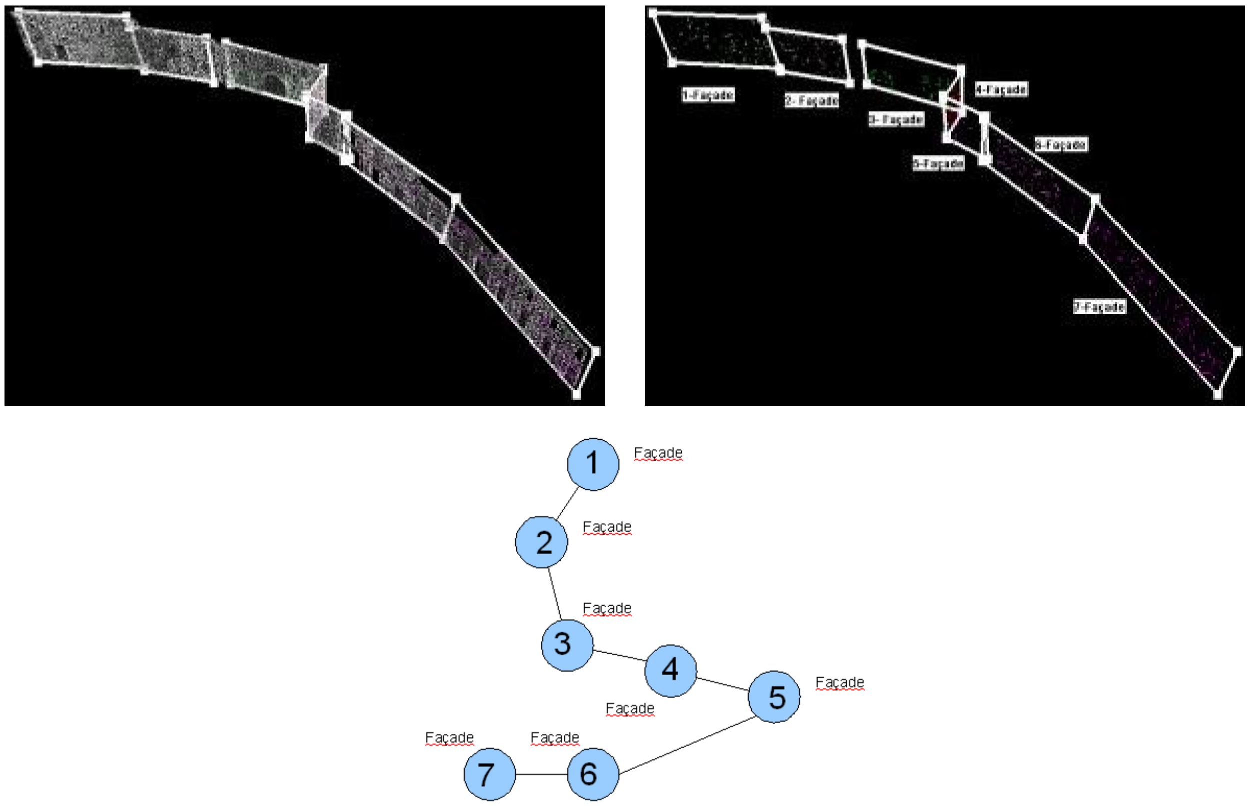

FIG. 4: Recognition and automatic labelling of planes in the streets of Paredes de Nava, Spain

Often the adjacency graph is not necessarily connected, not even for small urban environments. This can be due to thresholds for radiometric information (non-bounded extremes of streets or doors of country yards are not conveniently detected, e.g.) or to geometric considerations (self-occlusions, incomplete information about roofs or the ground, e.g.). The Fig.3 illustrates both troubles.

To solve these troubles, it is convenient to introduce a spatial or volumetric hierarchy obtained by cutting out the original cloud $\mathcal{C}$ of points with a bounding box. A regular spatial hierarchy is obtained from the superposition of an octree on the cloud $\mathcal{C}$ of points. In view of the large amount of information from original clouds, visualize sampled information of the whole cloud for each cell of the octree, only. However, by selecting the appropriate option in the menu, it is possible to increase the resolution for each octree cell. The recursive information management slows down the execution, but increases the performance of our application. The generation of polygonal of dominant planes corresponding to the street façades or surfaces bounding blocks allows to introduce an adaptive and more "natural" hierarchy attending to structural urban elements. In this way it is possible to generate small pieces of a spatial network where urban complex primitives inherits their characteristics from bounding surfaces in an automatic way.

5. DESIGNING SCHEMATA AND POPULATING ONTOLOGIES

Specific vocabularies for each knowledge domain provide the lowest level of ontologies corresponding to a typical lexicon; it is commonly managed in terms of relational database involving different kinds of multimedia documents. We have developed a specific lexicon and thessauri for each one of Ontologies relative to the domain, users and tasks to be performed related to interventions in Cultural Heritage buildings and urban districts. Labelling of multimedia documents supports the application of different kinds of representations for semantic of data. We have used RDF (Resources Description Framework) for information maintenance by means of a relational binary representation. Firtsly, we have applied this methodology to disperse Cultural Heritage goods in rural environments. In this case, we have populated this ontology by the manual insertion of tags according to Dublin Core Standards. The reuse of already existing DB for achieving a conceptual framework is performed by using local agents in a collaborative framework for documentation of strongly damaged vestiges of Cultural Heritage in rural environments. Limitations of inheritance procedures for traditional RDF are solved by means of the introduction of RDF schemata. However, a simultaneous searching of descriptions and RDF schemata requires a declarative language whose implementation is still in progress for this domain, including an extension to OWL and linked rules languages.

Having in mind cadastral applications for local administrations, we have developed an extended 3D Information System in a collaborative framework where several experts can perform different consultations, update information and generate reports according to access protocols. The simplest level for information management is performed in terms of a relational database with an extensible collection of terms and relations from users. A common conceptual scheme provides a mid-level structure for the domain ontology. The resulting methodology is being applied to conservation and restoration tasks in isolated buildings (cathedral of Leon), where several instances (General Direction of Cultural Heritage) or individuals (experts in conservation or restoration) insert terminological definitions which are very useful for populating the corresponding domain ontology. However, persists some ambiguity relative to the use of objects as concepts or, alternately, as things. Currently, labelling is performed in a manual way according to an extensible vocabulary on the 3D Information System GIRAPIM (Gestion de Informacion Relacionada con el Análisis Previo de las Intervenciones en Monumentos) which has been also developed by the DAVAP cluster.

The current version of the multiplatform software GIRAPIM is focused towards isolated buildings, and it provides a support for collaborative work of experts working on different layers with a common vector reference. GIRAPIM provides a support for retrofitting interventions in urban environments; it is designed and implemented following the CityGML standards, but by adding metric precision arising from range information (3D laser). Update and revision of daily information can be performed in a remote way, and the organization in different layers allows a remote revision and the insertion of simulated solutions (using VR tools which are being incorporated to UvaCad). To make easier and friendly for users the information management linked to GIRAPIM, a limited lexicon (about 250 terms) has been used for illustrating the reaching of this 3D Information System. This choice is justified by the need of development of robust solutions for generating the automatic association of labels to objects detected in 3D models arising from discrete clouds of points. The inherent ambiguity of traditional semantic approaches is avoided by taking as reference a hierarchy of 3D Geometric models for each level analysis in the same way as for CityGML.

6. EXPERIMENTAL SET-UP

Two sensitive parameters in the detection of dominant planes are the chosen resolution for the cloud of points and the tolerance relative to the deviation from a typical value for unit normal vectors. Due to irregularities in the distribution of clouds of points, for detecting dominant planes, it is convenient to work with redundant information; so, for simple geometric primitives (planes, spheres, cylinders, e.g.) it suffices to take some hundreds of points which can be obtained from several sampling procedures based in brute force (decimation) or smart (RANSAC or IMPSAC) algorithms. Tolerance (between 0 and 1) determines the granularity of the estimated plane; a very low tolerance generates too many non-meaningful planes due to noise, whereas a very high tolerance includes many different planes in only one, by losing meaningful information. In our examples, the value 0.04 has been chosen as the most appropriate for the information relative to dominant planes for houses of villages of Palencia. In our application, it is possible also to select the maximal number of triangles, and voting procedures impose strong limitations on the maximal number of dominant planes. This method has been applied to isolated houses, street façades, and blocks of houses.

If the cloud has lesser than 50.000 points the "soap-of-triangles" method combined with a search of nearest neighbours (managed with octrees) provides a collection of dominant planes in less than one second in a Core 2 Duo 2.0 GHz. For larger clouds, the performance is worse; so for instance, for one hundred thousand points with six thousand triangles, our processor spends almost five seconds.

7. WORK IN PROGRESS AND CHALLENGES

Nowadays, we are developing the appropriate interfaces for linking our processing tools with CityGML modules involving the Appearance, Building, and CityObjectGroup as the most meaningful models for levels 1 and 2 where we are working on (see CityGML UML diagrams). In the mid-term, the main trouble is linked to the design and implementation of appropriate taxonomies for populated Ontologies. Nevertheless the persistence of irregularities in façades (ornamental details in towers or cornices) and roofs (dormer windows in attic flats, e.g.) are not easy to recognise in an automatic way, and requires still a high degree of interaction from user.

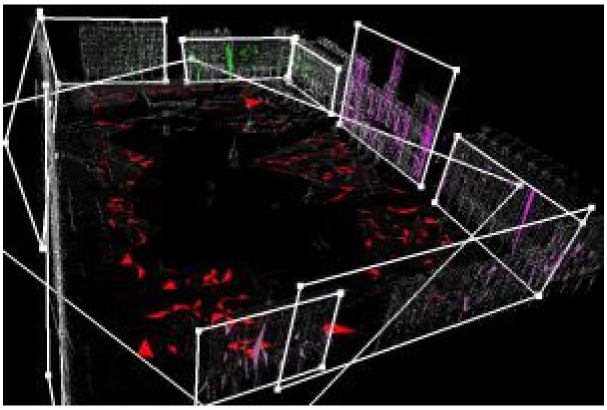

FIG. 5: Plaza Mayor Valladolid reduced by 1 point for 0.5 m. Automatic recognition is difficult for complex facades.

Design and implementation of taxonomies for urban environments concerns to the automatic extraction of structural elements and their automatic labelling depending on the functional role. An extension of GIRAPIM to larger urban environments of cultural interest is in development.

8. CONCLUSIONS

Semi-automatic Recognition requires the capability of relating structural elements of buildings with their meaning in urban context. Semi-automatic character corresponds to an interactive selection of parameters relative to resolution, tolerance and number of planes, e.g. In this work, we have developed a method for extracting and grouping dominant planes from sparse clouds of points without additional reference to cartographic information, according to levels of proximity and information coherence of small urban environments. Our application allows to obtain information about structural elements of buildings and blocks in regard to their urban environment (streets and squares, mainly) which are symbolically represented by means of a dynamic graph. The modular design of our application for the detection and grouping of dominant planes allows the adaptation to almost every urban environment, and its integration in any application related to management of architectural information. Furthermore, it is possible to add raster information (textures or roofs from ortho- or skew views), and export the resulting data to geometric formats compatible such as those used in CityGML or X3D.

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