Technical Push on 3D Data Standards for Cultural Heritage Management

Peter DORNINGER & Wolfgang KIPPES & Josef JANSA

Dr. Peter Dorninger & Prof. Dr. Josef Jansa, Vienna University of Technology, Christian Doppler Laboratory for "Spatial Data from Laser Scanning and Remote Sensing", Gußhausstraße 27-29, 1040 Vienna, pdo@ipf.tuwien.ac.at, jj@ipf.tuwien.ac.at

Dr. Wolfgang Kippes, Schloß Schönbrunn Kultur- und Betriebsges.mbH, 1130 Vienna, kippes@schoenbrunn.at

1 INTRODUCTION

The *World Heritage Site Schloß Schönbrunn* comprises various buildings and a park with different vegetation, altogether some 1.5 km². To provide an economic basis for future operation and maintenance, to extend the business area and to increase the service quality, an adequate information system based on spatially related data is essential. Data acquisition devices combining laser scanning (often referred to as LIDAR) and digital photogrammetry, are well suited to capture the geometric information together with the photo-texture of historical sites. The level of detail provided by such sensors is permanently increasing, thus, affecting data modeling and management. Unfortunately, broadly accepted standards for handling these data in a proper way are still missing.

This paper discusses attempts by the *European Commission* and by national authorities on standardizing spatial data management. The current trend towards *Free* and *Open Source Software* is highlighted as well. The conceptual design of the *Integrated Facility and Asset Management (IFAM) Schloß Schönbrunn* will be used to point out the advantages and deficiencies of currently available standards for spatial data interchange and management. The current status of three-dimensional data structures for efficient data management in spatial information systems are addressed, too.

2 DATA ACQUISITION

During the past ten years, an amazing shift, from basically manual geometric data acquisition methods based on analogue techniques towards automatic or at least semi-automatic workflows, mainly based on digital data acquisition, took place. Current digital cameras provide images at a resolution, comparable to analogue films. Laser scanning – airborne and terrestrial – enables the sampling of highly accurate three-dimensional point clouds of objects at almost any scale, ranging from large scale models at a very high degree of details (e.g. statues, coins, reliefs, etc.) to small scale representations of whole buildings or even cities. Therefore, these methods of data capture enhance the documentation of historical sites and cultural heritage.

The *Schloß Schönbrunn Kultur- und Betriebsges.mbH* participates in the *Christian Doppler Laboraty for „Spatial Data from Laser Scanning and Remote Sensing"*, affiliated to the *Institute of Photogrammetry and Remote Sensing, Vienna University of Technology*. Different data acquisition instruments and methods are currently investigated in order to define preferably automated or at least semi-automated workflows for data acquisition of the *Schönbrunn* facility. For testing purposes, the following datasets were recently acquired or already available:

full-waveform airborne laser scanning data, acquired by a *Riegl LMS-Q560* covering the whole area comprising the buildings and the park at a total extend of some 1.5 km²

"conventional" airborne laser scanning point cloud of the whole area (first and last pulse), acquired by a *Riegl LMS-Q280*

digital aerial images, acquired by the airborne digital camera-system *Vexcel Ultracam-D* (10 cm ground resolution in panchromatic mode and in pan-sharpened true color (RGB) and color infrared (CIR) mode)

laser scanner point clouds and digital color images covering several historic rooms, acquired by a *Riegl LMS-Z420i* in combination with a *CANON EOS 1Ds*

line drawings, orthoimages and CAD-based 3D reconstructions from facades

The following Fig. 1 shows a three-dimensional plot of the signal amplitude registered by the full-waveform laser scanning system *Riegl LMS-Q560*. The target was a horizontally fixed tree in front of a slab (see Fig. 2). As can be seen from Fig. 1, the amplitude of the backscattered signals on the slab is smaller for beams which have passed through the tree due to signal attenuation, i.e., the signal energy is partially absorbed by the tree.

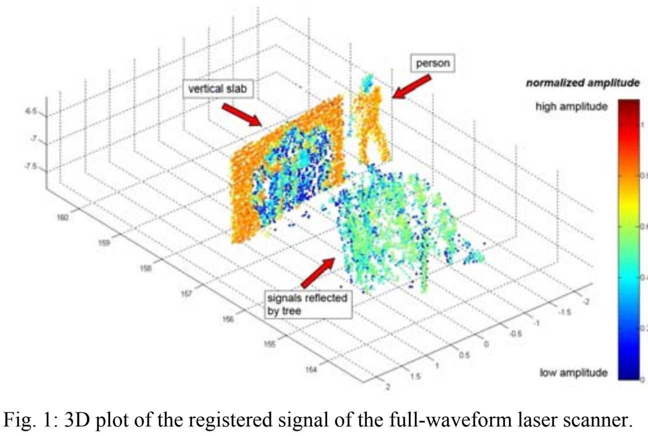

Fig. 1: 3D plot of the registered signal of the full-waveform laser scanner.

Fig. 2: Image of the full-waveform test field.

In this example, we registered up to 9 echoes per beam. This information will enable us to derive a truly three dimensional representations of the sensed objects as opposed to the prevalent 2.5 models derived form first/last-pulse data. Furthermore, even the

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surface characteristic (i.e. roughness, steepness, …) will become discernible. Wagner et al. (2004) describe the theoretical model and basic ideas of full-waveform laser scanner application.

Further investigations aim at:

automated modeling of roofs fusing airborne laser scanning and digital aerial images (Peternell und Steiner, 2004; Rottensteiner et al., 2004)

reconstructing historic rooms and facades for virtual modeling and further visualizations

These data acquisition methods will provide geometric models as a reliable basis for the *Integrated Facility and Asset Management (IFAM) Schönbrunn*. The *IFAM* is intended to support the maintenance and restoration of *Schloß Schönbrunn* as World Heritage Site in an economic manner and to increase the efficiency of the provided services (e.g. tourism). The fundamental basis of this system are geometrically accurate and topologically consistent models of the facility. As a matter of fact, the necessary data structure has to support four dimensions: three location coordinates (x,y,z) and the time component in order to maintain the historical state. As it might be used for planning purposes as well, future states have to be managed, too.

3 3D DATA STANDARDS

As mentioned above, current data acquisition workflows enable a fast and precise capturing and modeling of real world entities such as cultural heritage. Furthermore, the internet has emerged as the standard medium for data transport and distribution. Therefore, real-time data requests from different, distributed data repositories are feasible. This bears the possibility to create multi-nation information frameworks for any kind of spatial information. Thus, it should be easily possible to combine information and models available from different sites.

International and nationwide committees have recently started to work out and subsequently define standards for geo-data management and exchange. Their main intention is to create a basis for *eGovernment and eCommerce*. On the one hand, the efficiency of managing country-wide, or even continent-wide available spatial datasets (e.g. land register information, road maps, power lines, ...) shall be increased by avoiding redundant storage of information. Thus, only one institution which is in charge of the data has to manage it. On the other hand, the availability of the data for other administrative and commercial users shall be simplified by supporting direct access to the originally managed datasets. This principle is also knows as “data at the source” model.

3.1 International and European Frameworks for Data-Standardization

The *eEurope 2005 Action Plan* (eEUROPE, 2005) is a common initiative defined by the *European Commission (EC)*. This plan aims at *“developing modern public services and a dynamic environment for e-business through widespread availability of broadband access at competitive prices and a secure information infrastructure”*. The “*Interchange of Data Between Administrations*” (IDA, 2005) is a European program using advances in information and communication technology to support electronic exchange of information between public administrations across Europe. IDA as contributor to reach the *eEurope Action Plan* published a working paper *“Linking up Europe”*. This contribution aims at *“achieving acceptance from key decision and policy makers in Europe on the need for interoperability both within and between administrations and with the enterprise sector”*.

Infrastructure for Spatial Information in Europe (INSPIRE) is an initiative to *“create a legal framework for the establishment and operation of an Infrastructure for Spatial Information in Europe, for the purpose of formulating, implementing, monitoring and evaluating Community policies at all levels and providing public information.* […] *INSPIRE focuses on environmental policy but is open for use by and future extension to other sectors such as agriculture, transport and energy.* […] *INSPIRE will not set off an extensive programme of new spatial data collection in the Member States. Instead, it is designed to optimise the scope for exploiting the data that are already available, by requiring the documentation of existing spatial data, the implementation of services aimed at rendering the spatial data more accessible and interoperable and by dealing with obstacles to the use of the spatial data. INSPIRE will pave the road for a progressive harmonisation of spatial data in the Member States.“* (INSPIRE, 2005). The INSPIRE proposal for a directive has been adopted by the *EC* in 2004.

The *European Committee for Standardisation (CEN, Comité Européen de Normalisation)* set up a technical committee *CEN/TC 287 – Geographic Information* (CEN, 2005). This committee defined a set of eight European norms and four European reports from 1992 to 1999 concerning geo-data related topics (e.g. spatial schema, quality, metadata, ...). The *International Organisation for Standardisation (ISO)* set up the technical committee *ISO/TC 211* in 1995, absorbing the European work program of CEN in the beginning. Currently, ISO has already published some 20 standards. All together 40 work items concerning geographic information are currently dealt with. These are commonly referred to as ISO 19000 series (ISO, 2005).

3.2 Austrian Efforts

Several countries have already decided to realize web based data repositories of spatial data for public administration. E.g. the *British Ordnance Survey* (OS, 2005) provides its *Master Map* as a seamless and feature based dataset including topographic information on every landscape feature – buildings, roads, open areas, wooded areas, water and much more in a polygonal format. Data accessibility is realized using the standardized *Geography Markup Language* (GML – see section 3.3.1).

In Austria, several committees have recently started to work on standardization of spatial data management and distribution. A final decision is still missing. Active decision makers are *Österreichische Raumordnungskonferenz (ÖROK, 2005)*, *Österreichischer Dachverband für Geographische Information (AGEO, 2005)* and *Austrian Standards Institute (ON, 2005)*. *ÖROK* integrates members of the Federal Government, the Federal provinces and the communities. One of the goals of *ÖROK* is the definition of a framework for an Austrian Geo-Data-Infrastructure (GDI). It aims at preparing a statutory, nationwide framework for non redundant management and distribution of spatial data. *AGEO* acts as umbrella organization between the public and the commercial companies and thus, supports the acceptance of public decisions. Finally, the task of the *ON* is to provide an applicable framework of standards and norms, which meets the Austrian requirements.

3.3 Available Implementations

International and nation-wide standards define a basis for standardized data management and exchange between data vendors and customers. But they are not applicable for common usage. Therefore, widely acceptable implementation specifications and data formats need to be defined. An independent organization for standardization of spatial data is the *Open GIS Consortium* (OGC, 2005).

The OGC provides specifications at two different levels: *Abstract specifications* and *implementation specifications*. Abstract specifications define standards in a general way without considering their application on a specific platform. On the contrary, implementation specifications consider specific platforms. Therefore, they can be applied by software developers and data vendors.

OGC specifications define two structures for the representation of spatial objects. These are *geometrical (i.e. simple feature specifications)* and *topological (i.e. complex feature specifications)* (Stoter and Zlatanova, 2003). The Simple Feature Implementation Specification is implemented in many commercial systems. But Simple Features are restricted to a two-dimensional representation of simple geometry object types such as line, poly-line or arc. Some systems allow to assign a height attribute to each coordinate tuple, thus, describing a 2.5 dimensional geometric model. Three-dimensional objects cannot be represented using Simple Features.

Topology describes neighborhood relationships of objects. The basic structures are *nodes* (representing points), *edges* (representing border lines), *faces* (representing areas) and *volumes* (representing bodies). Two different types of topological relations can be defined. The *inner topology* describes the relationship between the elements of an geometric object. The *external topology* describes the relationship between different geometries. *ISO* and *OGC* have started to define specifications for *Complex Features* and *3D Geometries*. Up to now, only Technical Reports are available and no International Standard has been released so far.

3.3.1 Geography Markup Language

The *Geography Markup Language (GML)* is an application of the Extensible Markup Language (XML). XML is a structural and semantic language which enables to describe the encoded information using a predefined syntax consisting of three different logical structures: *Tags*, *attributes* and the *data* itself. XML is a meta language. Thus, it can be used to define other markup language such as GML. The valid structure of an XML document is defined either by Document Type Definitions (DTD) or by XML Schema Definitions (XSD). XML Schemas are standardized by the *World Wide Web Consortium (W3C, 2005)*, defined using XML and provide more flexibility than DTDs. Thus, they are preferably applied to define XML applications.

Currently, GML version 3.0 is released since January 2003 (version 3.1 is available as committee draft). The following list gives an overview on features of GML 3 which were not addressed or adequately met by the previous version 2 (Cox et al., 2003):

representation of geospatial phenomena in addition to simple 2D linear features, including features with complex, non-linear, 3D geometry, features with 2D topology, features with temporal properties, dynamic features, coverages, and observations;

an improved support for properties of features and other objects whose value is complex;

representation of spatial and temporal reference systems, units of measure and standards information;

usage of reference system, units and standards information in the representation of geospatial phenomena, observations, and values;

representation of default styles for feature and coverage visualization;

conformity with other standards from the ISO 19100 series.

Thus, GML 3 provides the capability to represent complex, non linear (e.g. Cubic Spline, BSpline, Bezier, Clothoid, ...) 3D geometries. By aggregation of individual geometry objects, more complex objects can be defined (e.g. facility models). Coverages can be used to describe surfaces e.g. as Triangulated Irregular Networks (TIN) or as rectified grids. The rectified grid specification allows any affine transformation of the given rectangular coverage. Furthermore, GML 3 supports to define a topology, but restricted to 2D.

3.3.2 Industry Foundation Classes

The *Industry Alliance for Interoperability (IAI, 2005)* is an international cooperation of more than 650 members drawn from more than 20 countries. It was funded in 1995. The IAI's vision is *"to provide a universal basis for software interoperability in the AEC/FM (Architecture, Engineering, Construction, and Facilities Management) industry"*. Its solution for common, global interoperability are the *Industry Foundation Classes (IFC)*.

The IFC are designed to support the whole life-circle of a facility from planning, through construction and usage, to its demolition. They define all available parts of a facility as objects. Thus, all applications supporting the standard are able to interpret the represented objects. In contrary to common 2D and 3D geometry data formats (e.g. DXF, ESRI shape files, ...), IFC are capable to model numerous attribute and meta information related to the geometry. The current version 2x2 supports 3D geometry types.

IfcXML (current version 2, ifcXML2) defines the complete IFC Model using the XML Schema Definition Language (XSD). The ifcXML2 methodology is compatible with the current pre committee draft (CD) version of the upcoming standard to convert EXPRESS structures into XML schema structures - ISO10303-28 ed.2. IfcXML2 is approved for the generation of XML schema definitions for IFC2x Edition 2 and forthcoming IFC releases (IAI, 2005).

Currently, the IFC-interface support of some 10 software developers (e.g. Autodesk, Bently Systems) is positively validated within a two step certification process by the IAI.

3.4 Database Management Systems

Almost any mainstream *Database Management Systems (DBMSs)* support spatial data types and spatial operators for Simple Features. Some systems provide very basic functionality (e.g. length, perimeter) to be applied to 3D objects which are evaluated three-dimensional. Even three-dimensional queries are supported to a certain degree. But no current system provides three-dimensional geometry primitives such as, e.g., tetrahedron or polyhedron and, as a matter of fact, more complex geometries are not supported, too.

Complex Features, i.e. topology, are currently not supported by most DBMSs. Oracle Spatial 10i (released in spring 2004) is the first and only commercial system which supports topologic primitives, i.e. nodes, edges, and faces. But these are restricted to coverages (two-dimensional). Nevertheless, several topological operations are supported (Oracle, 2004).

All above mentioned DBMS are based on the relational database model. This model describes real world object types (often named entities) using relation schemata R={A_1, A_2, ..., A_n} with the attributes A_i representing common properties of an object. Relational DBMS (RDBMS) are currently dominating the commercial market. This model was invented in 1970 by Edgar F. Codd (1970). Due to the restrictions of the relational model concerning the adequate management of objects, most systems implement so-called Object-Relational extensions. These provide object data types and adequate functionality enabling the modeling of geometry primitives (Simple Feature) as single attributes.

The *Object-Oriented Database Model* (OODBM) would be more appropriate for managing both, geometric and topologic information. A hierarchic approach for a geometric model of a building (e.g.: building – room – wall – surface structure – ...) could be realized easily using object-oriented data modeling. Furthermore, restrictions of the standard query language for relational databases, the *Structured Query Language* (SQL), could be overcome. For example, SQL can not be applied to navigate through a topological model (e.g.: follow the edges until the start point is reached again). But, there are several restrictive facts concerning OO-DBMSs. On the one hand, the commercial market is dominated by several powerful database vendors which rely on the relational schema. On the other hand, no standardized query language is available for OODMBs and the separation between the DBMS and the application is rather fuzzy (Oosterom et al., 2002).

3.5 Open Source / Free Software

Currently, there is a remarkable trend towards *Open Source Software (OSS) / Free Software (FS)* solutions. OSS means, that the source code of an application is available to the user. But an OSS need not be a FS as well. FS includes *"the users' freedom to run, copy, distribute, study, change and improve the software"* (GNU, 2005). This does not imply the availability of the source code.

Following this development, the *Schloß Schönbrunnges.mbH* migrated from a commercial *Windows* environment to an OSS/FS *Linux* system in 2004. This decision has two advantages: It helps to save license costs (but additional user training costs have to be considered) and it provides the possibility of source code transparency. Thus, it should be possible – for experts – to interpret the functionality of the software system and therefore, no hidden features should occur (e.g. unintentional information transfer to a third party, ...). The opportunity to modify the source, e.g. to guarantee data security, is another advantage which encouraged several national authorities to migrate from proprietary to FS/OSS solutions. Nevertheless, considering the complexity of several OS-systems, the effective transparency of the source-code might be questionable. Furthermore, the EC is currently thinking about new laws concerning copyrights and patent law of FS (and for commercial software as well) leaving a large field of uncertainty concerning possible future license costs or royalties.

4 DISCUSSION

The previous section gave an overview of the current situation on standard and software availability, necessary to build up a Geo-Data-Infrastructure (GDI). In the following, several technical aspects and decisions concerning the realization of a GDI are discussed. In this context, the conceptual design of the *IFAM* is used as exemplary application.

4.1 3D has to Overcome the Restrictions of 2.5D

Most spatial data repositories are based upon 2.5 dimensional geometric models. This might have historical reasons, as former data acquisition and management techniques were not able to support real three-dimensional data structures in an economic manner. E.g., an analog map is not an appropriate tool to represent the complex geometrical information modeling a facility like *Schloß Schönbrunn*. Furthermore, most currently available datasets (land registers, building maps, ...) were digitized once and stored in appropriate two-dimensional data formats. In some cases, an available height attribute was assigned. To model this information in a DBMS, the application of the Simple Feature Specification is sufficient. In order to realize a full three-dimensional cultural heritage management system like the *IFAM*, also data structures have to be realized throughout three-dimensional. This includes the availability of three-dimensional geometric data types, of topology representation and of appropriate functionality for management (e.g. indexing) and retrieval (e.g. querying) of the data.

4.2 Topology versus Geometry

As a matter of fact, a three-dimensional data structure is more complex to be dealt with compared to a 2.5 dimensional one. In order to increase the data quality by preventing redundant and inconsistent data, the modeling of the topology becomes essential. Oosterom (2002) lists the impact of consistent topologic models on the quality of the corresponding geometric model:

it avoids redundant storage (more compact than a full-polygon model);

it is easier to maintain consistency of the data after editing;

it is more efficient during the visualization in some kind of front-end, because less data has to be read from disk;

it is the natural data model for certain applications; e.g. during surveying an edge is collected (together with attributes belonging to a boundary); and

it is efficient for certain query operations (e.g. find neighbors).

Considering this, and due to the fact of the very inhomogeneous availability of the geometric information (ranging from very inaccurate, digitized old maps to highly sophisticated three-dimensional models, e.g. derived from terrestrial laser scanning and photogrammetry), the *IFAM* is intended to be based on a consistent topological model. The geometric information will be treated as attribute information with a strict relation to the topological model.

4.3 Features versus Maps

A *Web Service* is an interface that describes a collection of operations that are network accessible through standardized messaging, preferably based on XML (Kreger, 2001). Doyle and Cuthbert (1998) defined an *"essential model of interactive portrayal"*. A slightly modified visualization of this concept is shown in Fig. 3.

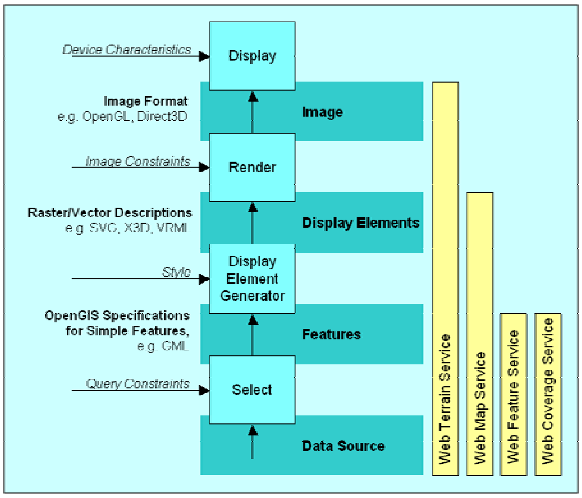

Fig. 3: Portrayal Model for presentation of spatial data (modified from Doyle and Cuthbert, 1998).

The portrayal model separates storage (data source), access (features) and manipulation (display elements), and presentation (image). Fig. 3 shows this separation and the corresponding communication between the different tiers. Possible formats for data representation at the individual tiers are given as well. The bars at the right side represent several OGC Web Services (OGC, 2005) and their integration in this model.

The current OGC standard for *Web Map Services* (WMS) was released in November 2001 (version 1.1.1, Beaujardiere, 2001). Since August 2004, a Draft International Standard of WMS 1.3 is available. According to the specification, a WMS dynamically creates maps of spatially referenced data from geographic information. This standard defines a "map" to be a portrayal of geographic information as a digital image file suitable for display on a computer screen (Beaujardiere, 2004, p. vii). The resulting maps are generally rendered in a pictorial format (GIF, PNG, JPEG and TIFF are supported), i.e. in a rectangular pixel array of fixed size. Occasionally, vector-based graphical elements (SVG, WebCGM) can be generated. Vector-based formats support a scale-independent description of the graphic elements to be displayed (including points, lines, curves, text and images), such that the size of the display may be changed while preserving the relative arrangement of the graphic elements. Almost any currently available Web Services on spatial data support static, pictorial formats, only. Dorninger (2004, p. 49ff.) compares pictorial and vector-based implementations of WMSs highlighting the higher flexibility of vector-based formats considering final presentation and rendering of the requested data.

Web Feature Services (WFS) provide the requested objects at the feature level without any rendering information. Providing spatial data at the feature level has several advantages compared to static (pictorial) formats. E.g. the rendering can be performed client-side, thus, bearing the possibility to consider the requirements of the user. Furthermore, data of different data sources can be combined easily to derive one integrated result-set, finally represented in an arbitrary format.

Unfortunately, providing features raises several problems. Compared to image data, it is very difficult to guarantee the correctness and the consistency of requested datasets. Therefore, it is essential to define a framework of standardized meta-data describing the content of a WFS-result-set. Furthermore, copyright issues have to be discussed. The data is provided in a "raw" format. This allows any kind of further processing and visualization. Therefore, it might become very difficult to control the future application of information once requested.

Anyway, defining a Geo-Data-Infrastructure on an image level would only be a very short time solution. Currently, several countries are preparing digital, three-dimensional land register systems (e.g. Norway, Sweden, Australia, British Columbia/Canada, ...) (Stoter et al., 2004). Providing three-dimensional information using image formats would be very restrictive. On the contrary, providing it at the feature level enables the support of three-dimensional geometries in an appropriate way.

4.4 Schloß Schönbrunn Management System as Standardized Prototype

Fig. 4 shows the conceptual design of the *IFAM*. It consists of three parts: The core *IFAM*, external data sources and a conventional facility management system. The fundament of the *IFAM* is an adequate data acquisition, providing the geometric information in a consistent manner, based on a predefined, topological model. In order to enable the management of historical states, an appropriate data repository is introduced. This is realized as a "snap-shot" representation of distinct historical states. Following the "data at the source model" (compare section 3), several external data repositories (land register, multi-purpose-map, ...) are integrated as well. This requires the availability of these data in an appropriate way: In a standardized format (e.g. GML) at the object level (e.g. WFS). Following the concept of the "data at the source model", actually acquired data is provided to the external repositories (dotted arrows) in order to enable a current state of these datasets. If data is requested from external sources, it is integrated into the *IFAM* as a virtual database. Thus, it is not transparent for the application server, if the data is managed internally or externally. According to the "Portrayal Model" the application server itself will implement OGC Web Services. Thus, it can be used to generate "final" results such as virtual models or proof documents for Cultural Heritage Certification (every Cultural Heritage has to pass a certification process every seven years in order to retain the status of a Cultural Heritage). And it might serve as external data repository for other systems as well.

An additional requirement is to support a future integration of a "conventional" facility management (FM) system. As there are several "of-the-shelf" software solutions available, the *IFAM* is not intended to serve as such an FM-system. But the concept should be defined, so that the *IFAM* and a future FM may communicate using an appropriate interface and thus, support each other without data redundancy.

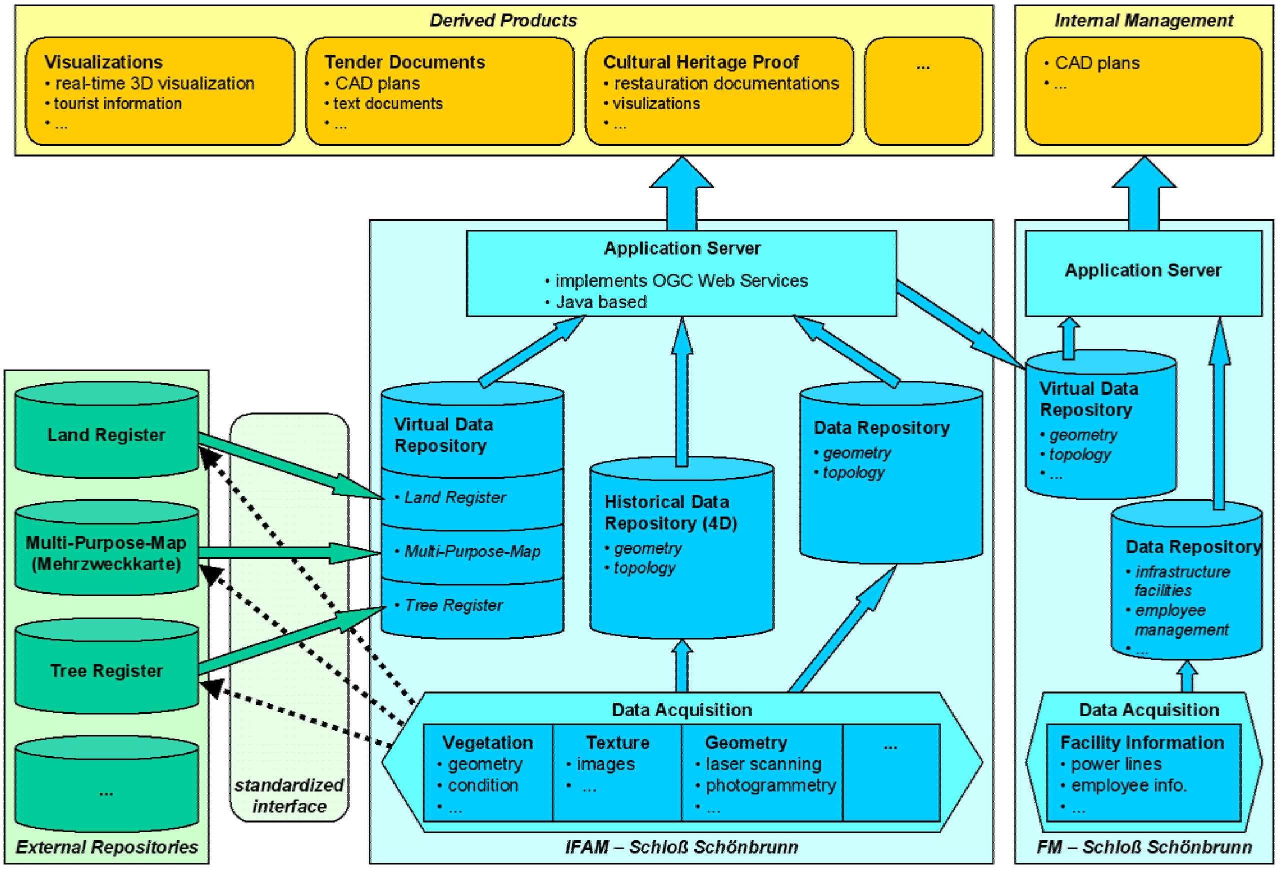

Fig. 4: Conceptual Design of the Integrated Facility and Asset Management System (IFAM) Schloß Schönbrunn.

A basic idea of the project is the integration of the *IFAM Schloß Schönbrunn* in existing public information systems (IS) using standardized interfaces. But most of these systems are currently not available in an appropriate way. That means, the responsible service providers do not support appropriate interfaces or the datasets are not available yet. Nevertheless, the *IFAM* is expected to be a test field for evaluating the conceptual design of such systems to be subsequently applied in a greater context (e.g. a detailed tree register comprising geometric and vegetation information on all trees for the whole city of Vienna).

5 CONCLUSIONS

There are several efforts on the European and on national level to define frameworks for spatial data interoperability. Several nation-wide providers of spatial data (e.g. Britain Ordnance Survey – Master Map) have already implemented standardized web interfaces to their data repositories enabling external data access at the feature level. The standardized availability of such nation-wide (or even continent-wide) spatial datasets would provide the basis for a European Geo-Data-Infrastracture (GDI). A standardized and consistent GDI would have a great impact on the European *eGovernment* and *eCommerce* efforts on the one hand. On the other hand, it might influence and support other systems, as well, as the GDI can be used as external data source. This was demonstrated by concepts for the *IFAM Schloß Schönbrunn*, a geometry-based management system of the *World Heritage Site Schloß Schönbrunn*.

The *IFAM* is intended to support the maintenance and restoration of *Schloß Schönbrunn* in an economic manner. A consistent, geometrical model of the facility enables the derivation of numerous applications. E.g. computer based virtual models of ancient rooms can be used to reconstruct historical states which are no more available in the real world. Another field of application might be a precise management of the park vegetation, based on, geometric models of every individual tree. This can be used to bridge the gap between the strict directives of nature preservation and the preservation of cultural heritage, as the concrete state of every tree can be described.

The following list summarizes the current state of the definition and implementation of a European GDI and its impact on other spatial information systems like the *IFAM*:

a basic framework for a GDI is currently defined by the *European Commision* (e.g. INSPIRE, 2005)

CEN and *ISO* have been or are still working on standards for spatial data management and exchange (e.g. ISO 19100)

standards for two-dimensional data representation are available (e.g. Simple Features)

standards for three-dimensional and complex (topology) features are worked on, but not released yet

OGC provides implementation specifications for Simple features but not for complex ones (are currently at work)

an effective GDI has to be based on appropriate DBMSs

DBMSs have great deficiencies considering three-dimensional and topological object representation and appropriate functionality (Are the currently dominating relational DBMS appropriate to serve as data repository for a GDI?)

considering further application (integration of different data sources) and three-dimensional datasets, it is essential to provide data at the feature level (WFS) instead of image level (WMS)

several countries have already realized first projects (British Ordnance Survey – Master Map, three-dimensional land registers, ...)

Austria has recently started to define a statutory framework for an Austrian GDI

information systems based on spatial data (e.g. the *IAFM*) can be realized more easily, as they can be based upon external data repositories, providing their data in a standardized way on the feature level

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