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OGC Web Services Architecture for CAD GIS and BIM

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Contents

i. Preface

This document lists the design principles and requirements for future versions of a potential architecture for integrating workflows and information models from Computer Aided Design and Building Information Modelling with the principles of the OGC Web Services Architecture. Refer to the latest version of the OGS Web Services CAD GIS and BIM (CGB) Interoperability Program Report (IPR) document for additional details.

This section describes the status of this document at the time of its publication. Other documents may supersede this document. The latest status of this document series is maintained on the OGC website.

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Initial research and development of this document was performed as part of the CAD GIS BIM thread of the OGC Interoperability Program OGC Web Services Phase 4 (OWS-4) initiative. The authors of this document are also OGC 3D Information Management (3DIM) Working Group members.

ii. Submitting organizations

This Interoperability Program Report is being submitted to the OGC Interoperability Program by the following organizations:

Harvard University Graduate School of Design

Bentley Systems, Inc.

Onuma Inc.

Hasso-Plattner Institute

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Technical University of Berlin

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v. Future Work

This document reflects the current thinking of the CGB testbed participants regarding integration of CAD, GIS and BIM information models and workflows with OGC Web Services Architecture. As the consensus of this group changes, this document will be revised.

Foreword

This document discusses the design principles and requirements for future versions of a potential web services architecture integrating the workflows and information resources of Computer Aided Design and Building Information Models with Geospatial Information Systems.

This report is informative, and is not a normative draft OpenGIS Implementation Specification. This report thus does not include any compliance clauses or other specification-specific information.

This document is structured according to the IPR Template for OWS-4. To post revisions in Microsoft Word, or compatible software, Accept Changes, and turn on "Track Changes."

Introduction

This document discusses design principles and requirements for OGC Web Services that integrate information resources and workflows from the world of Architecture Engineering and Construction (AEC) with the world of Open Geospatial Web Services. While the Geospatial world has typically concerned itself with information about the out-of doors, and largely two or two-and-a-half dimensional information as would be found in maps, images and terrain models, there are many assets and activities that occur in the three dimensional context of buildings. Integration of the information resources of the AEC world with Open Geospatial Web Services will provide very important information resources for decision makers in urban environments. Integration of OGC Service Architectures with AEC workflows will provide advantages of contextual information throughout the lifecycle of building design, construction and management.

The information workflows in the AEC world are associated with the tools of Computer Aided Design (CAD) and Building Information Modelling (BIM). The intention of this document is to present some elements of a roadmap for integration of these workflows with the information models and workflows of the geospatial world (GIS). The ideas presented here are the outcome of an OGC Interoperability Program Testbed, Open Web Services, Phase 4 (OWS-4) carried out between June and December 2006. Participants in the CAD-GIS-BIM (CGB) sub-thread of OWS-4 included leaders from industry, government and academia. In weekly discussions and a large amount of work in developing and demonstrating components many opportunities and issues related to CGB architecture were revealed. This Interoperability Program Report documents these ideas. This report has been subject to review and amendment by participants in the thread (listed in Section iii, above).

Workflows and information models in the AEC world are largely idiosyncratic with regard to a particular firm or project. Coordinate systems, for example, are almost always relative within a given document or building context. However, actors in the AEC world are converging on standards for structuring and exchanging highly detailed information about buildings and building project lifecycle. The development of a BIM standard is being coordinated by the International Alliance for Interoperability (IAI) through their development of the exchange specification, Industry Foundation Classes (IFC) . This general standard is being used as a platform for developing Domain specific views by government agencies and consortia in the AEC industry, Such as the National Institute for Building Standards (NIBS) National Building Information Model Standard (NBIMS); The United States General Services Administration (GSA) BIM Guide; INSPIRE in Europe and Byggsok in Norway. In response to all of this interest, Most developers of tools for modelling buildings are supporting IFC as an option for open exchange of building information.

At the same time, GML profiles are being developed for encoding information about buildings and their context at a broad scale. This activity, is largely the work of the Special Interest Group 3D of the Geodata Infrastructure in the German state of North Rhineland Westphalia Their specification, CityGML is now an OGC discussion paper, and will soon be promoted as a Best Practices Document by the 3D Information Management Working Group. CityGML is part of a growing trend for OGC services to include the third dimension; offering new challenges for feature services, exchanges for different sorts of portrayal and styling as well as integration of information from BIM. A few exemplary use-cases are briefly described in Section 2, below, and in more detail in the appendix.

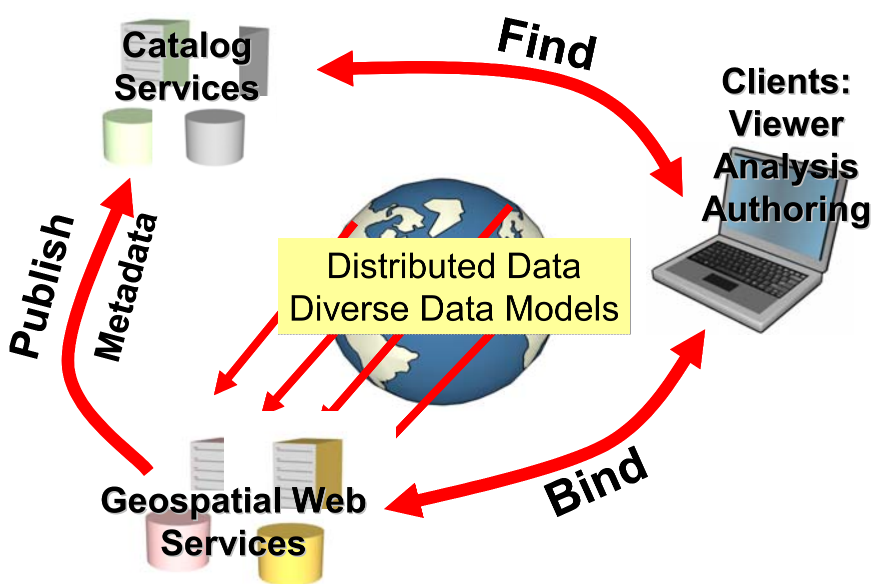

Figure 1: OGC Web Service Architecture, Publish Find Bind Pattern

Bridging the worlds of AEC Workflows with the Open Geospatial Web Services Architecture will allow the varied data models and information flows concerned with Architectural Development and Building Operation together with administrative information infrastructure that is broader in scope. The fundamental pattern of the OGC's Architecture is the Publish-Find-Bind Pattern that permits diverse information sources in a multitude of formats, distributed around the internet, to be discovered and accessed by multi-purpose clients. This integration of information will have benefits to actors in both areas and will enable applications in other areas as well.

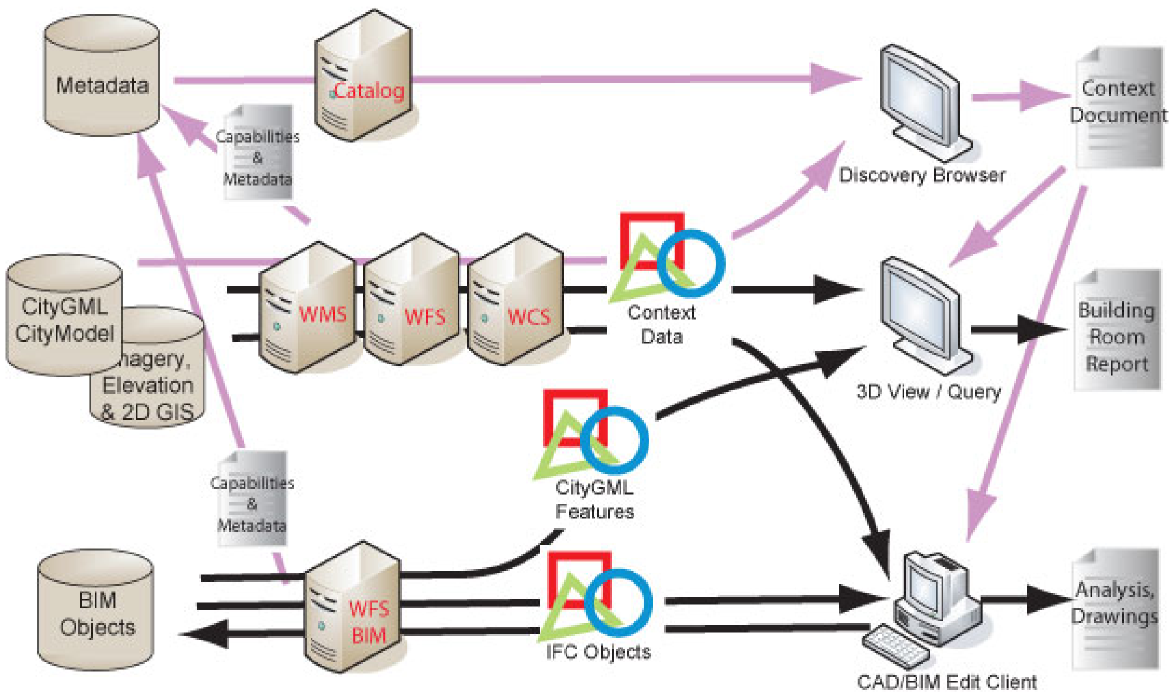

Figure 2: Overview of CGB Architecture and Components

The activities of the CGB thread resulted in the development of several new types of components that demonstrate the integration of BIM with Open Geospatial Service Architecture: A new type of Transactional Web Feature Service (WFS-T for BIM) that serves features from BIM in both IFC and CityGML; New client capabilities for three-dimensional thematic viewing and analysis of building information in CityGML; New capabilities in BIM authoring clients that consume CityGML from WFS and images from Web Map services to allow the development of BIM in geographic context. The testbed also involved several interoperability experiments that stretched the capabilities of existing OGC services to support the new problems of serving CityGML through web feature services. This testbed also resulted in fruitful discussions between the primary custodians of IFC and CityGML concerning the useful overlap of these two means of representing places.

1 Relationship to Other Activities

The following is a partial list of OGC and Non-OGC initiatives and specifications that are relevant to this project.

- *National Building Information Modelling Standard: http://www.facilityinformationcouncil.org/bim/index.php*
- *3D Information Management Working Group: http://portal.opengeospatial.org/?m=projects&a=view&project_id=164*
- *Web Feature Service: http://www.opengeospatial.org/standards/wfs*
- *International Alliance for Interoperability, Industry Foundation Classes : IAI / IFC - http://www.iai-international.org/*
- *CityGML - http://portal.opengeospatial.org/files/?artifact_id=16675*
- *Catalog Service - http://www.opengeospatial.org/standards/cat*
- *Web3D Service* - http://www.web3d.org
- *Web Terrain Service : http://portal.opengeospatial.org/files/?artifact_id=9083*
- *Web Map Context: http://portal.opengeospatial.org/files/index.php?artifact_id=5397&version=1*
- *Styled Layer Descriptors: http://portal.opengeospatial.org/index.php?m=projects&a=view&project_id=10*

&tab=0

- *KML/KMZ - http://earth.google.com/kml/*
- BLIS / SABLE - http://www.blis-project.org/~sable/

2 Usage Scenarios

This section highlights a few characteristic use cases highlighting the value of exchanging information from CAD and BIM with Open Geospatial Web Services.

2.1 Integration of Geospatial Information for Building Site Planning and Design

In the initial site planning stages of the AEC design process, it is useful to consider contextual information such as aerial photography, terrain and features in the near context, such as other buildings and roadways (existing and proposed), utilities, environmental hazards or concerns, etc. These information resources ought to be discoverable and accessed through OGC Web Services. The design process will be much better informed when CAD and BIM editor clients are able to access such resources. We see this integration with geospatial context as an incentive for dealing with geo-referencing of CAD and BIM models, which will in turn, allow the possibility that the authoritative information in distributed building models will be discoverable and accessible through geospatial web services such as Web Catalog Services and Web Feature Services.

2.2 Integration of Building Information Models Spanning Multiple Sites

Building design and building operations often involve question of the precise relationship of one building with another. Such situations might include the design of inter-building tunnels or skywalks or connection of other infrastructure. Inclusion of geospatial referencing systems in BIM, and the possibility of publishing the availability of specific BIM profiles through web service architecture will facilitate the integration of multiple BIM models for precise design. Naturally, such web availability presupposes some form of Digital Rights Management in order to restrict access to sensitive building information.

2.2.1 Integration of Building Information with location based services

In many situations, the availability of such building information will be required dynamically and almost instantly based on the location of the user. For example, an emergency operation team might want to navigate quickly to the target building using street navigation tools (GPS, voice navigation, street light control, etc.) but, once on site, they will want architectural and engineering details such as detailed plans of the building interior, electric and water supply in order to make effective decision.

2.2.2 Integration of Building Information with Broader Geospatial Query and Analysis

There are many imaginable use cases where information from multiple building information models will be of use in broad scale geospatial analysis. We expect that the most up-to-date information about spaces (rooms) in buildings – their capacity, their use, and their occupancy status will originate and be maintained in individual Building Information Models. It will be very useful for planning or emergency management to be able to assemble these information resources for broad-scale visualization, query and analysis. This capability will be a benefit of integrating distributed BIM with the publish-find-bind pattern inherent in the OGC Web Services Architecture.

3 Design Principles

The following design principles should be considered:

3.1 General

General design principles pertaining to OGC CGB Architecture include the following:

1. CAD and BIM authoring applications should support geo-referencing.
2. OGC CGB Interoperability should be targeted as a standard feature of CAD and BIM authoring applications. This should include the ability to retrieve contextual information from OGC Services into CAD Design documents, and the ability to export and post GML and IFC data to OGC WFS-T and WFS-T for BIM. Although transactions of sub-BIM features are a problem that was not addressed in OWS-4, transactions of complete feature collections has been demonstrated.

3. OGC CGB Interoperability should become an expectation in the management and sharing of information from BIM through the life-cycle of a building. In this sense it will be useful to describe particular views of BIM that may be of interest to specific user communities – such as Visualization, Space Management, Aeronautical Hazards, etc.

4. OCG CGB Interoperability should form the service architecture and exchange specifications for popular applications for sharing information about buildings. Tools like Google 3D Warehouse have exposed a great interest in the public for sharing information about buildings. As the desire goes deeper into building details such as rooms or other themes, OGC exchange specifications will provide the deeper semantic models, catalogue capabilities and service architectures that will be necessary.

5. OGC CGB Interoperability, when developed in potential specifications, must be accompanied by a comprehensive, completed test suite. An essential requirement in the OGC Interoperability Program process is the demonstration that all elements in a potential specification can be implemented. Therefore, implementation testing in the form of technology integration experiments must play a large part in any potential OGC-CGB Interoperability specification design.

4 Desirable Components/Capabilities for CGB Interoperability

An architecture for web services interoperability between AEC and Geospatial workflows will include developing capabilities of Servers, Clients and for Data Conversion. This section profiles several ideal components of a CGB architecture. Actual workflows that were enabled by the prototypes actually developed for OWS-4 are discussed in Annex A.

4.1 CityGML inWFS

CityGML is an application schema of GML, and yet it is somewhat challenging to load and manage and serve in an OGC WFS and especially from the perspective of transactions. The following is a list of issues and solutions in this regard that emerged in OWS-4. Note that some of these points are contradictory and emerged as discussions among our WFS implementers that may continue to be explored in future testbed activity. The OWS-4 demo had successful integration of CityGML city models of multiple levels of detail, including level 4 buildings with GSA Space Planning Attributes, served by the Snowflake Go-Publisher server.

1) Complicated Schema: While the typical OGC architectural studies shy away from technology viewpoint that lies at the database schema on servers, we found that the way information is translated from XML to a relational or object-oriented database makes a difference in terms of how or whether complex schemas such as CityGML or IFC can be loaded and probably also the versatility with which it can be queried.
2) Very Large Message Payloads: We found that even for a relatively modest demo dataset, that the transfer of raw CityGML as text was very slow. Snowflake developed a request that delivered a zipped CityGML stream which cut download times by as much as 90 percent.
3) Metadata for CityModels: We had some success with having WFS feature collections consisting of CityModel harvested by catalog servers, but this provides only very basic technical summaries of the content of the collection. There is a lot of work to do to consider the different sorts of metadata that would be desirable for cataloging and discovering information in CityModels. Some of these metadata may be imbedded in the GML schema itself, some of it may be attached in other ways.
4) Optional Elements: Within CityGML almost all elements are optional. Sample datasets could not be loaded into all WFS instances – e.g. Transactions failed on lat/lon's deegree WFS for a variety of reasons, especially geometry structure and missing CRS (srsName).
   To lower the implementation barrier for WFS vendors, a CityGML profile for WFS is desirable, which could e.g. integrate a mandatory 2D geometry for fast lookup of CityGML objects in a WFS datastore or a mandatory 3D geometry.
   (For more details, please refer to the lat/lon document as of 2006-12-11)
5) Adding a 2D geometry for indexing, may increase an implementation effort rather than decrease it.
6) If we jump to creating profiles too soon we risk creating overly restrictive profiles. Profiles should be built around use cases rather than implementation difficulties. If a particular use case only requires parts of CityGML this is a reason

to specify a profile for that use case. Having the profile then means that implementations don't waste effort on implementing features of the full spec that are not going to be used. If the profile is built around implementation issues it could exclude part of the spec because it is difficult to implement despite the fact that people need to use it. The result of this would be non-adoption of the standards since they do not fit the requirement. Profiling IFC to handle only spaces and space usage is a good example of a profile – those elements of IFC were the ones relevant to the use case. We need a body of serious use cases and experience to draw on to get the profile right – this is something for the long term.

7) Transactions on CityGML. This topic was addressed in OWS-4 only in terms of the exchange of complete feature collections in IFC. The notion of maintaining topological and semantic integrity in a transactional server is much more challenging. Perhaps specific views and profiles of BIM and CityGML could support insertions and deletions of content that could be considered self-integral. Simple changes of attributes would be a start. Transactions hold many challenges for the future. Workflow protocols such as service chaining and Business Process Execution Language BPEL may also hold out hope for handling long transactions and integrity checking necessary for dealing with feature-level editing transactions.

4.2 WFS for BIM

There are not many implementations of transactional BIM servers in the world, and through their participation in OWS-4 Onuma Inc. proved that a couple of tweaks to the classic WFS-T interface can provide BIM feature access to the geospatial community. A diagram and outline of the WFS-T for BIM workflow demonstrated by Onuma is given in the appendix to this document.

1) Focused Application Schema: It should be noted here that one of the reasons that this implementation was possible to do in the short time frame of OWS-4 is that the Onuma view on BIM is defined very specifically to serve the needs of space planners i.e. space geometries associated with large amounts of adjustable data is defined very specifically to serve the needs of space planners. As such is it avoids a great deal of the complexity that is possible to represent in IFC. The space planning view is well suited for translation to CityGML. Finally it should be

noted that however simple the geometric data requirements for space planning, compared with the potential complexity of BIM, this is perhaps the most valuable application from the perspective of broad-scale analysis. This is an important lesson for future extensions of this BIM server functionality: It is very useful to focus on a very specific and limited application view as opposed to trying to conquer the entire problem of transactional BIM services.

2) Metadata / Catalog Concerns: As mentioned in the WFS discussion, above, there will be a lot of value on exploring the sorts of identifiers that may be imbedded in IFC or otherwise attached to BIM feature collections that will facilitate their registry and discovery through catalog interfaces. One issue related to this would be the means of publishing specific feature types or profiles that are available on a server. Since these data don't exist as GML until they are requested, somehow their definition will have to be imbedded in or independent of the BIM feature store.

3) On-The-Fly BIM-GML Conversion: Our prototype focused exchanging information about rooms (IFC Spaces). The Onuma BIM Server stores these objects in an internal BIM format that incorporates the space attributer characteristics of the US General Serviced BIM Guide for Space Assessment. The BIM server is capable of retrieving space objects with these attributes either in CityGML or IFC format.

4) Transactions on BIM: These issues are similar to those discussed in the previous discussion on transactions on CityGML. It is perhaps more difficult because BIM and IFC and their transactions are potentially much more complicated than CityGML. Nevertheless, there is a large need to solve this problem. The OGC work on Digital Rights Management protocols will undoubtedly be very helpful in the development of transactional services that allow editing of selected BIM objects.

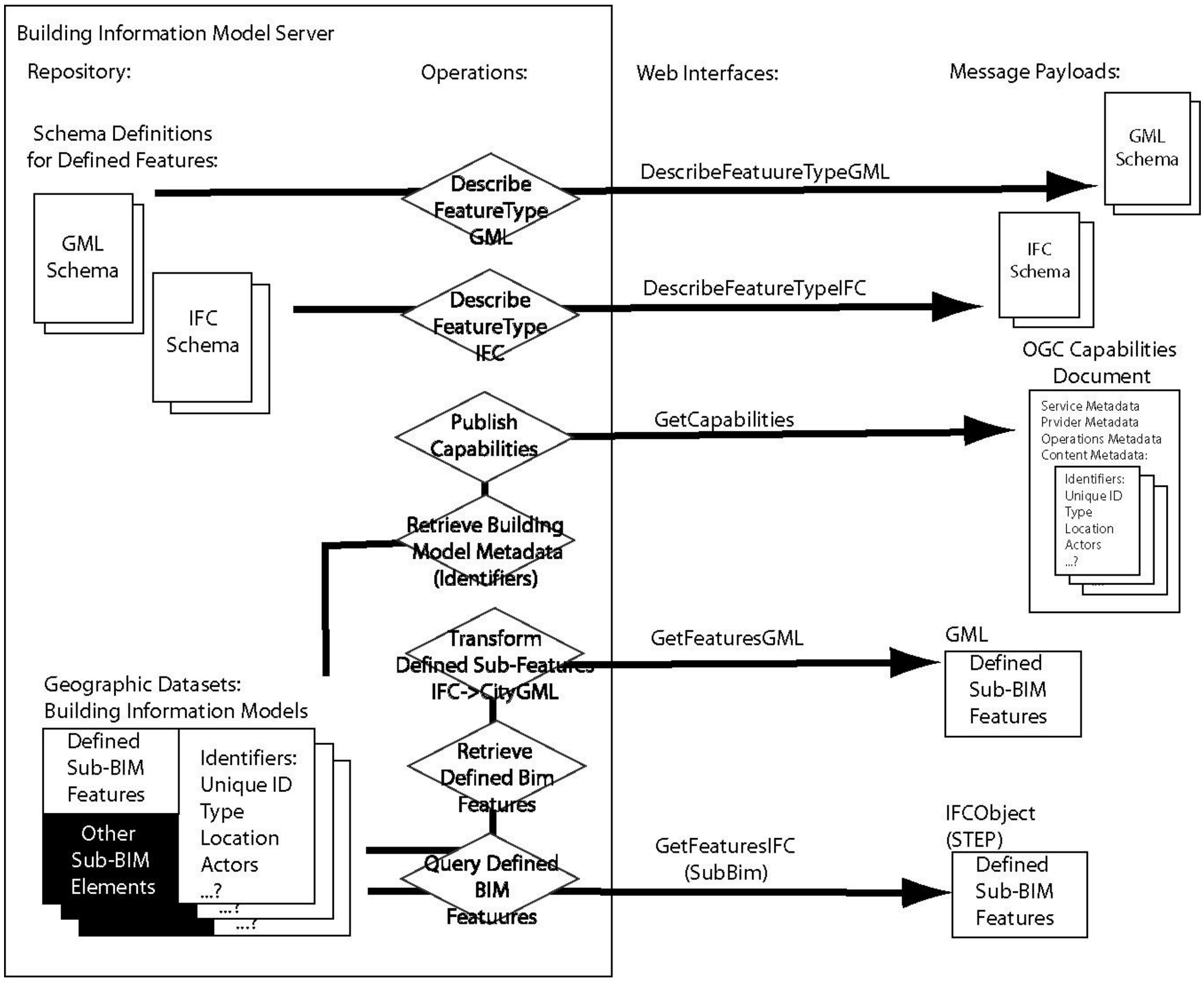

Figure 3: Web Feature Service for BIM

4.3 CAD / BIM Editors and Analytical Tools

This section discusses desired capabilities of CAD/BIM authoring tools that relate to Open Web Service Architecture for CGB. Subsets of these capabilities were prototyped and demonstrated in this testbed by Bentley Systems, Inc. and Onuma Inc. An outline and diagram of the Bentley and Onuma workflows are provided in the Annexes of this document.

1.) Able to Assimilate Georeferenced Data: As has been noted in Section 2, the ability to easily consider contextual circumstances in design is very useful. For this purpose, CAD and BIM editors should be able to assimilate information resources that may exist in different coordinate systems, and to register georeferenced architectural detail. Information should be able to be assimilated directly from Web Map Services (Imagery and thematic maps,) WCS (terrain and quantitative surface data, and WFS) for vector features and CityGML. It will be very helpful if CAD/BIM editors were able to visualize and query the semantic information in CityGML.

2.) Catalog Discovery Context Capabilities: Part of the problem (and advantage) of assimilating information from OGC Web Services should be the access to the search and discovery capabilities of catalog servers. This calls to mind a need for Catalog client functions to be built into ACAD/BIM Authoring Clients. Further, the references to assimilated OGC layers should be able to be saved and exchanged via OGC Context documents.

3.) Able to Export well known Exchange Formats: It is increasingly common for CAD/BIM editors to be able to import and export IFC as a fully capable BIM exchange format. KML is also a common export format for lightweight portrayal. We are also seeing the utility of encapsulated 3D document formats such as 3D PDF and DWF which perform as end-product documents from the design process. It will be useful for CAD/BIM editor clients to be able to exchange information as CityGML, such as might be needed to post space planning details to a WFS-T.

4.) Able to distribute efficiently enormous amount of data: Buildings can potentially have numerous details, and IFC has been designed for supporting this level of detail. Therefore, a single multi-storey building can require 10s if not 100s of megabytes. Transferring all this data on the Web will require different techniques (Compression, levels of detail, streaming,) in order to provide quickly an overall view (like the shell of the building) and gradually providing details if required. The structure of IFC Express is not as suitable for this kind of incremental delivery as the IFCxml. This is a topic for more investigation in OWS-5.

4.4 CityGML and BIM Analysis Client

A large part of the value of integrating AEC workflows and exchanges with the OGC web services architecture comes in the ability to integrate BIM information related to multiple sites over broad areas. This was demonstrated in OWS-4 through modifications to the LandXplorer viewer by the Hasso-Plattner Institute. A more thorough explanation of the implementation of this viewer is provided in Annex B of this document.

1.) Able to Assimilate data from OGC Services such as WFS, WMS and WCS.

2.) Able to create thematic views based on the attributes of CityGML objects: In our case it was important to be able to deal with attributes that were associated to GML objects via property sets representing the space properties used by the general services administration. To the extent that metadata explains the character of these properties e.g. their attribute names, it is important that these be displayed in an informative way.

3.) Catalog/Discovery/Context Capabilities. See notes listed above in CAD/BIM Editor Clients.

4.) Domain-specific analytical tasks. A chief advantage of the GML/BIM analysis client, which takes its input as CityGML, as opposed to more visualization-oriented clients that may use more streamlined exchange formats such as X3D or KML, is that the semantic and topological information capabilities of the CityGML information model may be used with local programming logic that may be applied to study aspects the aggregation of built assets in over a broad area. Such questions may be related to space planning, as we demonstrated in OWS-4, but might also involve such questions as Location-Based Services, the impact of hazards or nuisances on urban areas, or analyzing the loads on urban infrastructure under different scenarios.

4.5 Procedures/Tools for Generation of CityGML from IFC BIM

IFC is established as a generic information exchange model for BIM. It serves as an exchange format that has been adopted by many purveyors of CAD/BIM clients and servers. There is a good deal of attention being given to the development of specific application views of IFC for particular domains of BIM, Notably the NBIMS, GSA BIM standards initiatives in the U.S.; and INSPIRE in Europe, and BLIS/SABLE and Byggsok in Norway. Therefore we see that in the AEC world, IFC is a relatively stable information model structure. Yet, IFC and BIM leave much to be desired in the representation of building context. CityGML, on the other hand is establishing itself as a very semantically rich and versatile information model for structuring information about contextual features and cities as a whole. While it is decidedly less detailed in comparison with IFC, CityGML is well-adapted for representing those features that are apparent to such devices as airborne, ground-level, or interior. CityGML also provides an appropriate level of semantic capacity that may be applied to the geometric aspects and their relationships with one another.

OWS-4 participants, including the principal developers and custodians of IFC and CityGML are in consensus that these two information models are complementary. While each model has its distinct strengths within its area of focus, they also have areas of overlap. Therefore we believe that it is likely that some details of building context that end up in an IFC model may have originated in a broader–scale CityGML model. Likewise, some building details that may be desired in a CityGML CityModel, such as the gross building detail and up-to-date information concerning space use and occupancy, may originate in a BIM, exchanged as IFC.

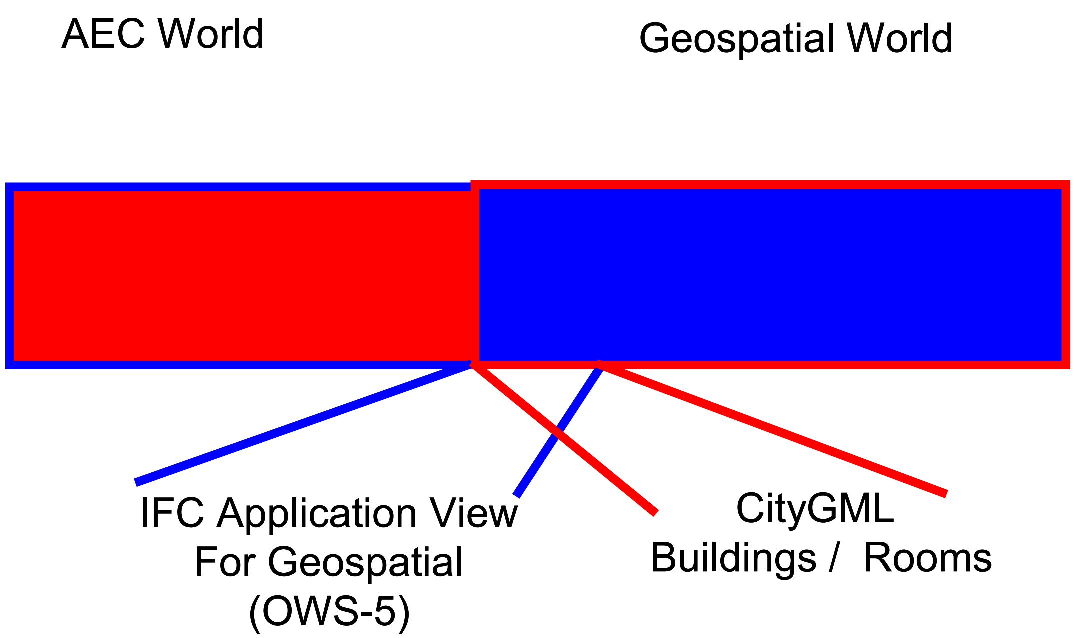

Figure 4: IFC and CityGML Bridging Strategy

With this in mind, there is a great deal of value in the specification of specific content and methods for translating some subset of IFC to CityGML and vice-versa. There is a start on this work already in the literature (Liebich, 2004) and at the Forschungszentrum

Karlsruhe Institute for Applied Computer Science (Haefele, 2006)

4.6 Architectures for Portrayal of Urban Landscapes

While IFC and CityGML are very rich geometric and semantic models, highly suited for structuring and exchanging relatively comprehensive information about buildings and their settings, these are not the sort of streamlined formats for exchanging information for the portrayal of appearance for real-time 3D applications.

1.) Exchange Specifications for Appearance Modeling: In this area, we look toward specifications such as X3D and KML.

2.) Service Models for Portrayal: We can see the tremendous traction established by Google Earth in its very powerful means of assembling and delivering real-time views of cities. As KML moves closer to being the subject of consideration as a specification of the OGC community, we should look more closely at how the Google-Earth-like architecture may work as a means of returning visualizations of urban scenes. This activity will be in concert with ongoing activities in various OGC working groups investigating such architectures for 3D portrayal, as the Web 3D service and Web Terrain Service.

3.) Server Based Analytical Query and Visualization: A strong architecture for portrayal of urban landscapes may lead us to think differently about the ways that functions we have associated with the 3D GML Viewer and BIM Query tool might be shared more with the remote server. Using such technology as Styled Layer Descriptors (SLD) and ad-hoc query interfaces, the problem of translating a rich semantic model into a visualization to answer a specific question might be accomplished by sending a query to a server that sends back a thematic 3D portrayal to a very light-weight viewer. In this case, the attributes of specific features might be queried from the server by following an Xlink from a clicked object.

5 Summary and Future Collaborations

5.1 Development of Web Feature Services for BIM:

The design of the WFS-T for BIM is intended as an extension to the standard WFS and WFS-T. This will enable implementers to minimize the work in design and specification of interfaces. It will also mandate active participation with the OGC activities related to development of these services, especially in the area of complex transactions with integrity constraints.

5.2 Collaboration with IAI Communities:

We recognize that IFC is the industry standard for structuring and exchanging information in BIM. This establishes a need for close collaboration with IAI in understanding this specification and where it is headed – particularly with regard to geo-referencing and the development of specific user-community efforts to develop specific Model View Definitions and Exchange requirements.

5.3 IFC / CityGML Bridge:

While IFC is a compellingly rich information model for buildings, it specifies very little concerning the circumstances of buildings, such as roads, terrain, walkways, vegetation, etcetera. In this regard, CityGML is a much more capable data model. We anticipate that the future of OGC CGB interoperability involves the development of an understanding of how IFC and CityGML will overlap and complement each other. Some BIM information may be portrayed in CityGML, and information, for example, originating from automated geometry capture techniques, may be translated from CityGML to rough IFC models for modelling in CAD or BIM authoring tools. This development of views, profiles and tools for bridging between IFC and CityGML will certainly be a concern in future testbeds.

5.4 The BLIS / SABLE Project:

The BLIS / Sable service oriented architecture for BIM represents a well-thought-out service architecture for BIM. Much work has been invested in the back-end data models (characterized by the Technology Viewpoint of OM-RDP) other significant work has been accomplished in the specification of Domain-Specific views of BIM, such as Architectural and Heating and Ventilation. We expect that OGC web Services Architecture for BIM to be complementary with this work, providing request specifications and such auxiliary services and workflows such as Catalogue and DRM.

5.5 Geo-referencing IFC:

Though our OWS-4 prototype implementations did achieve the exchange and proper registration of georeferenced BIM, we did not implement the Geo-referencing model of the proposed draft standard IFC2x3g. Yet we understand that this geo-referencing model instantiates the full Geo-referencing specification of the European Petroleum Survey Group (EPSG) and we presume, ISO19111. We believe that this indicates a fairly complete specification of the sorts of coordinate referencing systems expected in the world of AEC and portends a high level of interoperability with other geospatial service architectures; this should be the subject of further study in OWS-5.

5.6 Portrayal and integration of other OGC services in Three Dimensions:

There are other OGC specifications and working papers dealing with the exchange terrain and land cover information: Web Coverage Services and Web Map Services; and for portrayal: Styled Layer Descriptors; Web3d service and Web Terrain service. We expect that the opportunities and challenges surrounding mutual integration of these types of services with building information will make collaboration among the CGB project and these others propitious.

5.7 Encapsulation of 3d Geometry:

Outside of the OGC, there are architectures and exchange formats that should be of interest in the area of high-efficiency portrayal. An interesting approach to this is the encapsulation of 3d geometry with textures and other information in such forms as PDF, Multipatch, and DWF and KMZ. This means of packaging 3d renditions for visualization may be worth looking at as models for consensus based industry standards.

5.8 Collaboration with Catalog WG:

Building Information Models and CityGML CityModels represent fairly specific profiles of the generic idea of Feature Collection. In OWS-4 we had some success in publishing generic WFS capabilities and feature collection information to be harvested by catalogues. There is much more work to be done in understanding the sorts of discovery workflows that are of particular interest with regard to CityModels and Building models and to understand how the existing attribution in IFC and CityGML may be used in this regard or how these specifications should be extended in order to develop more useful catalogues.

Annex A: Use Cases (informative)

A.1 Introduction

This annex provides more information about the functional behavior of OGC Architecture for *CAD GIS and BIM*

A.2 Use Case 1: Transactional Access to WFS-T for BIM

The Web Feature Service for BIM with some transactional functions and the capabilities listed in this use-case were developed in the OWS-4 testbed by Onuma Inc.

Use Case Description	
Name	Transactional Access to WFS-T for BIM
Priority	Undefined.
Description	A space planner requests information about a building's spaces from a WFS. This information is returned as IFC. The planner uses an editor client to create a new space scheme for this building. The new scheme is returned to the server. The service metadata including this new scheme is harvested by an OGC Catalogue Service.
Precondition	A Web Feature Service for BIM exists that includes information about the spaces in a building.
Flow of Events – Basic Path	
1.	The space planner searches a catalogue for services that include features of type IFCSpace for building information models within a specific bounding box
2.	The catalogue service returns the URL for a WFS for BIM and a query string that will retrieve the appropriate space features

Use Case Description	
3.	The space-planner enters the query string into his BIM authoring client and sends a GetFeatureIFC request to the WFS for BIM.
4.	The WFS for BIM retrieves the appropriate features and prepares an IFC exchange and sends it to the client, compressing this data using zip or gzip if requested.
5.	The BIM Authoring Client receives the IFC exchange (uncompressing it if necessary) and renders it for editing.
6.	The space planner alters the representation of the geometry and attributes of various spaces to create a new space scheme for the building.
7.	The space planner initiates an upload of the new scheme to the WFS-T for BIM.
8.	The BIM Authoring Client packages the new building space scheme as an IFC file (compressing it if needed) and issues a PostIFC request to the WFS-T for BIM
9.	The WFS-T for BIM accepts the IFCPost and creates a new feature collection containing the new scheme.
10.	The WFS-T for BIM updates its GetCapabilities statement
11.	The feature service metadata is harvested by OGC catalogue services.
12.	The new building space scheme is reflected in the catalogue
Post-Condition	Spaces from the new scheme are now available for request in either IFC or CityGML format.

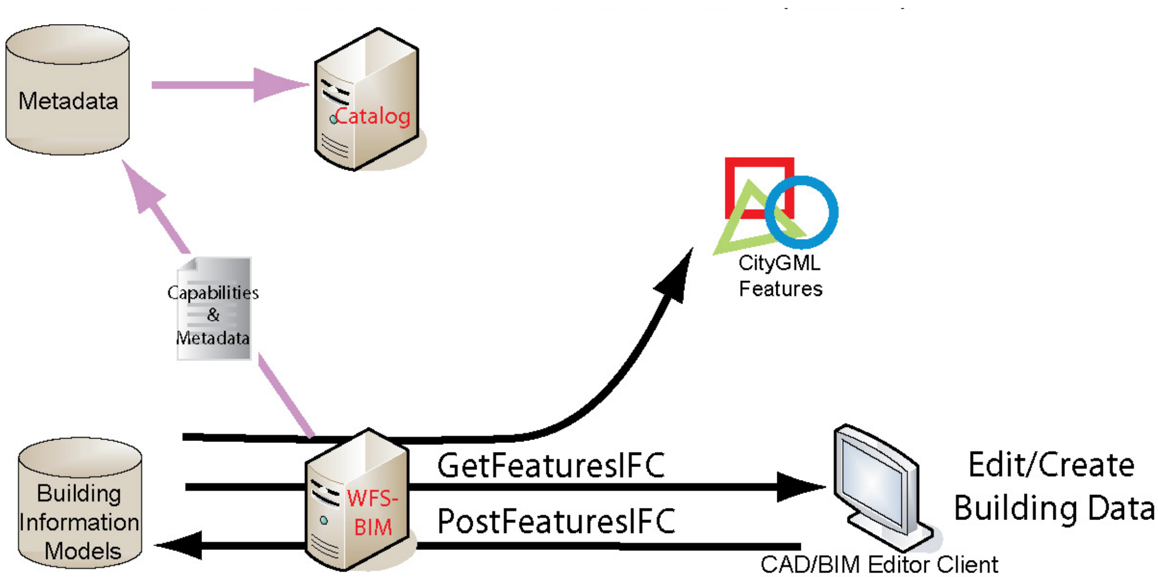

Figure 3: Transactional BIM Authoring Workflow

A.3 Use Case 2: BIM Authoring with Context Data from Open Web Services

The capabilities of a BIM authoring client listed below were implemented in OWS-4 by Bentley Systems, Inc.

Use Case Description	
Name	BIM Authoring with Context Data from Open Web Services
Priority	Undefined.
Description	A building project is initiated. The designer obtains contextual information from OGC services to inform the design of new building elements.
Precondition	Web Feature Services exist with CityGML data in building context area, Web Map services exist with aerial photography for the area.
Flow of Events – Basic Path	

Use Case Description	
1.	The designer queries an OGC catalogue service for photography and CityGML CityModel feature collections and IFC space information overlapping with the bounding box of his area of interest.
2.	The catalogue service returns the URL for a WFS and WMS and query strings that will retrieve the appropriate contextual and building information
3.	The BIM authoring client retrieves CityGML, WMS and IFC information
4.	This contextual information is integrated with detailed building model information stored locally, or retrieved from the WFS for BIM. (In OWS-4 the CAD models were local)
5.	The designer uses this information to plan his building intervention.
6.	All of this information is integrated into design documents and building information models that are passed to builders, architects and others involved in the AEC process.

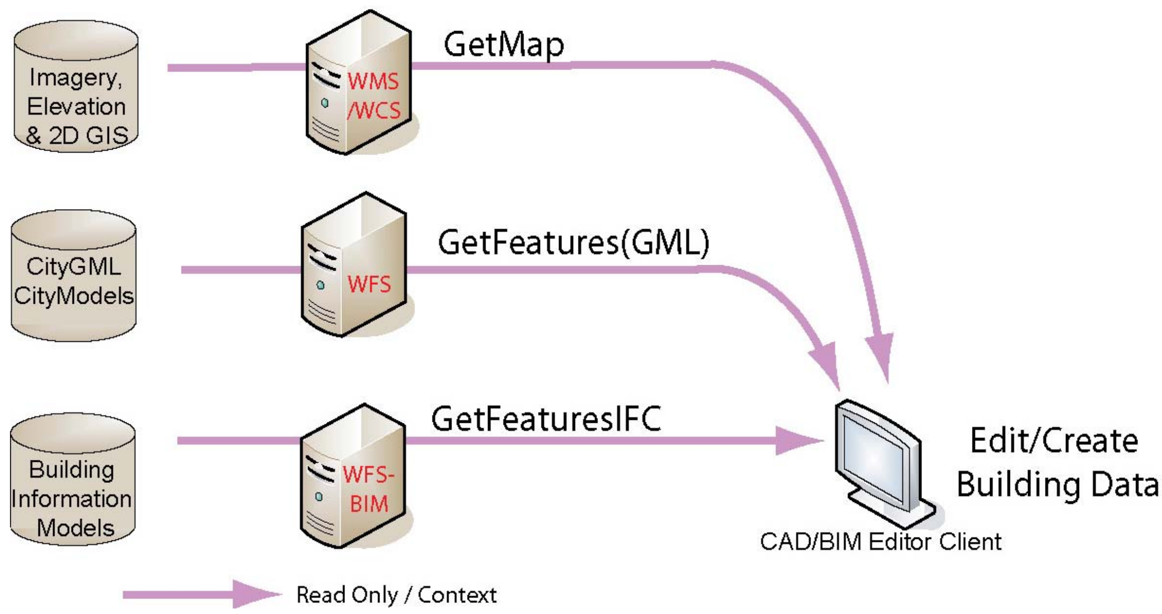

Figure 4: BIM Authoring in Geospatial Context Workflow

A.4 Use Case 3: Analysis of Building Information over Broad Geographic Area

Use Case Description	
Name	Analysis of Building Information over Broad Geographic Area
Priority	Undefined.
Description	A planner needs information on the building space attributes for all of the buildings in a broad area of interest. Through a query to an OGC Catalogue Service he discovers services with useful information and retrieves building space information for several buildings from WFS for BIM and other city features and terrain from a WFS containing CityGML CityModels. In addition he retrieves aerial photography from a WMS. All of this information is combined, and several thematic displays and analytical reports are generated that help the planner make a decision.
Precondition	Web Feature Services exist with CityGML data in building context area, Web Map services exist with aerial photography for the area. Web Feature Service for BIM has building space information for buildings in the area.

Use Case Description	
Flow of Events – Basic Path	
1.	An area of interest is chosen for analysis
2.	Web Catalogue Services are consulted regarding information about buildings and other city features, rooms, terrain and aerial photography existing for the area of interest
3.	Resources are discovered in Web Feature Services (CityGML CityModels,) Web Map Services (Aerial Photography) and BIM features in CityGML format (from Web Feature Service for BIM.
4.	A three dimensional scene is generated from this information in a viewer that permits real time flythrough.
5.	Features are thematically displayed based on their attributes. In our case, our CityGML building room features are tagged with IFCSpace attributes as specified by the General Services Administration BIM Guide for Space Assessment.
6.	Selected building elements can be queried with regard to their topological or semantic relationships with other features in the model.
7.	A space analysis is performed and a report is generated listing specific rooms and room complexes satisfying a particular need.

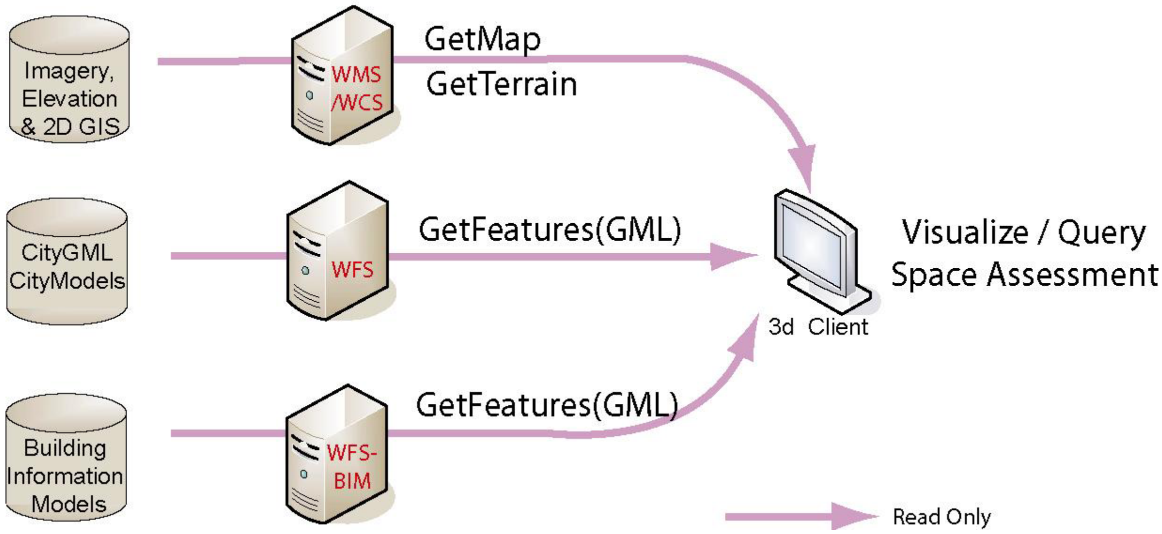

Figure 5: Analysis of Building Information over Broad Geographic Scope Workflow

Annex B. LandXplorer CityGML Viewer

B.1 Introduction

The contributed LandXplorer CityGML Viewer bases on the LandXplorer framework for the construction, editing, analyzing, and visualizing of geospatial information in 3D geovirtual environments (GeoVE) which is developed in cooperation of the computer graphics research group at the Hasso-Plattner-Institut at the University Potsdam[1] and 3DGeo[2]. The LandXplorer CityGML Viewer is a tool for the construction of GeoVE from terrain information, terrain textures, large and complex building models or arbitrary 3D geometry, which is typically loaded from file.

For OWS-4, the viewer was extended for enabling access to distributed geoinformation via OGC web services (WMS, WFS). Thereby, the LandXplorer CityGML Viewer serves for the integration of various building information that are exchanged in the CityGML format, but also for the integration of common 2D geoinformation as map layers.

The correlation of detailed semantics and detailed geometry in CityGML data is preserved along the visualization process and is accessible in the final geovisualization: E.g., thematic information can be displayed and edited for selected objects.

In OWS-4, the capabilities of CityGML are used for bridging the gap between CAD and BIM on the one hand and GIS on the other hand, supported by a transformation of BIM data into CityGML. For demonstrating this functional interoperability, the LandXplorer 3D CityGML Viewer was further extended with a building room report utilizing the building information implanted into CityGML.

B.2 Scenario Workflow

The sequence diagram in Figure B.1 visualizes the activities performed by the LandXplorer CityGML Viewer in the context of the OWS-4 testbed scenario. The viewer client is capable of loading context information (representing the Common Operational

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[1] http://www.hpi.uni-potsdam.de/3d

[2] http://www.3dgeo.de

Picture provided by the PEC) for WMS and WFS. These contexts provide the sources to request. Additionally, object catalogues by Onuma and Snowflake are used for finding servers and information to access. The Snowflake WFS is accessed for retrieving terrain information, context buildings, and a LOD4 representation of the hangar building. The Onuma BIM-WFS provides room models which derived from the IFC spaces of a complex BIM. The LizardTech WMS is accessed for retrieving aerial images for the scene. In addition to data integration, there is the task of building assessment which is supported by colored visualizations and textual display of room attributes. The output of the work with the viewer client is a reference which identifies the building and room to be used as a temporary field hospital and is virtually passed to the scenario's next step (hospital space planning).

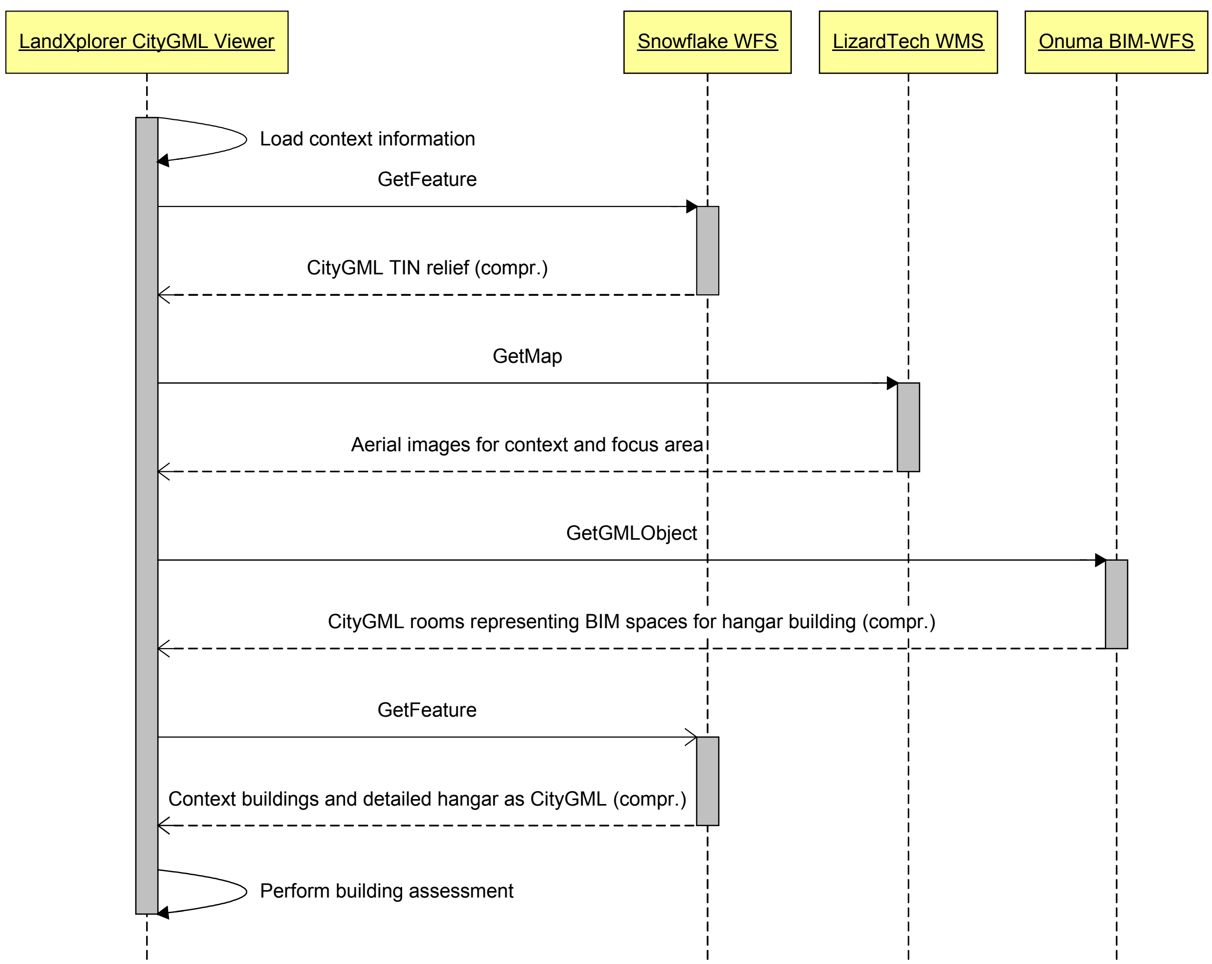


Figure B.1: Workflow sequence for LandXplorer CityGML Viewer.

B. 3 Viewer Client Functionality

For the web service-based creation of the GeoVE, we have accessed a variety of OpenGIS data services and portrayal services. The following subchapters address important implementation issues for the interoperable OGC web service-based viewer client.

B.3.1 Service discovery

The operations of an OGC web service are defined by the various service-specific implementation specifications. Additionally, binding information is necessary about server address and port number. On a more fine-grained level, information about the special geoinformation (features, map layers) is needed for retrieving the appropriate information for the special use case.

For the thread's workflow, different approaches for finding sources of relevant geoinformation were used.

B.3.1.1 Catalogue Service

Onuma set up a so-called object catalogue, which provides URLs for requests to the BIM-WFS. This object catalogue itself was registered at the CubeWerx Web Registry Serviane which is an OGC catalogue implementation[3] and allows a search for information sources by geographic bounding box and keywords. Another object catalogue was provided by Snowflake. These catalogues contain full HTTP request lines for accessing different configurations of building models in the CityGML format.

B.3.1.2 Context document

The interface to the previous scenario steps is the common operational picture which should be stored and transferred as an OWS context document. This has been done for testing. Until now, the LandXplorer CityGML Viewer is not capable of reading OWS context documents but is able to load Web Map Context information (WMC). This includes a bounding box and a set of layers (servers, layer names, etc.) which can be used

[3] http://demo.cubewerx.com/ows4/cwwrs/cwwrs.cgi

for reconstructing a scene by accessing the information sources. Leaning against this WMC specification an arbitrary text-based context description has been defined for WFS layers.

It should be investigated in detail, to which extend the OWS Context is applicable to the definition of 3D geovirtual environments.

B.3.2 Data Loading

B.3.2.1 Supported access methods and formats

The viewer client allows the user to load information from a context file (arbitrary text-format leaned against OGC Web Map Context) or to define a request URL as it is provided by the Onuma and Snowflake object catalogues. The viewer client supports only HTTP GET request at the moment. This leads to restrictions for the length of the request string and so reduces the complexity of service requests. Even so, there was no such problem for the testbed demonstration. Even filter encoding was possible within the request string.

Currently, the viewer clients WFS adapter only supports the reading of (compressed) CityGML data. Pure GML data reading is not activated.

B.3.2.2 Geo-referencing CAD data

In CAD tools, geometry is defined relative to a reference point in a local coordinate system. For GIS application geo-referencing is elementary. For supporting this, the provided CityGML data contains extra information which is read out by the viewer and is used for calculating an offset vector for translating the building geometries. This method worked well for the testbed but is not a general solution: The geo-referencing attributes do not have a well-defined format and there is no specification about how to apply them to the retrieved geometries. Furthermore, this approach is a logical break between service request and service response, as the geospatial position of retrieved geometry does not match to the requested bounding box. For supporting better interoperability, geo-referencing should be performed by the service itself.

B.3.2.3 Different Coordinate Systems

Because different geoinformation sources (WMS, WFS) might support different coordinate reference systems (e.g., for request's bounding box or responded geometry), it is necessary to transform imported coordinates. As WSG84 was defined as the one and only spatial reference system for this testbed, a first implementation of coordinate adjustment for data loaded by context definition was not followed up.

B.3.2.4 CityGML Compression

CityGML data can be very large but can be compressed to a much smaller data amount, easily. This compression must be supported by WFS server and client. Compression can be handled at transport layer (HTTP compression) or at application layer. The latter is chosen for this testbed: The WFS provides separate service endpoints which responses (gz or zip) compressed data which is detected and uncompressed by the CityGML Viewer. For general, the usage of HTTP compression should be favored as it increases the decoupling of client and server.

B.3.2.5 Preserving the semantic structure

The geometric, topologic, and semantical structure of a building model and the correlation between this information is contained in CityGML and so can be transferred. The LandXplorer CityGML Viewer preserves these structures and correlations along the visualization process. The CityGML Browser allows the user to access all the objects of an urban model, to display attributes and their values, or to edit them. Furthermore, the user is able to select objects in the visualization which results in the display of the corresponding entry in the CityGML Browser.

B.3.2.6 Visualizing different model representations and states

A new item is inserted into the LandXplorer project for each loaded information entity (map layer, city model). These items are arranged in a tree view and can be deselected from the visualization which is very useful for the simultaneous integration of different representations of a building (e.g., detailed building models on the one hand and room models generated from IFC on the other hand). This also can be used to integrate different planning states of a single building and to identify the changes by switching between their visualizations.

B.3.2.7 External References in CityGML

CityGML data can carry external references. In our scenario, the external reference represents a link to the IFC data which were the basis for the CityGML creation. For the finally selected building and room this link can be accessed via CityGML browser and can be forwarded to space planning. Again, CityGML supports the functional interoperability between different applications and application domains.

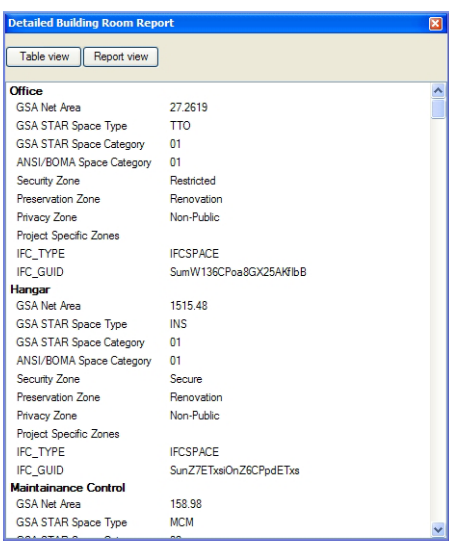
B.3.2.8 Groupings in CityGML

CityGML supports the grouping of different city objects in a so-called CityObjectGroup by referencing to various CityObjects. The CityGML specification suggests using this CityObjectGroup for establishing building complexes, storeys, etc. As a CityObjectGroup is not attached explicitly to a specific building object, the correlation between building groups and contained groupings is given only implicitly.

B.3.3 Building Room Report and Building Assessment

The implemented building room report is an application for the utilization of building information in the geospatial context. It uses the room information which is integrated in the CityGML description that was provided by the BIM WFS.

This information is stored as StringAttributes in the CityGML rooms. Each of them consists of an attribute name and value – examples are area size or space category. The building room report shows this information in report or table style. Additionally, this building information is utilized for a visual building assessment. The rooms' attribute values are color-coded which allows the user to see the properties of the rooms together with the geospatial relationship of the building in one view. (Figure B.2)

a)


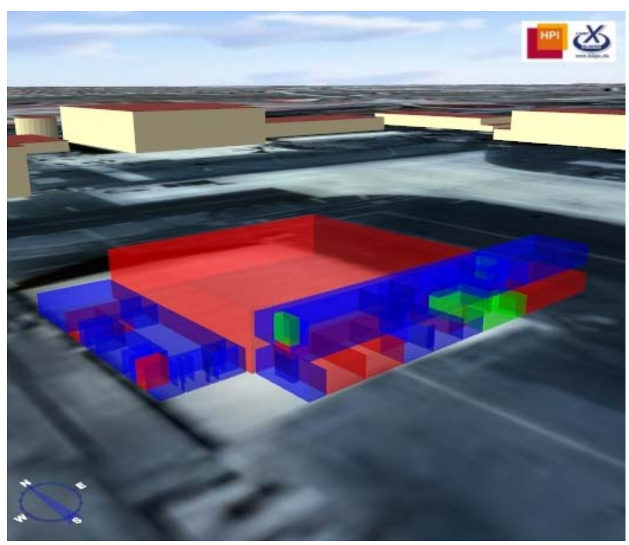
b)


Figure B.2: Textual building room report (a) and visual building assessment color-coding security zone attribute (b).

In addition to CityGML rooms (these are IFC spaces) further building entities could be used for such a building assessment. The introduction and application of attribute profiles (e.g., as application domain extensions as currently proposed for CityGML) would be great for allowing some predefined color-codings which result in better visualizations.

In the normal view the buildings' rooms are rendered transparent, for as they are often additional information in CityGML files. For the assessment view, rooms are displayed semi-transparent for enabling a look through and so to investigate the whole building at once – building parts which are not rooms are removed from the visualization.

B.4 Lessons Learned

For decision support, it can be useful to integrate building models –which are available in CAD format only– into a geovirtual environment via CityGML. In the concrete testbed scenario, this enables the user to evaluate buildings and different planning states in interrelation to other features and geospatial information. The geovirtual environment serves as a platform for the seamless integration of geoinformation which are different in source, format, and semantics.

Context document are essential for an easy description of a GeoVE and for its construction from distributed information sources.

The integration of building information into CityGML is currently done by simple StringAttributes. This should be done in a more formal manner with defined structures and content. The planned application domain extension (ADEs) for CityGML should be a suitable solution for this problem. In the context of BIM, information from different BIM models according to different BIM standards could be included.

As described above, geo-referencing of CAD data should be done at server side for that the internal spatial referencing of CAD tools must not be supported by the client for reaching interoperability.

Compression of CityGML data is very important for service-based access. On a technical level it reduces the data size and so the network load and transfer time. On the application level it supports shorter response times and so increases the usability of a service-consuming client.

B.5 Future work

On a technical level, the current viewer client implementation should be improved according to efficiency in data access and processing. This includes issues as asynchronous service access, data caching and preloading. Additionally, there should be functional extensions as a more dynamic data binding (via GetCapabilities request) or the possibility to store the created GeoVE in a context description for service-based re-construction or as a CityGML file for easy transfer and for increasing the interoperability between different systems, applications, and processes.

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