Indoor Abstract Spaces: Linking IndoorGML and LADM

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SUMMARY

In this paper we investigate the possible synergy between two different but related standards: OGC's IndoorGML and ISO TC211's LADM. Both (can) deal with 3D spaces with properties, constraints and associations attached and both can operate with abstract notations of space. But there are also differences, e.g. LADM is a conceptual model, while IndoorGML is also an actual XML schema (technical model), which can be used directly for data exchange and storage. Also, the scope is different; e.g. IndoorGML focuses on indoor spaces, while LADM addresses all spaces (in principle a complete subdivision of the countries territory, including outdoor, water and surface spaces). LADM models legal and administrative concepts such as use and ownership rights of spaces related to certain parties. IndoorGML puts emphasis on connectivity of spaces related to the navigability as one of the main use cases. These characteristics make the two standards quite complementary and this motivates our exploration in the combination of both. The spaces defined by LADM are the results of legal/administrative rights, restrictions, responsibilities (largest possible homogeneous spaces with respect to these RRRs). The space subdivision of IndoorGML is based on navigable areas and their connectivity. IndoorGML also recognizes other spaces, called abstract spaces. The paper will compare the space characteristics of the two models and will explore options to combine the models.

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1. INTRODUCTION

Many indoor applications deal with abstract spaces, i.e. spaces which do not have well-defined physical borders (such as walls, ceiling and floors), to identify a function, use or right on the space. For example, a room can be further subdivided into several sub-spaces indicating 'information corner', and 'working area', or a 'security area'. Figure 1 illustrates such examples. Such functional areas need to be identified and usually this is done by applying geometric or semantic approaches fro partitioning of space (Bandi. and Thalmann, 1998, Becker et al 2008, Goetz and Zipf, 2011, Khan and Kolbe 2012, Afyouni et al 2012, Brown et al 2013, Zlatanova et al 2013, Kruminaite and Zlatanova, 2014). Although the importance of such spaces is recognized, their modelling is still insufficiently explored, especially in the context of human perception and human navigation (Fallah et al, 2013).

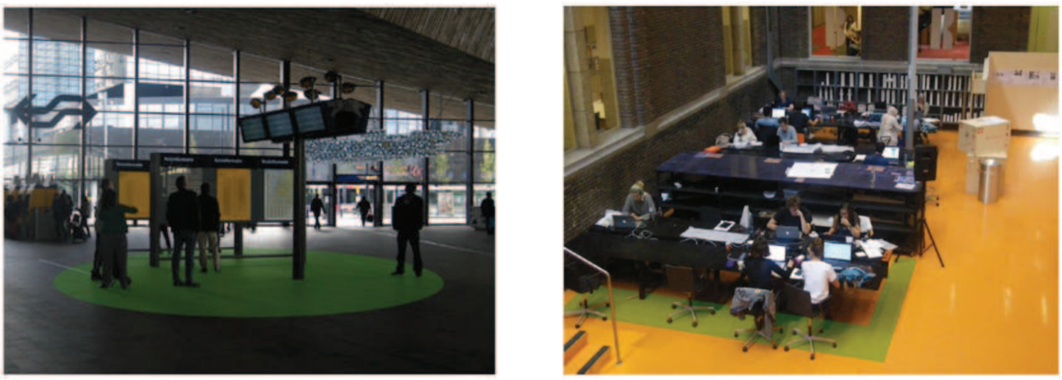

Figure 1. Examples of functional areas (in green): information corner and working area (Kruminaite and Zlatanova, 2014)

In this paper we investigated two international standards IndoorGML (Lee et al 2014) and LADM (ISO 19152 (E), 2012), which allow the description of abstract spaces. We investigate how to bridge these two standard to allow space identification on the basis of ownership, right and restriction on properties. We wconsider two options:

- a formal approach for deriving a LADM space layer within IndoorGML context
- a 'equivalence' association between LADM LA_SpatialUnit and IndoorGML abstract space for rights (RRRs), similar to other associations of LADM classes and other external classes.

The remaining part of the paper is organized as follows: next section briefly presents some of the IndoorGML concepts and specifically the mechanism for derivation of a network for navigation. Section 3 presents the concepts for bridging the two standards from IndoorGML point of view. We discuss our further investigations in the last section.

2. INDOORGML

IndoorGML was adopted as an OGC standard in December 2014 (Lee et al 2014, Li, 2016). IndoorGML is intended to support development of indoor navigation systems, by providing description of indoor space and GML syntax for encoding geoinformation (geometry, network or path) for indoor navigation. In this respect IndoorGML is application-oriented standard and differs from generic 3D standards such as CityGML, KML, and IFC. It is based on subdivision of the interior space. The obtained cells are described with its geometry, semantics and topology that are important for indoor navigation. In this respect, IndoorGML can be seen as a complementary standard to CityGML, KML, and IFC to support location based services for indoor navigation. IndoorGML defines the following information about indoor space: navigation context and constraints, space subdivisions and types of connectivity between spaces, geometric and semantic properties of spaces and navigation networks (logical and metric) and their relationships.

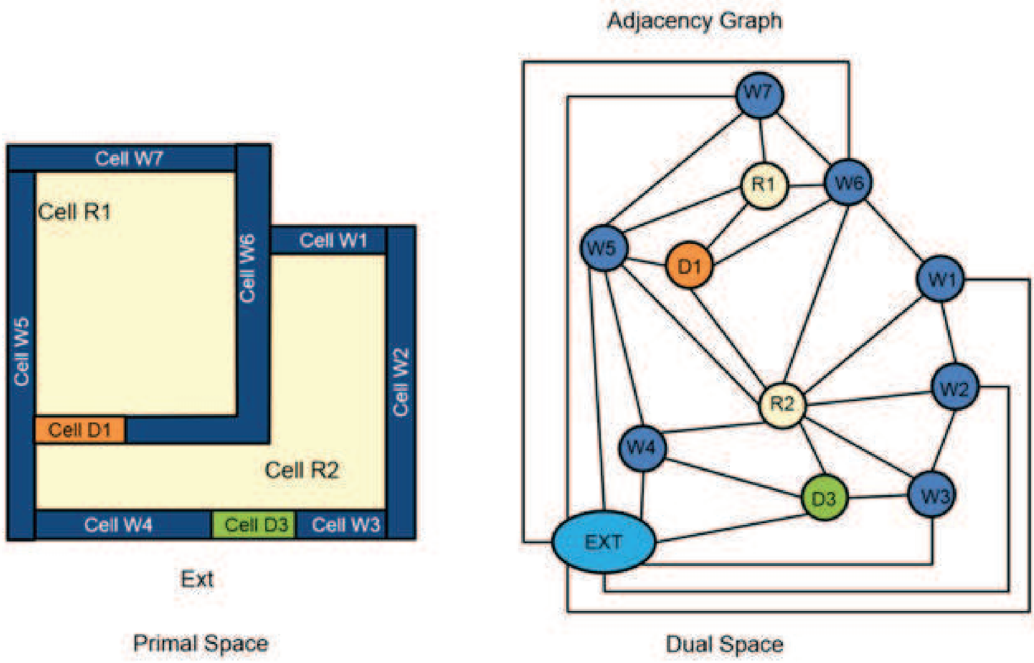

Figure 2. Example of spaces in a building: a) non-navigable (in blue) and navigable (in yellow, orange and green) b) derived network

The notion of space or 'cell' is the most important concept in IndoorGML (Figure 2). A building or groups of buildings are subdivided into non-overlapping cells. The cells are further classified into navigable or non-navigable. The adjacency network is then to be derived by applying Poincaré duality, i.e. each cell in the 3D space (named also primal space) is mapped in a node in 2D space (dual space) and the adjacency between the spaces represents the edges. For the purpose of navigation, non-navigable spaces are not of interest and have to be excluded from the adjacency network. Considering the remaining links and the semantics of the spaces (i.e. which spaces are doors), the navigation/connectivity network is derived. An important characteristic of the IndoorGML is that cells do not need to be bordered by physical features. Cells can be defined as aggregation of features or a physical space can be subdivided into smaller units. It is also possible to neglect the size of some physical features, e.g. doors, windows. As visible on Fig 1, the doors are represented as spaces, but the standard allows to represented them as borders (i.e. 'thin doors') between two spaces. In that case there are no door nodes in the navigation network.

IndoorGML allows multiple space subdivisions per building (Figure 3). A space subdivision can be derived from the topography of the building, the function of spaces, the security restrictions, but can be also with respect to coverage of sensors (wifi or RFID) or the legal (LADM RRRs) status of spaces. Different spaces are to be organized according the Multi-Layered Space Model

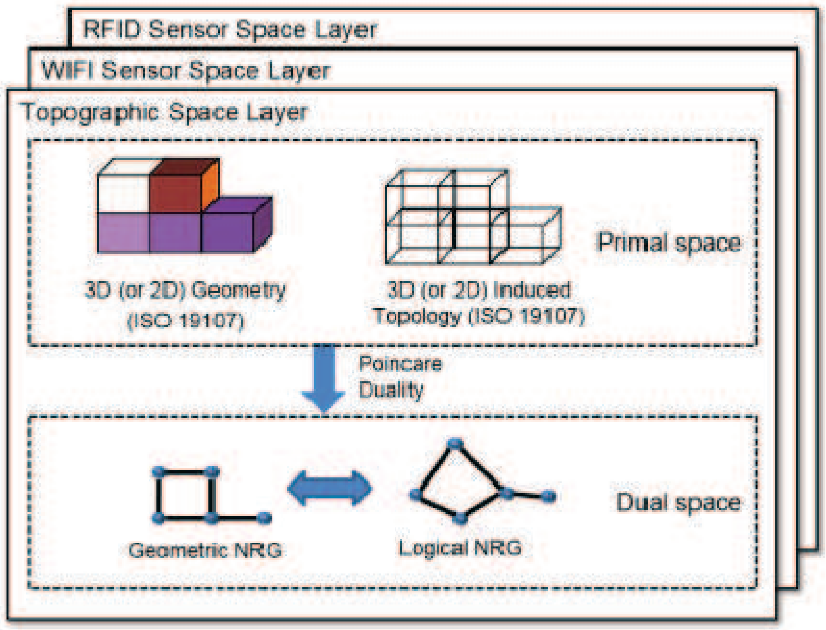

Figure 3. Multi-Layered combination of alternative spaces (Lee et al 2014)

Space modelling with respect to its legal use is specifically interesting for IndoorGML. Restrictions, rights and responsibilities on a part of a floor or a building can influence the accessibility and can significantly change the set of cells that can be used to derive a network. Many office buildings share common entrance and registration areas and they share the responsibilities for the maintenance of the common area. Shopping malls may also share access to different departments and sections but they also have clearly defined area which are give for use only to them. In many public building restricted or security areas are clearly identified by requiring security cards and/or security doors. Such RRR are rarely identified with physical brothers and are usually difficult to model.

Modelling is always within a certain domain and scope, despite the fact that many concepts are also linked to more concepts. In the past, the conceptual models of LADM and Land Parcel Identification (LPIS) have been linked (Inan et al, 2010; ISO, 2012) as it makes sense to combine the information of cadastral parcels (LADM) to agricultural parcels (LPIS) for the management of subsidies to the farmers. For this purpose, EU member states have established Integrated Administration and Control Systems (IACS), including Land Parcel Identification Systems (LPIS) as the geospatial component. LPIS concerns 'outdoor' parcels. For the (extended) indoor environment it does make sense to combine the conceptual models of

IndoorGML and LADM. With this the two domains information from these two domains can be used together in a meaningful manner.

Examples of indoor environments that are influenced by RRR could be:

- Shopping malls, which consist of areas in which are all visitors are welcome, areas avaible for employees of the specific shop, areas accessible for maintenance/cleaning services only.
- Railway and metro stations, which have areas for all users, platforms avaible only for passengers, metro tunnels avaible only for train personnel, ticket service area avaible only for clerks selling the tickets, etc.
- Museums, which have large exhibition halls used by visitors, storage halls used only by exhibitors, administration areas, restauration areas, available only for experts.
- Airports, which consist of common spaces accessible for all visitors, check-in area accessible only for travelers, passport control accessible for checked-in travelers, waiting/shopping areas, boarding gates, transit areas, ‘international space’ (‘no men’s land’), and so on. Similar for non-common spaces and restricted areas.
- Hospitals consists also for common access areas, sections for examination patients, areas for hospitalized patients, surgery, laboratories, storage of medical equipment, etc.

Considering the example above, we distinguish between the following use cases:

- Restrictions and responsibilities for users of indoor environment. The different functions as mentioned in the overview include all kind of restrictions (formal or informal obligation to refrain from doing something) and responsibilities (formal or informal obligation to do something). A building administration may impose all kinds of restrictions and on the use of the building which can be modelled in LADM and visualized to the user of indoor navigation. This may be linked to liabilities in certain situations.
- Restrictions and responsibilities for maintenance of indoor environment. This use case is similar – but now for persons responsible for the maintenance of services in buildings or for persons with responsibilities in case of emergencies. In this type of situations the link to administration/ownership and territory should be clear.
- Design and maintenance of networks - To manage a network in indoor environment it is important to know the legal ownership of the space where it is installed. This is a use case in design of (extensions of) the network for IndoorGML.
- Maintenance of datasets for administration purposes. The construction of external databases with party data, address data, taxation data, land use data, valuation data, physical utility network data, and archive data, is outside the scope of the LADM. However, the LADM provides stereotype classes for these data sets.

3. USE OF LADM FOR INDOORGML

In this paper, we propose two approaches to link IndoorGML and LADM. The first approach is to define an extension module of IndoorGML for supporting the LADM standard within IndoorGML. This approach is quite straightforward due to the equivalence of two classes, `CellSpace` of IndoorGML and `LA_SpatialUnit` of LADM, although they are defined for different purposes. The second approach is to provide a mechanism to associate features in datasets of different standards. For example, we can access from a feature in IndoorGML to LADM feature via the external link, which is a pointer such as URI to an object in other dataset.

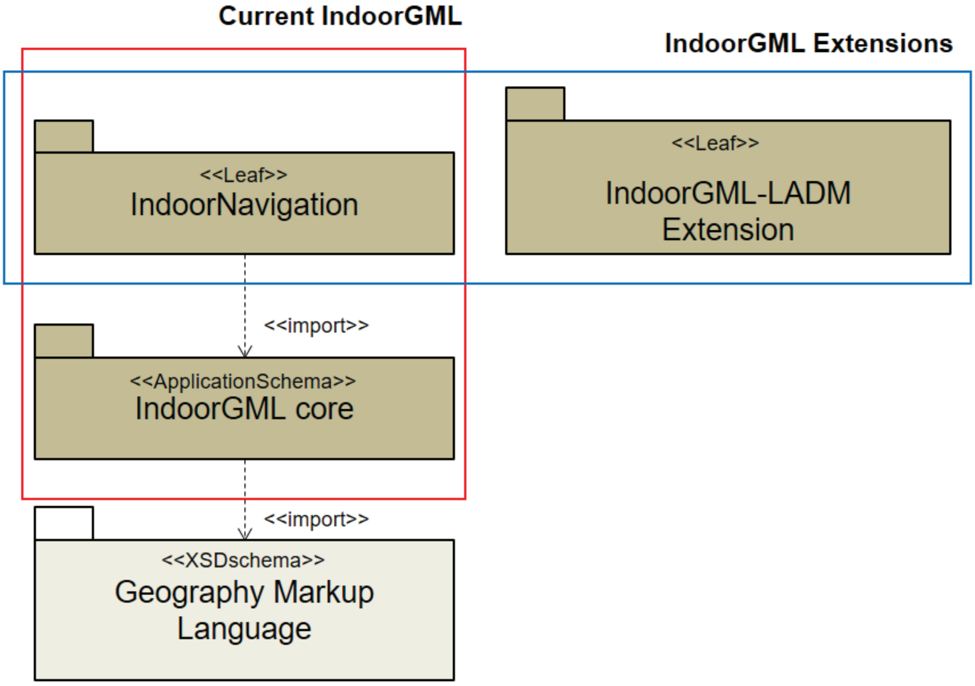

Figure 4. Core Module and Extension Modules of IndoorGML

3.1 IndoorGML-LADM extension

In this section, we explain the first approach in detail. IndoorGML has its module structure as shown on Figure 4. It is composed of one core module and extension modules. Only indoor navigation module has been defined as an extension up to now. The first approach is to include the IndoorGML-LADM module as an extension of IndoorGML.

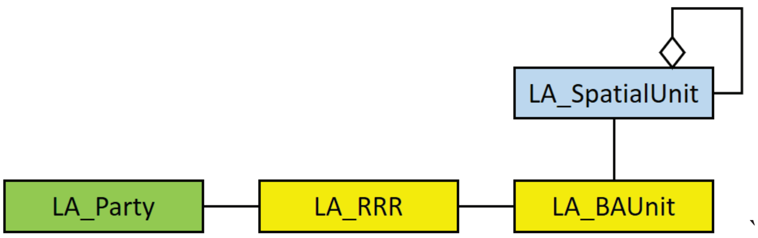

Figure 5. Core Classes of LADM

The data model of LADM (Lemmen et al 2010, 2015) is briefly summarized by Figure 5 where each class in the model is defined as follows;

- `LA_Party` is a person or unit with rights
- `LA_BAUnit` stands for Basic Administrative Unit
- `LA_RRR` stands for Right Restriction Responsibility
- `LA_SpatialUnit` stand for the physical (spatial) representation

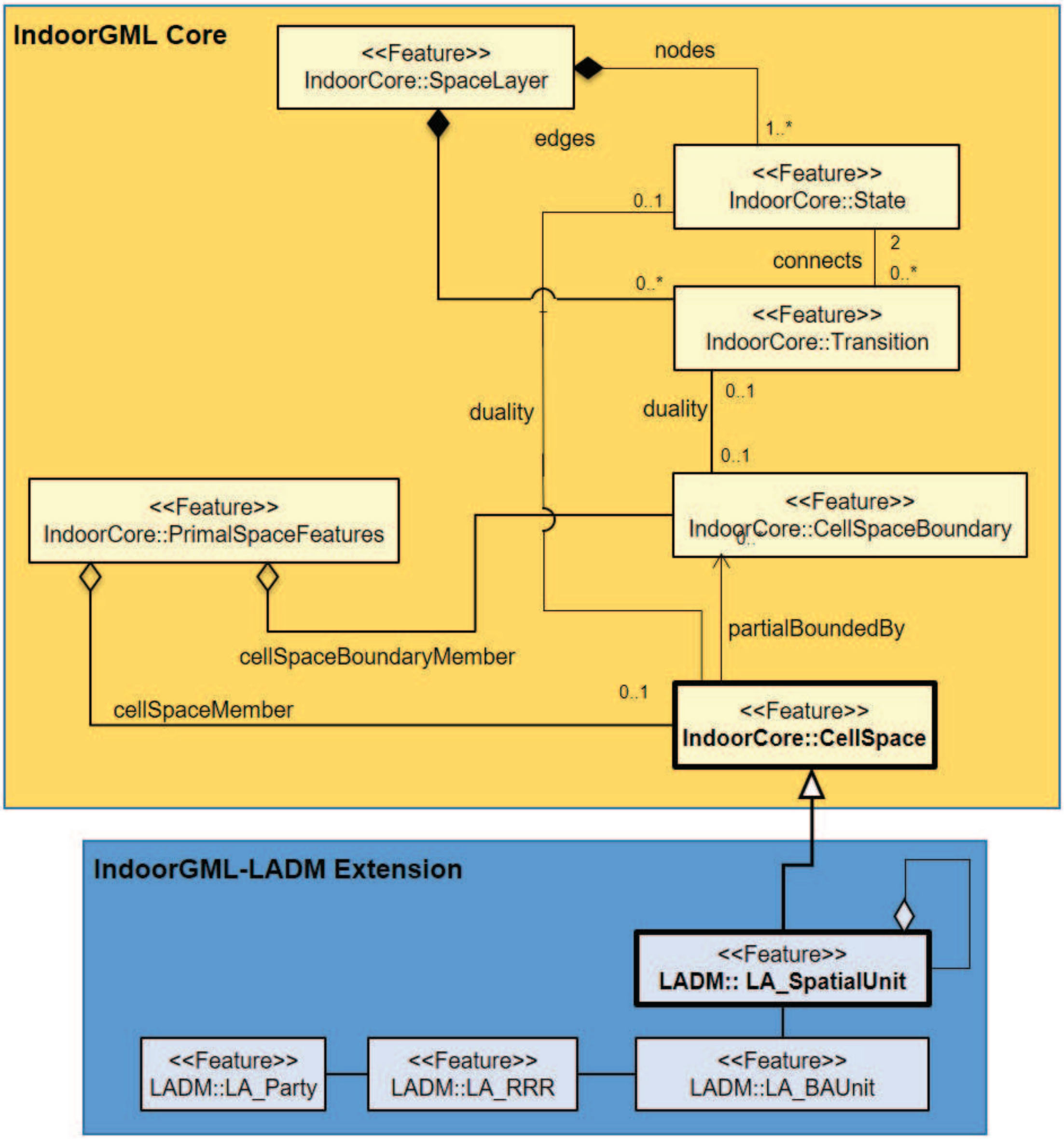

Figure 6. LADM Extension of IndoorGML

We observe that the class `LA_SpatialUnit` in LADM corresponds with `CellSpace` of IndoorGML, which are both considered as a space unit in indoor space. Since `LA_SpatialUnit` has more properties related to the legal information in addition to geometric data, it is defined as a subclass of `CellSpace` in the extension module as shown in

Figure 6. Then the 2D or 3D cell geometry is inherited from `CellSpace`. The other cadastral information is defined in `LA_BAUnit`, `LA_RRR`, and `LA_Party` in IndoorGML-LADM extension. Because the geometry types of both standards are based on the same geometry model, ISO 19107, no geometric type conflict is expected.

3.2 IndoorGML-LADM extension

If the correspondence between features in LADM and IndoorGML is one-to-one, the objects of LA_SpatialUnit in IndoorGML-LADM extension are constructed in a straightforward manner. However, a cell object of `CellSpace` may not exactly correspond to one single object of `LA_SpatialUnit` as shown in Figure 6. For example, Cell C_2 defined from Corridor corresponds to two objects of LA_SpatialUnit SU_1 and SU_2, and two cells C_3 and C_4 corresponds to an object SU_2. In this case, we need to apply the Multi-Layer Space Model of IndoorGML. The Multi-Layer Space Model in IndoorGML allows that a single indoor space can be differently partitioned according to different interpretation of space and each partitioning forms a single space layer as shown in Figure 7b and 7c.

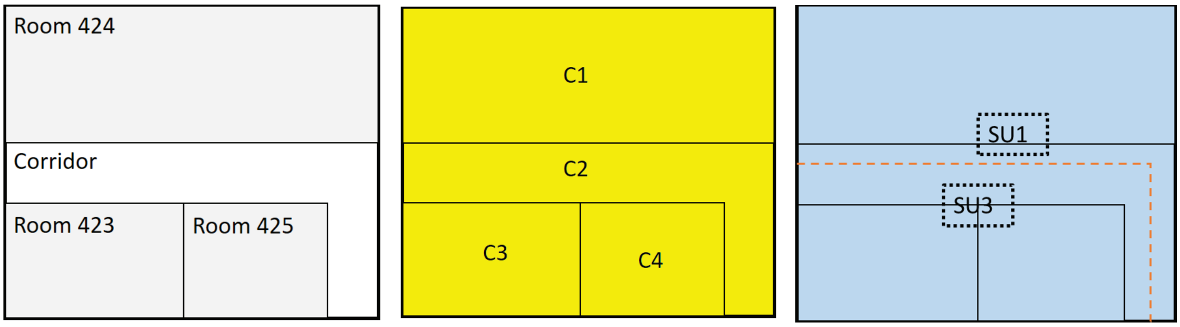

Figure a
Given Indoor Space

Figure b
Cell Patition

Figure c
SpatialUnit Partition

Figure 7. 1-n, m-1, and n-m Correspondence between features in LADM and IndoorGML

And the relationship between different space layers is described by interlayer connections with topological property. For example, interlayer connection (C_1, SU_1, `Inside`) means that C_1 is connected to SU_1 with `CInside` topology. In this way, two space layers with interlayer connections are included in IndoorGML data, where the objects in `LA_SpatialUnit` Space Layer of Figure 8 comprise the features of IndoorGML-LADM extension.

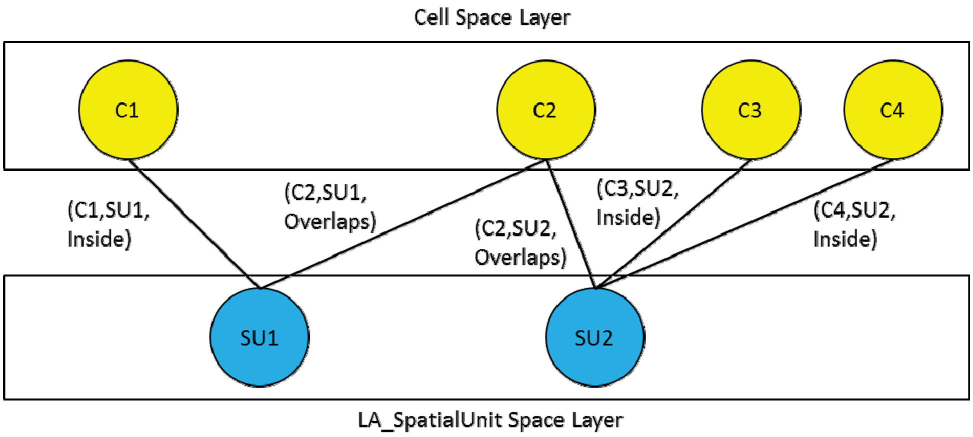

Figure 8. Inter-Layer Connection of IndoorGML Multi-Space Layer Model

4. USE OF INDOORGML FOR LADM

Another interesting aspect to be explored is the fact that IndoorGML contains 3D topographic information (in way similar to LandXML, InfraGML, CityGML, BIM/IFC), which can be identical or not to the architectural structure of a building. 3D legal spaces often need reference objects to make sense (for orientation and understanding purpose). 3D legal space can have their own independent geometry and topology, but usually it is not that well defined and rarely geometrically modelled. IndoorGML can be used for the definition of LADM's legal spaces. Since the IndoorGML cells have to be always geometrically modelled, the subdivision/aggregation invoked by RRR will lead to identification of the RRR geometry. This operation could be quite complex and be a sequence of operations such as buffer of a 3D space, or a middle of a 3D wall/floor space to be assigned to neighbor room space, or aggregating a number of room spaces, etc.). In such a way, we can related the use of abstract spaces in LADM we can relate these to the cell spaces in IndoorGML as in the original indoor model.

Usually many spaces (rooms) make one property (LA_SpatialUnit with same ownership rights), but as seen in the previous example this is an n-to-m association. Actually this implies reuse of geometry (coordinates, surfaces) and enhances consistency between the various representations. However, after this preparation and defining the IndoorGML abstract spaces it is clearly possible that LA_SpatialUnit inherit this geometry. It is questionable if this can be done for all LA_SpatialUnit. Remember that some spatial units are not related at all to a building, but just to land (or subsurface space). Perhaps an n-to-m association would be better. Next issue is to have 3D geometry at both sides of model or to have it at one side when possible (e.g. 1-n and n-1 associations, and in other cases add additional boundary faces), If geometry is duplicates then constrains should be sued for proper data content according to semantics.

5. CONCLUSION

In this paper we have analyzed a few options to bridge the IndoorGML and LADM. The bridging seems natural and can be of benefit for both models. IndoorGML can be augmented with space cell based on rights, restrictions, responsibilities and LADM can inherit the geometry from the IndoorGML partitioning and/or aggregation. It should be further investigates how to create the legal spaces, which can be verbal and not very accurate. The next step would be to establish a set of geometric and topological operations which can ensure that the descriptive definition would be accurately modelled. Still to be investigated is which of the approaches mentioned above would be most appropriate for enhancing IndoorGML space definition (a space layer or direct link). If RRR have many facets and is highly depended on the type of user (visitor, maintenance team, employee, cleaning, deliver, etc.), the list of layers might become very long and not practical.

In future research, we will concentrate on the most prominent use cases and will experiment with the conceptual linkage between the two models as presented above.

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BIOGRAPHICAL NOTES

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