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Improved and More Complete Conceptual Model for the Revision of IndoorGML

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Abstract

With the increasing number of indoor navigation applications, it is essential to have clear and complete conceptual model (in the form of UML class diagram) for IndoorGML. The current version of IndoorGML standard has an incomplete class diagram (incomplete w.r.t. attributes, of which some are appearing in the XML/GML schema), and that provides confusion for the users of the standard. Furthermore, there are some issues related to unclear association names, unclear class names, classes that related to the Primal space and the Dual space, code lists not specific per type (which should have their own code list values), untyped relationships to external object classes, and semantically overlapping classes. In this paper, we propose an enhancement for IndoorGML conceptual model (UML class diagram) to avoid the misunderstanding. We propose a conceptual model that maps the classes of the standard in a better way. This conceptual model is the basis for 1) a database schema when storing IndoorGML data, 2) the XML schema when exchanging IndoorGML data, and 3) when developing IndoorGML applications with an intuitive and clear GUI. Furthermore, the proposed conceptual model provides constraints for more meaningful model and to define more sharply what is considered valid data. This paper briefly reports these preliminary results on the UML conceptual model.

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Keywords and phrases Navigation, Space, Boundary, CellSpace

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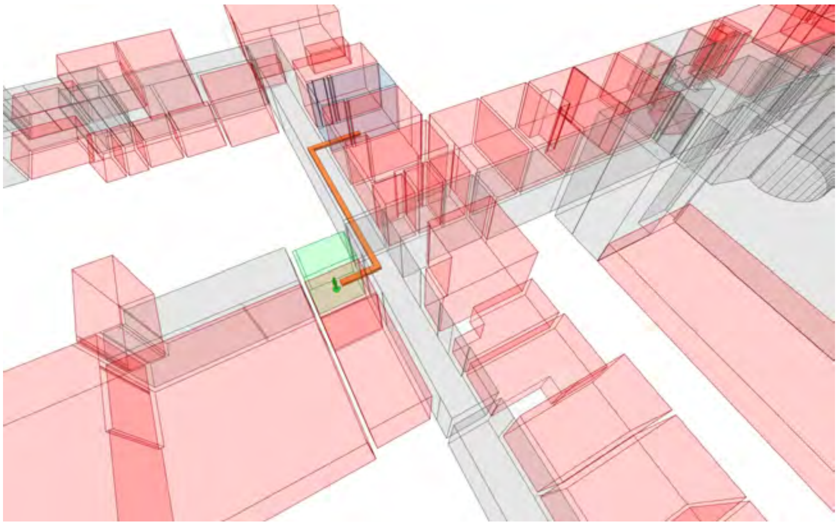

Figure 1 Indoor navigation path.

1 Introduction

Over recent years, the research area of navigation has become very active with an extensive variety of applications. Navigation is essential but also complex human activity. While initially navigation systems have been established for outdoor environments (such as for cars on the road), presently they have subsequently developed to be an essential field of interest for indoors (Makri et al. [11]). According to (Klepeis et al. [8]) around 87% of the people in the USA spend most of their lives inside buildings and the movement of the user of the indoor environment has been affected by the massive size of the indoor environment. The public buildings in our cities such as airports, train stations, hospitals, offices and university buildings, confront users with difficulties to find their destinations, and thus various research has been carried out that has resulted in many navigation models as shown in Figure 1. In this paper we concentrate on IndoorGML, adopted as a standard by Open Geospatial Consortium (OGC).

IndoorGML delivers a framework for indoor navigation systems to offer a description of the indoor space and provide Geography Markup Language (GML) syntax for encoding geoinformation (Zlatanova et al. [15], Kang and Li [6]). IndoorGML consists of two parts, first the core data model which describes geometry and topology connectivity, and second, a data navigation model that provides semantics for the navigation process (Lee et al [10]). The main purpose is to establish a methodology to classify spaces (rooms, corridors, etc.) and their indoor characteristics rather than represent architectural elements (Li, [9]). However, the current version on IndoorGML has incomplete UML model and that affects the quality of applications that depend on it. In this paper we propose an enhancement for the new version of the standard. We have also discussed alternatives in several cases and provided arguments pro and con each option and based on this selected best option. We classify some critical aspects that we have considered in this process:

- Complete attributes and code list for all classes.
- Better representation for the Primal space and Dual space.
- Clear terminology (vocabulary).
- Introducing geometry as attribute of classes (making the model more clear).

The methodology of this research is based on the following research phases: 1. Analyzing current version of IndoorGML and finding missing and weak parts, 2. Proposing options for solutions, 3. Discussion the pros and cons of the various options, 4. Selection the best option and make this part of improved IndoorGML proposal, 5. (Future work) develop technical model and populate with real data (to assess the conceptual model of IndoorGML) and further fine tune model when needed, 6. (Future work) bring our proposal into the standardization process within OGC (and collect opinion of the members of the IndoorGML team). The output of this investigation will be provided as input to OGC for an enhancement of the future version of the standard.

In Section 2, we discuss the research and developments related to IndoorGML in general and the UML model of IndoorGML, while in Section 3 we propose the enhanced UML model for IndoorGML. Finally, Section 4 concludes this paper.

2 Background

IndoorGML is an OGC standard that presents an elaboration of the indoor space and GML syntax for encoding geoinformation for the purpose of navigation (Zlatanova et al., [14]). IndoorGML defines a model to represent the geometry, topology and semantics of the indoor spaces which are used for the components of navigation network. The indoor and outdoor spaces differ from each other in many characteristics. Based on the indoor requirements for the spatial applications, the standard have to be reviewed with respect to the type of indoor applications. There are two categories indoor spatial applications: 1) managing the building components and facilities, and 2) using the indoor space. The first category mainly focuses on the architecture elements of the building such as walls and roofs (this discipline is called FM, facility management). The second category deals with the usage and localization properties of the indoor space, which refers to representing spaces such as rooms, corridors, and constraints elements such as doors. IndoorGML defines a framework to locate static or mobile objects (agents), and provide spatial information services (navigation) by using their positions in indoor space. IndoorGML represents the spatial character of the indoor spaces and provides information about their connectivity (Lee et al., [10]).

The indoor navigation research community broadly re-uses concepts such as Dual and Primal Space and automatic derivation of Dual Space that are part of IndoorGML (Diakite et al., [3]). Thus, research and developments depend on the standard to build applications based on the spatial framework of the standard. In that regard, software tools, e.g. an editor and a viewer have been developed by (Hwang et al., [4]) to support related studies. Concerns have been expressed about representation in 2D and 3D and the link between indoor and outdoor. (Kim and Lee, [7]) have proposed a semi-automatic approach to create IndoorGML data from images. In the same direction, (Mirvahabi and Abbaspour, [12]) have proposed an automated method to extract IndoorGML data from OpenStreetMap. (Diakite et al., [3]) have proposed a concept study for space subdivision to distinguish two significant aspects: the occupancy of the indoor space that influences the notation of indoor cells, and the description of criteria to support the automation of the space subdivision process. (Diakite and Zlatanova, [1]) have introduced an approach that creates the geometrical and topological valid IfcSpace classes in an IFC model, which can then be utilized for deriving a navigation network. Also, (Ryu et al., [13], Iida et al., [5]) have tried to enhance some characteristics of the current standards such as introduce attributes to support visually impaired people.

However, none of these researches have addressed the issues that relates to the UML model of IndoorGML. For navigation, it is important to include the access rights and/or restrictions of a user (group). When, developed a combined IndoorGML-LADM, we were confronted with the incompleteness of IndoorGML conceptual model (Alattas et al., [2]).

The current IndoorGML UML model contains the classes and their relationships as shown Figure 2. It has four different type of classes (GML, IndoorCore, IndoorNavi, and Not implemented). Most of the classes do not have attributes: no attribute names, no attribute data types. Further, the associations that link the classes has names that bring some confusion to the user. The GeneralSpace and the TransferSpace classes have attributes that contain the same code list values. But, if code lists are values equal, it is unclear what has to separate the code lists. The SpaceLayer class has a relationship with the CellSpace, State, and Transition classes and that create misunderstanding for the user of the standard (as it is not directly clear from the model that CellSpace/ State represents primal space and that Transition represents dual space). Furthermore, including AbstractFeature class is not the best way for illustration, because it has many relationships with other classes. Furthermore the type of the link is a generalization with lines in the illustration to nearly all other classes: spaghetti drawing. The standard represents the geometry data as separate classes and that allows mixing of the geometries to different objects (which could have been sharper typed). In addition, having geometry as separated classes in the illustration of the model increases the number of boxes and lines (i.e. creates spaghetti feeling). Therefore, in this paper we carry out a deeper study on several issues that relate to the UML class diagram and provide an enhancement for the new version of the standard.

3 Proposed UML Model for IndoorGML

In this section we present the proposed improvements, refinements and changes to the IndoorGML conceptual model. The current UML classes of IndoorGML are represented in pink color and the proposed UML classes are presented in light blue color.

3.1 From Classes to Attributes

Solid, Surface, Point, and Curve are geometry classes (as defined in ISO 19107) in the current version of IndoorGML with associations to classes that have geometric representation. Although this approach might be beneficial for keeping consistency, it is rather unclear for implementation. Therefore, we propose to convert the classes into attributes. The CellSpace class will have two additional attributes to represent the geometry data types as shown in Figure 3. The 3DGeometry attributes will have the GM_Solid value, and the 2DGeometry attributes will have the GM_Surface value. The CellSpace class will have a constraint that only one of the attributes (3DGeometry or 2DGeometry) has to be filled to ensure that the user correctly using the standard. The CellSpaceBoundary will have two additional attributes, first 3DGeometry attribute that has the value GM_Surface, and, second 2DGeometry attribute that has the value GM_Curve. The CellSpaceBoundary class will have a constraint that only one of the attributes (3DGeometry or 2DGeometry) has to be filled based on the type of geometry that has been used in the CellSpace class. Because the geometry of the CellSpace can (conceptually) be derived from the geometry of the associated boundaries, this is indicated with a forward slash before attribute name; e.g. /2DGeometry.

The Point Geometry type will be added as an attribute to the NodeInDualSpace class and the RouteNode class (for intermediate point) as an attribute that call Location and has the value GM_Point as shown in Figure 4. The curve geometry type will be added to EdgeInDualSpace class and RouteSegment class (for route parts) as an attribute that call Geometry and has the value GM_Curve as shown in Figure 5.

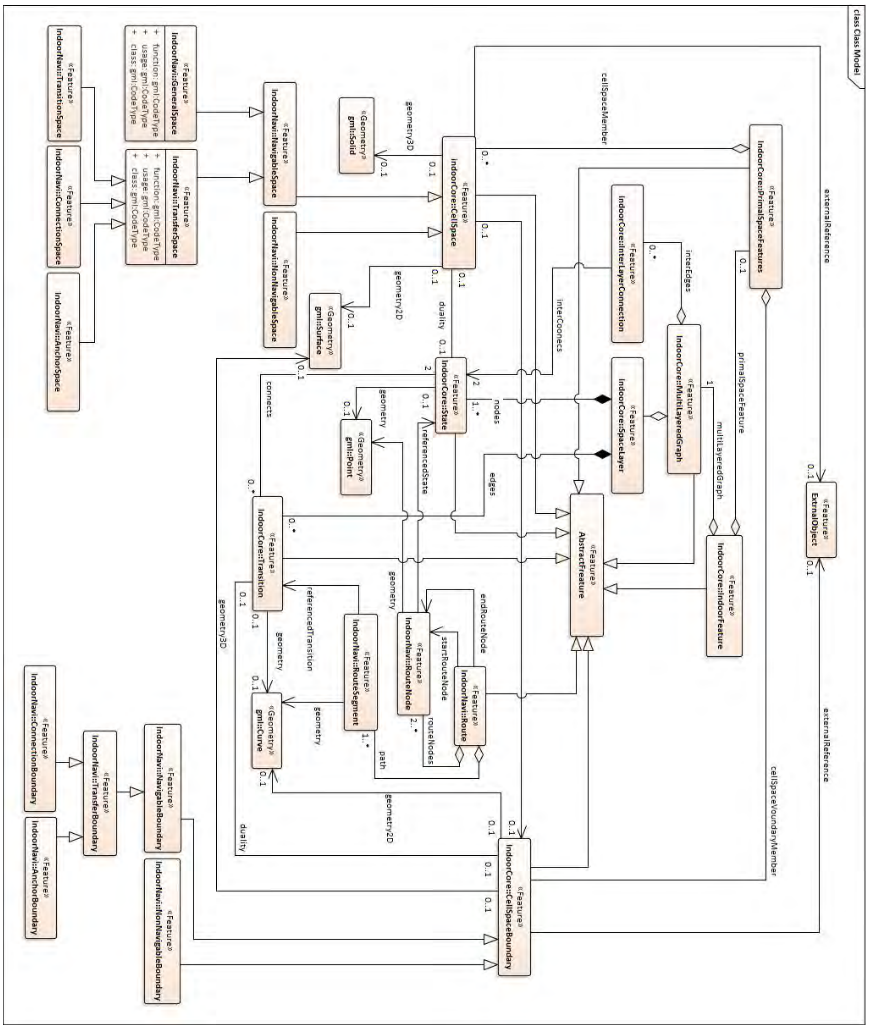

Figure 2 The current UML model of IndoorGML.

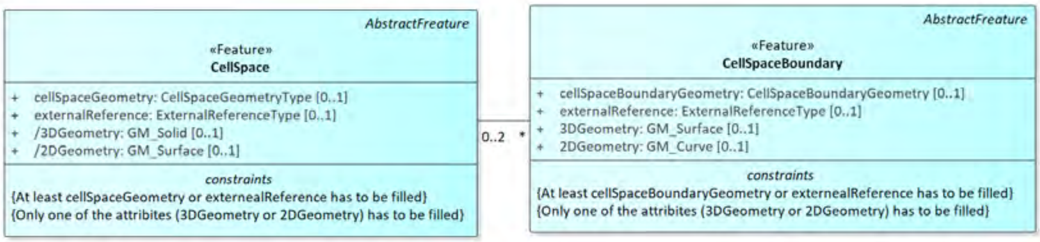

Figure 3 Additional geometry attributes for CellSpace class and CellSpaceBoundary and their constraints.

3.2 ExternalObject Class

The current UML model contains ExternalObject class that has an association with CellSpace class and CellSpaceBoundary as shown in Figure 1. We propose that the current ExternalObject class to have two external object classes. The new two classes will have

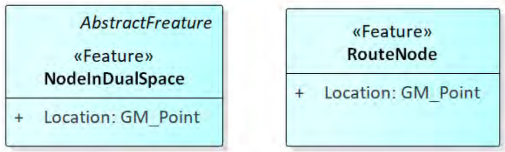

Figure 4 New attributes for NodeInDualSpace class and RouteNode class.

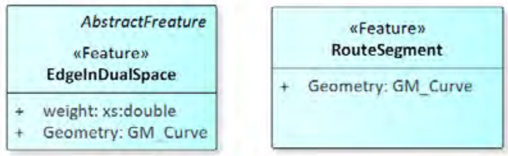

Figure 5 New attribute for EdgeInDualSpace class and RouteSegment class.

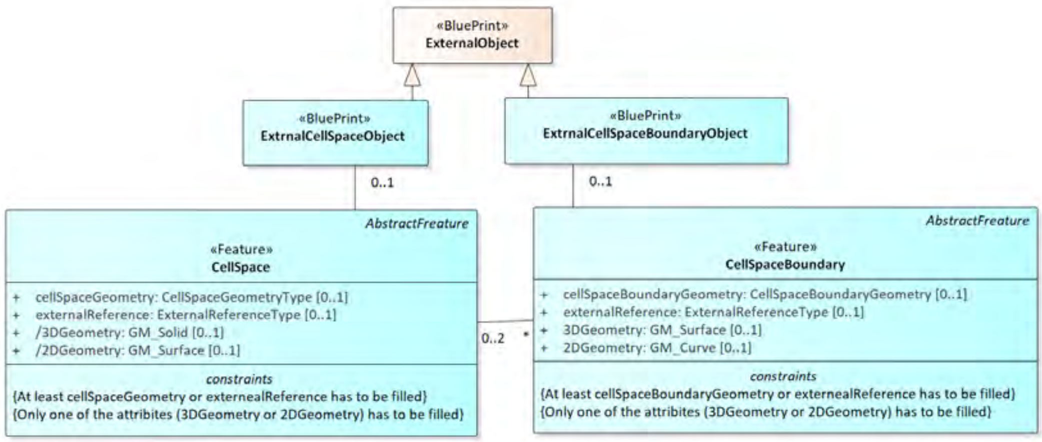

Figure 6 The proposed ExternalObject classes.

associations with the current ExternalObject class (as superclass), the new subclasses are also more precise typed. The CellSpace class will have an association with a new class that call "ExternalCellSpaceObjec" and it is responsible for providing the object reference of the Space from the ExternalObject class. Also, the CellSpaceBoundary class will have an association with a new class that is called "ExternalCellSpaceBoundaryObject" and it is responsible for providing the object reference of the boundary from the ExternalObject class. This method will bring more flexibility to the representation space and boundary as shown in Figure 6. Also, the type of the class of the ExternalObject has been changed from Feature type to the Stereotype «BluePrint», because this class represents a reference that not include in the model.

3.3 Association Multiplicity of CellSpace and CellSpaceBoundary

The association multiplicity between CellSpace and CellSpaceBoundary in the current version of the standard shows that each CellSpace has many Boundaries, and each CellSpaceBoundary has zero or one CellSpace as shown in Figure 1. However, in reality each CellSpaceBoundary could have one or two (or zero if boundary not used) CellSpace as shown in Figure 6.

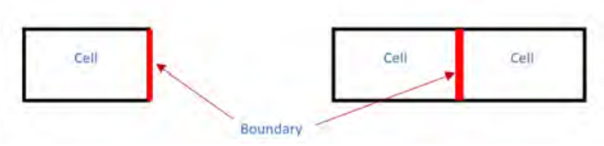

Figure 7 CellSpaceBoundary could have one or two CellSpace.

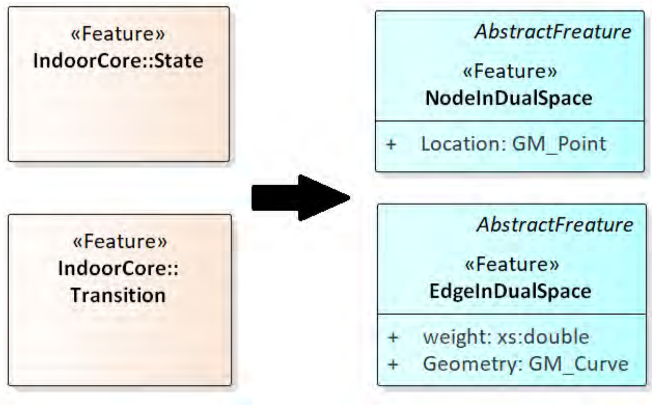

Figure 8 Proposed terms for State and Transition classes.

Furthermore, in case of so called functional areas or virtual spaces, the neighbor cells do share a one boundary. The multiplicity has been modified as shown in Figure 7.

3.4 The terms State and Transition

We propose to change the terms State and Transition into the more intuitive terms Node and Edge. In addition, we suggest adding the Dual terms to each class and that will make them understandable for the user that they are belong to the Dual space. The term State has been changed to NodeInDualSpace and the term Transition has been changed to EdgeInDualSpace as shown in Figure 8.

3.5 Code Lists

The current version of the standard has the same code list values for GeneralSpace class and TransferSpace class (gml:CodeType). We have changed that by adding different names for the code list as shown in Figure 9 (in total 7 different code lists).

The GeneralSpace class has three attributes (function, usage, and class) and each attribute has a code list value, with example code list values as shown in Figure 10. The Usage attributes has a code list values that represent the user groups of the space such as student group, employee group, and visitor group.

The ConnectionSpace class is a subclass of the TransferSpace and it has three attributes (function, usage, and class) and each attribute has a code list value as shown in Figure 11.

The AnchorSpace class is a subclass of the TransferSpace and it has three attributes (function, usage, and class) and each attribute has a code list value as shown in Figure 12.

The SpaceLayer class has six attributes (usage, terminationDate, function, creationDate, and class). The class attribute has a code list type value which is the SpaceLayerClassType as shown in Figure 13. Note that the values of an enumeration type are fixed (and con not be extended as for code lists).

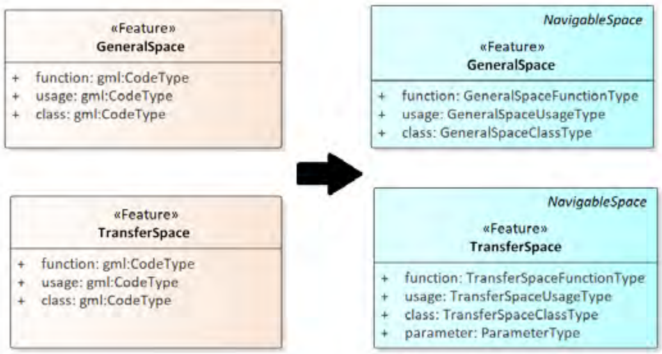

Figure 9 New code list names for GeneralSpace and TransferSpace classes.

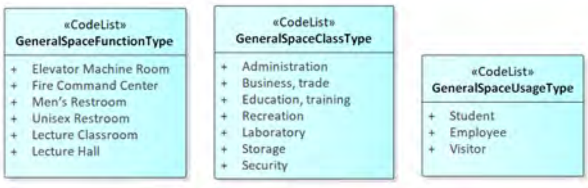

Figure 10 Code list for the attributes of the GeneralSpace class (with example values).

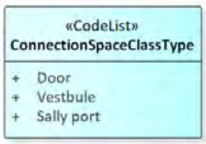

Figure 11 Code list for the attributes of the ConnectionSpace class.

Figure 12 Code list for the attributes of the AnchorSpace class.

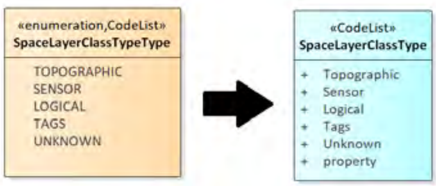

Figure 13 Code list values for the attributes of the SpaceLayer class.

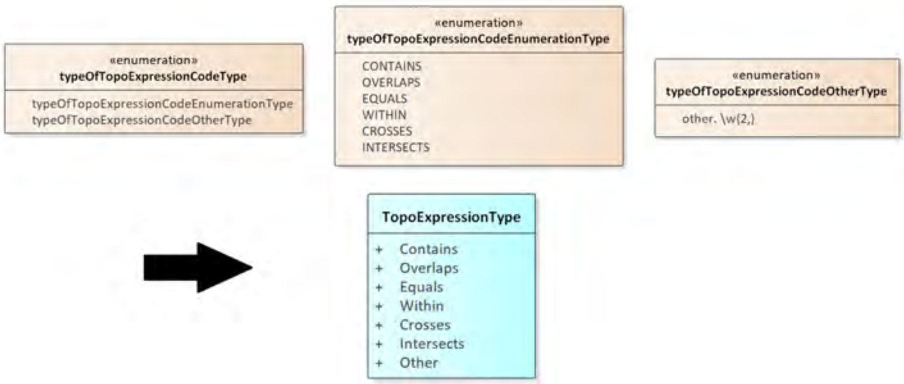

Figure 14 Enumeration values for the attributes of the InterLayerConnection class.

The InterLayerConnection class has two attributes (typeOfTopoExpression and comment). The typeOfTopoExpression attributes has an enumeration value which is the typeOfTopoExpressionCodeType and it consists of two enumeration values (typeOfTopoExpressionCodeEnumerationType and typeOfTopoExpressionCodeOtherType), however, we propose to replace these 3 «enumeration» types with a single «codeList» that has the name TopoExpressionType as shown in Figure 14.

3.6 Classes and Associations

The current UML model contains an association between SpaceLayer class and NodeInDualSpace (State) class and EdgeInDualSpace (Transition) class have been defined as Composition association as shown in Figure 1. However, instead of connecting these two classes to the SpaceLayer, we have proposed a new feature class call DualSpaceNetworkLayer that will be as a collecting class for the Node and the Edge of the Dual space. We want to emphasize that the layers can be for both: the Primal and Dual Spaces. The SpaceLayer class will have an association with the CellSpace class and the SpaceLayer will be collecting class for the spaces of the primal space. The name of MultiLayerGraph class has changed to MultiLayerNetwork because a graph does not need to have geometry and in the case of IndoorGML there is a need for geometries at least for the Nodes. The MultiLayerNetwork will has association with the NodeInDualSpace and EdgeInDualSpace instead of the association with the SpaceLayer because it deals with the Dual space as shown in Figure 15.

Also, the current UML model of IndoorGML standard has defined names for the associations between the classes such as duality, edges, nodes, geometry, and partialBoundaryBy which bring a lot of confusing during the generating of the XML schema as shown in Figure 1 as these association (role) names are very close to the names of the involved classes (and add little/no value). The propose UML model does not include all the defined names of the associations to avoid confusing as shown in Figure 16. Additional, the TransferSpace class and CellSpaceBoundary has parameter attributes that have the type (virtual, real) to allow aggregation and subdivision of CellSpaces. Furthermore, the TransitionSpace class has been removed from the UML class diagram because it is difficult to semantically distinguish this from the ConnectionSpace class.

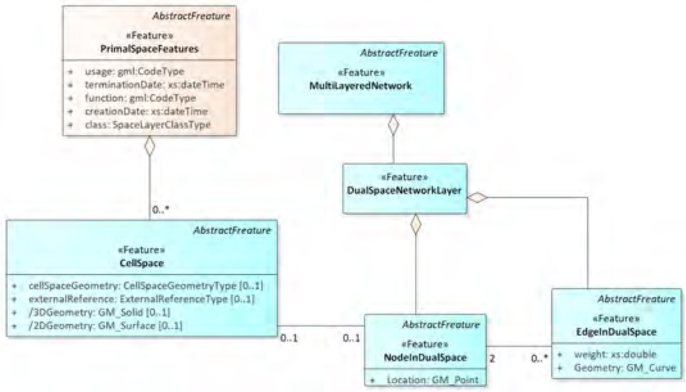

Figure 15 New DualSpaceNetworkLayer class and their associations with the NodeInDualSpace class and EdgeInDualSpace class.

4 Conclusion

In this paper, we proposed an enhancement for the UML class diagram of IndoorGML standard. We suggested the following improvements for the conceptual model (as input for the revision of the standard within OGC, See Section four for more details):

- The ExternalObject class has two subclasses (ExternalCellSpaceObject and ExternalCell-SpaceBoundaryObject). The CellSpace has an association with the ExternalCellSpaceO-bject and the CellSpaceBoundary have an association with ExternalCellSpaceBoundary-Object to improve the concept behind the ExternalObject class.
- Association multiplicity of CellSpace and CellSpaceBoundary is corrected.
- The terms State and Transition are changed into NodeInDualSpace and EdgeInDualSpace because they better represent the nature of these classes and improve the perception.
- The geometry classes are converted into attributes of the classes that need them to ensure better understanding during the implementation from the user.
- GeneralSpace class and TransferSpace class have different names for the code list and we have created code list classes to define the values for each attribute.
- DualSpaceNetworkLayer is introduced as a collecting class for the node and the edge of the dual space. The SpaceLayer has an association with the CellSpace class only and is a collecting class for the spaces of the primal space.
- TransferSpace class and CellSpaceBoundary have additional attributes that have the value (virtual, real) to allow aggregation and subdivision of CellSpaces.

This paper comes as a proposal for IndoorGML to include the above-mentioned suggestions. Additional investigation is required to define attributes for all classes. This paper reflects the initial developments of a more complete and enhanced conceptual model for IndoorGML. The future work includes additional investigations to define more attributes for the classes as well as development of prototype implementations such as SQL implementation, XML encoding, and Application with GUI. All of them will be based on same conceptual IndoorGML model. Furthermore, we will bring our proposal into the standardization process within OGC. This is expected to validate the proposed model extension further and accelerate the development of indoor navigation applications.

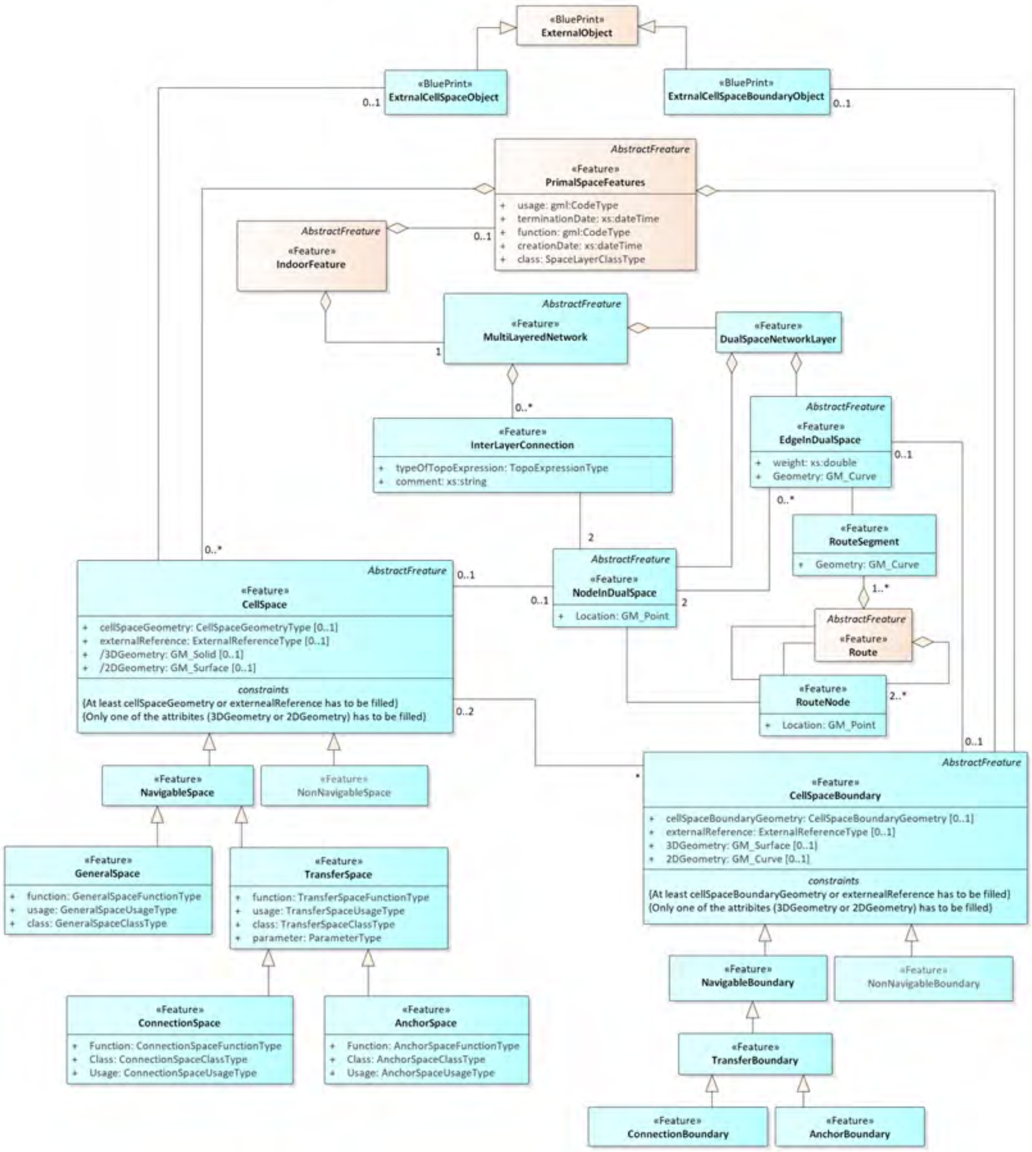

Figure 16 Proposed conceptual model of IndoorGML.

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