Investigation of BIM and GIS Information Exchange Standards for Urban Utility Tunnel Construction

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Abstract

The planning and construction of urban utility tunnel symbolizes the important indicators of urban overall upgrading and modernization. Urban utility tunnel BIM model can be used as the underlying data of the current GIS operation and maintenance management platform, including the geometric attributes, data resources, material attributes, operation and maintenance requirements and attributes of the model, it can be directly used in CityGML. The format will reduce the investment of a large amount of manpower in the construction of the GIS model. Although each BIM and GIS technology has corresponding functional features, it is still unable to serialize and convert the format and data. The generated IFC format is used for the comparison and application of the CityGML grid test in GIS, and it is known that there is still a problem of information asymmetry and omission. This paper takes the IFC and CityGML, which are common in BIM and 3DGIS, as the main language objects of analysis, and discusses the interactivity and operational technology architecture of BIM-IFC and GIS-CityGML. Finally, relying on a practical case for application and discussion.

Key words: Urban Utility Tunnel, BIM, GIS, Interoperability

I. Introduction

The planning and construction of urban utility tunnel construction symbolizes the important index of urban overall upgrading and modernization. In the future, the overall construction of urban utility tunnel will further develop towards digital construction, intelligent pipe corridor and other aspects in order to maximize public benefits. With the application of BIM (Building Information Modeling) technology in construction projects becoming more and more mature, other municipal projects such as roads, subway, bridges, comprehensive corridors and other municipal projects are gradually flourishing to introduce the application of BIM technology. The utility tunnel construction project discussed in this paper is different from the fixed location and volume characteristics of the general single building. Compared with the characteristics of the single building, it can be seen that the utility tunnel itself is composed of the building structure and has the continuous linear underground space distribution characteristics. Therefore, it conforms to the application of BIM and GIS in the representation and presentation of the building information model in the layers at the same time. Therefore, if the BIM model of urban utility tunnel construction can be used as the underlying data of the current GIS operation and maintenance management platform, including the geometric attributes, data resources, material attributes, operation and maintenance needs and attributes of the model, and can be directly applied to the CityGML (City Geography Markup Language) format, it will reduce a lot of manpower investment in the construction of the GIS model, although each BIM and GIS technology have corresponding functional characteristics. However, it is still impossible to connect and convert formats and data in series. In the past, relevant studies have compared and applied CityGML formats in GIS for IFC formats generated by BIM building ontology[1-4]. It is known that there are still problems of information asymmetry and omission[2]. In this paper, the common data model standards IFC (Industry Foundation Classes) and City Geography Markup Language (City Geography Markup Language) in the field of BIM and 3D GIS are used as the main language objects for analysis, and the interaction and operation technology framework between BIM-IFC and GIS-City GML are discussed.

II. Interaction and Operational Technology of BIM-IFC and GIS-CityGML

BIM technology in the field of construction engineering and informatization of GIS technology in the field of geographic information have become a hot research and application topic at home and abroad[1,2]. If a complete set of geographic information system technology can fully apply the completed BIM model, it will save a lot of manpower and material resources in the drawing of GIS model. Therefore, how to connect IFC format in BIM model to CityGML lattice in GIS Formula will become an important data interface and research issue. The similarities and differences between BIM model and GIS model are shown in Table 1. There are differences in geometric expression, Semantic information, model appearance and scale of representation. Therefore, it is difficult to achieve the complete mapping between IFC and CityGML. The functional characteristics and comparison results of BIM and GIS technologies show that the details and uses of BIM and GIS technologies are different, but BIM and GIS belong to two different fields in the past. Therefore, how to connect the related technologies in series to achieve the technology of sharing one platform between the two models, and how to continue to expand and apply, is the research and investment at home and abroad.

TABLE I
SIMILARITIES AND DIFFERENCES BETWEEN BIM AND GIS

Content comparison	IFC	CityGML
Geometric expression	Boundary description Body formed by stretching or rotation. Solid geometry	Boundary description
Semantic information	A large number of architectural detail descriptions and spatial relationships between different components	Multilevel Semantic Information Classification
Model appearance	Less texture, mainly material presentation	Multiple LOD levels have corresponding texture features
Representation	Presentation of a single building or entity	Wide-ranging presentation

III. Development of Integrated Framework of BIM-IFC and GIS-CityGML for Urban Utility Tunnel Construction

The interface of BIM-IFC and GIS-CityGML semantics information is shown in Figure 1. It consists of BIM module, GIS module and system architecture module. Finally, it develops into a set of interfaces of BIM-IFC and GIS-CityGML semantics information. The details of the three modules are as follows:

A. BIM module: The design and construction drawings of urban utility tunnel are mapped into BIM model, and the required information of main components, including geometric instruction parameters and geometric primitive parameters, is input into BIM model, and then the IFC format is exported, which can be used to classify the required information according to the level of development of different models.

B. GIS module: The area and scope covered by urban comprehensive corridor GIS are used as data base to produce visual content of spatial analysis, which can be used as visual information of GIS. By exporting CityGML format, the information required by different LOD (Level of Development) models can be classified.

C. System Integration Module: It consists of three sub-modules: Technical Architecture, Standard Architecture and Management Architecture. It is described as follows:

(1) *Technical Framework:* For the core of this project's algorithm and computing engine, there are 900 different types of IFC, which store different types of information, related relationships, attributes, geometric expressions and so on. Among these types, not every type contains the geometric information needed for conversion, nor does all the geometric information need to be converted to CityGML. According to the engineering characteristics of urban comprehensive corridor and the requirement field of IFC format, all types of objects in the comprehensive corridor can be obtained in object format, and based on IFC format, including floor type, site type and component class. In order to provide basic information for semantic comparison of GIS CityGML, the final output is geometric attribute and related attribute fields. The goal is to lighten the model and make the model compatible.

(2) *Standard Framework:* This paper discusses BIM-IFC framework and GIS-CityGML framework format standards and characteristics, and carries out analysis, definition, comparison and consolidation of column element attributes required for urban comprehensive corridor in two formats. Semantic information comparison between Building Element and CityGML in IFC model. Because the semantic information of CityGML is relatively small, most of the semantic information of CityGML can be obtained from IFC model by means of semantic correspondence method.

(3) *Management Framework:* For this project data extraction and application oriented management architecture, BIM-IFC and GIS-CityGML in data extraction and application management architecture and process, including design, construction, operation and maintenance of the required items, objects and so on. Finally, it is assembled into IFC and GIS-CityGML interactive architecture for data extraction, storage, output, decision-making and other management purposes. In terms of semantic mapping, the IFC model contains four different levels, including resource layer, core layer, information exchange layer and domain layer. The information exchange layer defines architectural design, construction management, and a large number of architectural elements for information exchange between projects. IFC and GIS-CityGML model transformations can start with the Entity information layer in the information exchange layer. Architectural elements include the basic components of the building model, such as beams, floors, walls, etc. Each building element contains information such as Defined Type, Enumeration, Select Type and Entity, and each Entity contains information such as geometric expression, location and so on. In CityGML, different LOD levels contain different semantic information, each type has its own characteristics, describing the characteristics of the semantic information in CityGML.

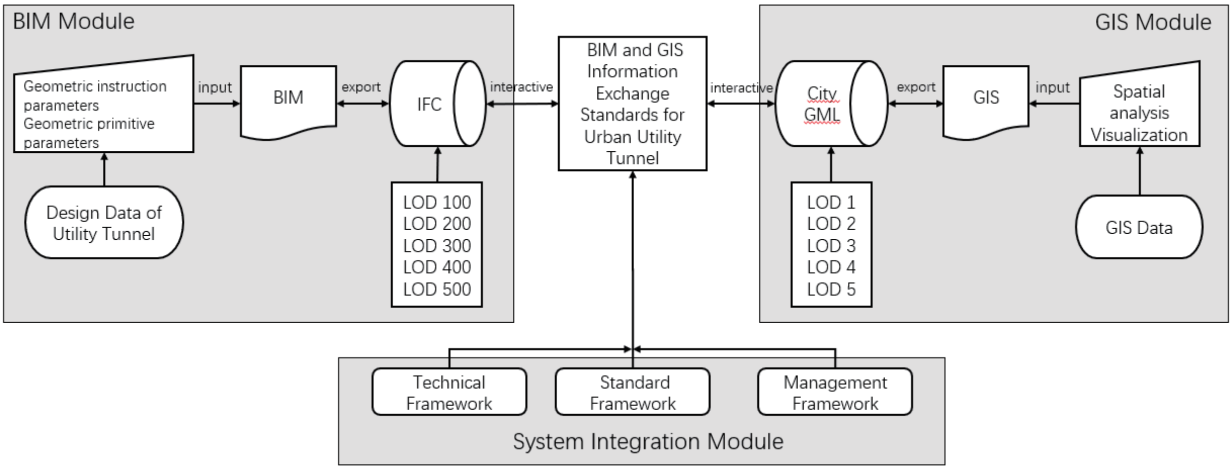
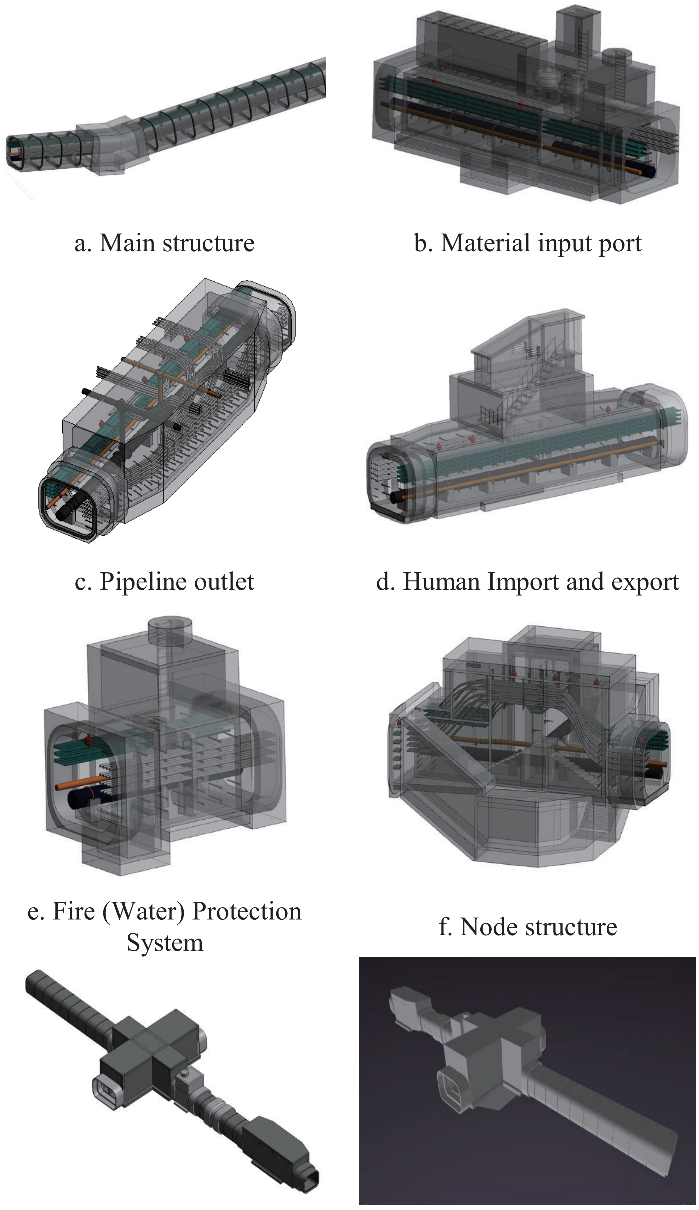


Fig. 1 Framework of BIM and GIS Information Exchange Standards for Urban Utility Tunnel

IV. Discussion on the Requirements of Integrated Utility Tunnel BIM Importing GIS Platform

The case applied in this study is a urban utility tunnel construction project in Xiamen City, China, which has been completed design stage. The BIM model is currently in the LOD300, and the modeling software used in this study is Autodesk Revit®, the GIS platform used SuperMap®. According to the building characteristics and related facilities of the urban utility tunnel project, the BIM model of the urban utility tunnel includes master plan, structure, auxiliary structure, auxiliary system and so on, Relevant design model as shown in Fig 2a-f. In the aspect of GIS requirements corresponding to BIM model, this research, after investigating the actual situation of GIS technology companies, aims at the needs of GIS graphics, GIS operation and maintenance, and graph lightweight, as shown in appendix table 1. The effect of the conversion is shown in Figure 2g-h. It can be known that in general planning, because most of the contents, such as site conditions, have been included in the software of GIS, and the vertical configuration and content of the integrated corridor can be reflected in BIM modeling, it is not necessary to import the BIM model into GIS for presentation or use at this stage. In the aspect of structure, after the investigation of actual operation and maintenance needs, in the aspect of structure, only the utility tunnel ontology as a visual management object is needed. In fact, it does not need operation and maintenance of the utility tunnel ontology, only the main structure is retained and there is a lightweight demand. In terms of the structure of the utility tunnel, because of the need for more ventilation ports, feeding ports and so on, it is necessary to connect sensors or manage personnel access in the future. Most of the projects have the needs of GIS graphics, operation and maintenance and lightweight. Others, including homes and pipeline drainage, do not need to be included in the scope of operation and maintenance, only need visual presentation and lightweight. In terms of ancillary systems, most systems involve future operational maintenance requirements, including graphical, operational maintenance and lightweight requirements.



a. Main structure b. Material input port

c. Pipeline outlet d. Human Import and export

e. Fire (Water) Protection System f. Node structure

g. BIM model (before import) h. GIS platform model

Fig. 2 Utility tunnel Structure, auxiliary structure and conversion model

V. Conclusion and suggestions

This study attempts to discuss the framework and planning for the operability of BIM model and GIS data interchange based on the urban integrated corridor project, and propose the corresponding application scope for the future operation and maintenance needs of the integrated corridor project. The research results show that in the future, through the integration of BIM technology and GIS technology, IFC and CityGML common format interaction interfaces, including technical framework, standard framework, management framework, and then through the development and integration of system architecture, the compatibility and effectiveness of information needed for urban comprehensive utility tunnel construction can be improved, and the purpose of high information integration can be achieved. On the other hand, the BIM design model of the urban utility tunnel includes the main structure, auxiliary structure, auxiliary system, etc. It corresponds to the model needed by the operation and maintenance of the GIS platform, and has its specific model parts and operation and maintenance and application requirements, which can be used as the basis for the BIM model to be imported into the GIS platform system.

Follow-up application of BIM and GIS in urban utility tunnel includes: 1. Information and attribute analysis needed to convert BIM model of urban utility tunnel to GIS; 2. Lightweight technology of transforming GIS model by BIM model; 3. Semantic compatibility and conversion of attribute fields in GIS model; 4. Discussion on the framework of BIM and GIS operation and maintenance management platform.

Acknowledgement

This research is supported by the Xiamen University of Technology research project (No. YKJ15039R), Xiamen Science and Technology Bureau Research Project (No. 3502Z20173039), and the Fujian Natural and Science Foundation Research Project (No. 2017J01725), and thanks Silverdata spatial information company (Xiamen) for providing GIS data platform and system testing.

References

[1] Liu, X., Wang, X., Wright, G., Cheng, J., Li, X., & Liu, R. (2017). A state-of-the-art review on the integration of building information modeling (BIM) and geographic information system (GIS). ISPRS International Journal of Geo-Information, 6(2), 53.

[2] Karan, E. P., Irizarry, J., & Haymaker, J. (2015). BIM and GIS integration and interoperability based on semantic web technology. *Journal of Computing in Civil Engineering*, 30(3), 04015043.

[3] Liu, R., and Issa, R. (2012). "3D visualization of sub-surface pipelines in connection with the building utilities: Integrating GIS and BIM for facility management." 2012 *Proc., Computing in Civil Engineering*, ASCE, Reston, VA, 341–348.

[4] Zhang, C., Li, W., and Zhao, T. (2007). "Geospatial data sharing based on geospatial semantic web technologies." *J. Spatial Sci.*, 52(2), 35–49.

APPENDIX TABLE 1
REQUIREMENTS OF INTEGRATED UTILITYTUNNEL BIM IMPORT GIS PLATFORM

Stage	Content		Requirements for GIS		
			GIS Graphics	O&M	Light
LOD 300	master plan	Site Planning and Arrangement	-	-	-
		Vertical configuration and Association	-	-	-
		Section Configuration	-	-	-
	structure	foundation pits	–	-	–
		foundation	–	-	–
		Main structure	●	-	●
	auxiliary structure	Inspection hole	●	●	●
		Material input port	●	●	●
		Vent	●	●	●
		Node structure	●	●	●
		Human Import and export	●	●	●
		Pipeline outlet	●	●	●
		Fire (Water) Protection System	●	●	●
		Support and hanger	●	-	●
		Waterproof and drainage	●	-	●
		indication sign	●	●	●
	auxiliary system	drainage system	●	●	●
		ventilation system	●	●	●
		Power supply and lighting system	●	●	●
		fire extinguisher system	●	●	●
		Monitoring and Alarm System	●	●	●