Integration of Building Information Model and RFID Tag

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Abstract. Building Information Modelling (BIM) creates a way for all parties to share, exchange, and manage building information throughout the lifecycle of the building. On the other hand, radio frequency identification technology (RFID) has become one of the key technologies for automatic data collection and information storage. RFID can store building lifecycle information and context-aware information in a distributed database, so it can be considered as a component of the building information model. Therefore a standardized definition of the RFID components in the BIM is required. This paper proposes a standard method for adding RFID data definitions to BIM, and maps RFID data to related items in the BIM database. This study also defines the relationship between RFID tags and building components, and proposes the use of predefined relationships. The method of associating BIM data and RFID data can automatically select data related to RFID tag data by the relationship defined in BIM. Finally, the technical feasibility of the proposed method is proved by actual case test in the existing BIM software.

1. Introduction

In the process of computer-aided design, planning, construction and operation, it is necessary to base on the standardized information model. The key function of building information model is to address collaboration and integration issues related to information creation, sharing, exchange, and management throughout the building's lifecycle. The Industry Foundation Class (IFC) standard developed by the Building SMART Alliance (BSA) has been recognized globally as a mature BIM standard to support and promote interoperability at all stages of the building lifecycle. IFC is a set of object-oriented Non-proprietary shared building data model. However, the object model in construction industry is quite complicated. Therefore, the Building SMART Alliance (BSA) provides a rich extension interface to the IFC model by using extensible architecture definition for each domain.

Motamedi and Hammad have proposed an IFC extension framework for implementing various data operations throughout the lifecycle of a building. Radio frequency identification (RFID) technology is similar to bar code. It is a thriving technology that recognizes and tracks objects. RFID-based systems have been widely used in different fields of building construction and operation, such as component tracking and positioning, inventory management, equipment monitoring, schedule management, facility maintenance, tool tracking, material management and quality control. Motamedi and Hammad have proposed to permanently attach RFID tags to the asset and the accumulated information which is
used to integrate and coordinate different processes throughout the lifecycle can be obtained from the standard BIM database over the lifecycle of the asset. For example, the technician can be provided with maintenance instructions for the asset. In addition, the facility device with the RFID tag can automatically provide its location data to the users. Froese et al. analyzed the relationship between IFC and the project management process, including project planning and cost estimation. The research and testing conducted confirmed the overall applicability of the method and proposed improvement suggestions; Weise et al. proposed IFC extension for structure which was not supported in the early version IFC, and gave some suggestion on structure analysis extension, including the data exchange scenarios in the phases of conceptual design and modeling; Fu et al. proposed an overall architecture of IFC-based nD modeling tool, and developed an IFC viewer as the user interface of the nD modeling tool; Ma and Lu proposed a way to represent information resources by analyzing the available IFC entities and relationships; Ma et al. proposed an cost estimation information model for Chinese bidding and construction based on IFC. At present, no research has been proposed to integrate RFID technology application to IFC.

Based on the assumption that RFID tags can be permanently connected to building components, tags can be considered as an integral part of a building, so these RFID tags and their associated attributes and parameters need to be formally defined in the building information model. The definition is critical for tracking and maintaining RFID components throughout the lifecycle of a building. In addition, since the BIM data is stored in the RFID tag, defining the RFID as an object in the model also contributes to the creation and management of the data relationship. Therefore, the creation and maintenance of the relationships between data can be realized by defining the RFID system component as objects and logical relationship in BIM.

The purpose of this study is to: (1) analyze the core requirements for adding RFID tag and reader attributes to BIM; (2) study the strategy to integrate new attributes into the IFC by creating relationship object or mapping attributes to existing IFC definitions; (3) prove the technical feasibility of the proposed method through actual case application research.

2. Integration of RFID Data and BIM
RFID tags for facilities can be used to store data for asset management. According to IFC's inherent framework and property management mechanisms, these data are dynamic and can be obtained from standard distributed BIM databases. Figure-1 illustrates how to copy the data blocks of the BIM database into the memory of different RFID tags.
The label's memory can contain both of the maintenance information for the asset, such as last checking condition or date, and the data related to multiple assets or spaces. For example, the RFID tag can contain location coordinates of various assets in the room or a list of the room users. The entities and the relationship with related tags should be identified and modeled, then the BIM entities information can be associated with the memory of the related tag. The data to be stored in the tag memory can be conveniently selected with the relationship definition in BIM. For example, in order to copy the last inspection date of an asset into the memory of the tag, all of the related data will be copied into the tag's memory by locating the existing asset associated with the tag and querying the inspection dates in the model.

Taking the scenario of updating asset location coordinates in the location tag as an example, the RFID location tag is an information tag of related assets in a certain area that is stored in the memory, and the coordinate list of the related asset is stored therein and updated at any time. Therefore, when the user is querying the asset, the location of the target asset can be queried by reading the data of the location tag, and the location can be displayed on the floor plan. Figure 2 illustrates the process of updating the asset coordinates in the location tag memory: (1) scan the tag, and the software reads the ID; (2) the software queries the ID in the BIM database; (3, 4) the software reads the attributes of the associated tag in the IFC file, and verify whether the current tag is for location; (5) the software uses the available relationship objects in the IFC file to identify the relevant assets; (6) the software reads the location coordinates of each related asset from the IFC file; (7) the software creates a data file containing the results of the query; (8) integrate the data file into the data tag.

![Figure 2. Flow Chart of Updating the Location Tag Data](image)

3. **IFC Extension Framework**

   This study uses the definition and data structure of the latest version of the IFC as the basis for the extension module, then the number of definitions for new objects and relationships can be minimized. Furthermore, the existing relationships and attribute sets are reused to avoid redundant model extensions.

   **3.1 RFID System Definition**

   The study defines the elements based on the RFID hardware properties, including the introduction offered by its manufacturer and the needs of field research, then the definition of the RFID component can be added to the IFC model. Based on the method proposed in this study, the possible relationship between RFID and building components is defined, and the RFID tags are assigned or attached to the existing building components framework. The design of the framework definition should be based on modularity and extensibility principles to accommodate newer types of tags, readers, and antennas, thus a modular approach to define elements and their attributes is used. The RFID hardware can be divided into three categories: (1) RFID tags (2) RFID readers (3) RFID antennas.

   **3.2 RFID Element and Property Set**

   The RFID component is defined in the electrical IFC module, which forms part of the IFC model domain layer. This study proposes a new system type that includes four enumerations: (1) passive tags (2) active tags (3) passive readers (4) active readers. Other possible types can be identified by using a combination of attributes associated with the types mentioned above, such as semi-active RFID that inherits active and passive tag attributes.
3.2.1 **RFID System Property Definition**

The tag attributes are defined according to the framework assigned by the IFC attribute set. To define the attributes specific to RFID, this study defines a set of attributes that contains all types of shared attributes. Therefore, the type-specific information can be described by defining independent sets of attributes. For example, the battery life can only be an attribute of an active tag. In the scenarios of RFID-related application, housing material identification of the label is particularly important because the radio communication capabilities of the label will be greatly affected by the material type of housing when attached to a metal object.

3.2.2 **Locating the RFID Tag and Reader**

The location of the RFID system entity is modeled with the existing IFC framework. The related direction and position are defined as follows: (1) Absolute position (relative to the axis position of the world coordinate system) or relative position (relative to the axis position of another object), and reference to the axes grid. (2) The RFID system entity is located in the building and the ground space, and the location of the tag can be identified based on the inclusion relationship.

4. **Relationship with Other Objects**

The RFID tag/reader is attached to the asset/building component or serves as a subcomponent, and they are physically attached or decomposed. Figure-3 illustrates how an RFID tag or reader has a one-to-one physical relationship with the objects to which it is attached. Although each tag/reader is connected to only one component, multiple tags/readers can be physically attached to the same component.

The IFC relationship can be used to define the decomposition relationship between the RFID tag and related elements. The relationship between the tag and its related elements can be realized by an entity such as IfcRelDecompose and its subtype IfcRelAggregates. The reader can be part of a handheld computer or mobile phone, in which case an exploded relationship can be used to identify this setting.

IfcRelConnectsElements and IfcConnectionGeometry can be used to describe the physical connection between the RFID tag/reader and the asset or component. The geometric constraints of the physical connection of the two objects can be described by adding the IfcConnectionGeometry entity. The physical connection information can be determined by precisely specifying the location of the connection and the associated elements. The location gives. The IFC provides the offset subtype to describe the connection when there is a distance between the tag and the element, and provides the following geometry/topology connection types: (1) point/vertex (2) Curve/Edge Curve (3) Surface/Surface.

![Diagram of RFID Tag Association and Deployment Relationship](image-url)
5. Conclusion
This paper elaborates on the requirements, purpose and significance of integrating RFID to the IFC standard, and proposes a definition method for the related attributes and relationships of RFID system components that need to be identified during the concept design phase. This study shows that the current IFC application tool has some restrictions on the extension definition. The IFC file exported from a specific modelling tool lacks part of the detail definition when it is opened in the standard IFC parser and there are compatibility issues when the IFC file is opened in other BIM tools. The above conclusions indicate that current application has significant limitations for adding new objects, relationships and attributes to current versions of IFC. In the case study, a combined application of IFC tools is used, and standard EXPRESS code is manually added. Finally a standard parser software is used to display the model. Future research will continue to propose recommendation of new IFC objects to the Intelligent Building Alliance for the upcoming IFC standard release, and the same method can be used to add other types of sensor definitions to the standard BIM architecture.

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