Informatics Knowledge for Setting Requirements on IFC Data and Its Suitability in Education for Chemical Engineers

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Abstract. IFC becomes popular for the exchange of building information model data among participants in construction projects. To get the desired data, it is necessary to specify requirements on these data. The paper identifies fields of informatics knowledge required to understand the IFC data schema mostly to get the ability to define requirements on the desired IFC file content. There were identified mostly topics connected with the EXPRESS data specification language but also with the STEP data format and computer graphics. There were also mentioned fields of informatics knowledge related to processes that use or produce the data. It is generally assumed that building information model data collected and stored during design and construction processes are valuable also during the operation of the modeled facility. Sometimes the biggest value is expected during the operation of the modeled facility. Then the requirements on data for facility operation may differ based on the purpose and use of the facility. Specific knowledge related to the purpose of the built environment may need to be taken into account during the setting requirements on building information model data – including IFC data. This sets the question about the importance of informatics knowledge for setting requirements on building information model data (also IFC data) also for other professions than those from information technology and civil engineering domain. A brief review of the discussion about using building information modeling principles and building information model data for plant engineering is included in the paper. The focus is on the use of the IFC data. It was found that the building information modeling principles and informatics knowledge connected with an understanding of the IFC data schema may have an important role also in education for chemical engineers especially with the connection to the development of the implementation of building information modeling principles in plant engineering.

1. Introduction
IFC data structure becomes popular for the exchange of BIM data among participants in construction projects. “Today, IFC is typically used to exchange information from one party to another for a specific business transaction” [1]. To get the desired data is necessary to specify requirements on these data. Requirements on the desired data content in the IFC file differ based on the intended use of the data, which is usually called as a BIM use [2]. This use of the data is specific to the user needs. To be able to specify the desired content of IFC file is necessary to understand IFC data structure and user processes that require and/or produce desired data. This ability is connected with the knowledge of some fields of informatics, whose identification is the topic of this paper. Nývlt and Prušková [3] describe BIM as “a methodology that generates, exchanges and manages a constructed facility’s data
throughout its life cycle”. Valuable use of BIM data should be also in the phase of operating a facility including its reconstruction. This is also the reason why the acquisition of BIM data is considered also for existing buildings [4, 5]. Gao and Pishdad-Bozorgin [6] found BIM’s potentials in improving facility operation and management activities and providing new functionalities for facility managers, such as intuitional 3D visualization, comprehensive analysis, and real-time building information access. Prušková [7] points out the importance of knowledge management within BIM technology also during the phase of facility management. The requirements on the data, that are often exchanged in IFC files, may depend on the purpose and use of the facility. Nowadays the use of building information modeling principles and the use of BIM data in plant engineering are discussed, so the paper also includes a brief review of this discussion and also asses the suitability of the informatics knowledge education for chemical engineers.

2. IFC data structure
BuildingSMART explains IFC as following [1]: “In general, IFC, or ”Industry Foundation Classes”, is a standardized, digital description of the built environment, including buildings and civil infrastructure. It is an open, international standard (ISO 16739-1:2018), meant to be vendor-neutral, or agnostic, and usable across a wide range of hardware devices, software platforms, and interfaces for many different use cases.”

As already mentioned, IFC itself is the international standard and 4.0.2.1 version is published as [8]. This section of the paper focuses on the description of this IFC version. The Industry Foundation Classes (IFC) specify a data schema and an exchange file format structure [9].

The data schema is defined in the EXPRESS data specification language [10]. The exchange file formats for exchanging and sharing data according to the conceptual schema are clear-text encoding of the exchange structure [11] known as STEP format. There are also other possibilities of encoding, e.g. in XML and JSON formats [1], but the STEP format is most often used in practice.

The IFC schema specifies types, entities including attributes, rules, and functions [9] according to the EXPRESS data specification language. Moreover, IFC specification includes a description of terms and concepts using the plain English words [9] and also defines some property sets and quantity sets [9].

3. Required informatics knowledge to understand the IFC data structure
It can be assumed that any IFC data receiving party has some requirements on the data being received. This implies that some specification of the desired content of the IFC file is required. If any data about part of a facility are required it must be specified how to represent it in limits of IFC schema – using its entities, attributes, pre-defined properties and/or quantities, and/or user-defined properties and/or quantities. To be able to specify the desired content of the IFC file may be necessary to understand the IFC data structure, which requires some fields of informatics knowledge. This section of the paper focuses on the fields of informatics knowledge that may be necessary to understand the IFC specification described using the EXPRESS data specification language.

There is also IFC schema specification described using XML Schema definition language (XSD), but the XML schema definition is generated from the EXPRESS schema according to the mapping rules defined in [12]. Moreover, IFC data are in practice most often exchanged in STEP format and validation of STEP file is possible against the EXPRESS schema.
3.1. Terms and principles used in IFC data structure specification
As IFC stands for “Industry foundation classes” the first term that should be understood is the “class” term. IFC schema specification [9] contains the data schema, represented as an EXPRESS schema specification. So the “EXPRESS schema” is another basic term.

Because IFC schema specification uses EXPRESS data specification language to specify the schema, most of the terms come from EXPRESS data specification language. The first such term is the “entity” term, which is closely related to the “class” term. Because IFC file in STEP format contains entity instances, it is necessary to know the “instance” term meaning and how is related to the “entity” term. The IFC schema specification uses an inheritance relation between entities. So the “subtype” and “supertype” terms and inheritance principles are part of the knowledge required to understand the structure of IFC schema.

Within entities are specified attributes and their data types. Attributes may be optional and uniqueness can be also specified. The EXPRESS data specification language distinguishes three kinds of attributes. These are “explicit”, “derived” and “inverse”. All of them are used in the IFC schema specification. The topic on attributes datatypes is quite big since there are various simple data types, aggregation data types, named data types, and constructed datatypes used in IFC schema specification.

IFC schema specification offers various ways to store information about a geometric shape. Basic ways of geometric shape representation are [9]: CSG primitive, Extruded solid, Surface model, Brep model or Tessellated item. Knowledge of these shape representations principles is required to understand how geometry is represented in IFC files, but also advanced geometric shape representations are included in IFC schema specification.

IFC schema specification contains also a specification of property sets and quantity sets. It is necessary to understand the principles of how properties are assigned to property sets and property sets to objects. A similar situation is with quantities and quantity sets. Moreover, there are predefined property sets and quantity sets for specific objects and also a possibility to define new own property sets and quantity sets.

To understand the IFC data structure specification is necessary to know how the above-described terms and principles are used for the description of IFC schema. EXPRESS data specification language offers a way of description in textual form, but partial information has also representation in the graphical form called EXPRESS-G [10]. IFC schema specification also contains EXPRESS-G diagrams. Moreover, instance diagrams also take place in the IFC schema specification.

3.2. Informatics knowledge related to the planning of processes of creation and use of IFC data
To set requirements on IFC data not only knowledge of IFC data structure is required. But also knowledge of processes in which data will be produced and used is important. For this purpose exists various ways of modeling processes. The most common way of modeling process behavior is the Business Process Model and Notation (BPMN) standard, which is defined in [13]. This standard specifies how to graphically describe the sequence of activities during the process or collaboration. It also allows us to show used and produced data, events in the process and participants of collaboration. BPMN standard was recommended or adopted in various guides and templates for creating a BIM execution plan (e.g. [2]) and an Information delivery manual (e.g. [14]). These adaptations may be also included in the knowledge portfolio including their reasons. There are also other ways of the description of processes like Event-driven Process Chain (EPC) [15], UML activity diagrams [16], or Business Objects Relation Modelling (BORM) [17]. These may have also a particular role during the description of the building information modeling process.
During the data exchange, it may be also necessary to validate and/or verify the received data. So knowledge of principles of data validation and data verification and the difference between these two procedures may be required.

3.3. IFC data content-related knowledge

“The Industry Foundation Classes IFC represent an open specification for Building Information Modeling BIM data that is exchanged and shared among the various participants in a building construction or facility management project.” [9]. Setting requirements on IFC data for construction and also facility management requires knowledge from the civil engineering domain. It can be assumed that facility operation and management may require also IFC data that are specific to the purpose of the use of the modeled facility. So the knowledge required for setting requirements on IFC data should be multidisciplinary – consisting of knowledge from the field of informatics, construction engineering but in the case of use of data for facility operation and management also from the domain related to the purpose of the building.

4. Suitability of identified informatics knowledge in education for chemical engineers

As already mentioned in the previous section of the paper, one of the purposes of using IFC data is for facility operation and management. “The schema specification can describe how a facility or installation is used, how it is constructed, and how it is operated. IFC can define physical components of buildings, manufactured products, mechanical/electrical systems, as well as more abstract structural analysis models, energy analysis models, cost breakdowns, work schedules, and much, much more.”[1]

Nowadays there is a discussion on using building information modeling for storing data for the design and operation of plants. By Woziwodzki and Ośkiewicz [18] advantages of implementing BIM methodology in reducing construction costs and project delivery time that are expected in [19] poses new challenges in implementing the BIM methodology and concerns not only the construction industry but also all other industries including chemical and process engineering. Mitkowski and Bal in [20] mention the possibility that plant design management system (PDMS) type software is a forerunner of building an information management (BIM) concept. Zhou et al. in [21] present a study with the goal of investigating the feasibility and benefits of four-dimensional modeling in supporting LNG construction projects and identified the need for more studies in order to reveal potential benefits of BIM/4D adoption from the different perspectives in LNG projects. Software vendors are offering solutions for building information modeling for plant design. E.g. Autodesk in [22] mentions Autocad for Plant 3D and Revit.

Even if software application for building information modeling have their data formats for storing BIM data, many of them are also capable to import data from IFC data structure encoded in STEP format and export data to IFC data structure encoded in STEP format for data exchange purposes. One such software application is Autodesk Revit already mentioned in connection with plant design. Marini et al. in [23] inspects the IFC data schema and found two domains for plant systems - “IfcHvacDomain” and “IfcPlumbingFireProtectionDomain”. Their findings include that IFC schema contains 36 main plant entities managed with ifcHvacDomain, 10 plant entities managed with IfcPlumbingFireProtectionDomain, and numerous sets of descriptive parameters. Even if there will not be all necessary entities in IFC schema for the description of a plant, it is under continuous development and may be extended in the future.

Increasing interest in the implementation of building information modeling principles into plant design and engineering is described in the literature [18, 20-23]. Also, software vendors are developing solutions for such implementations. Building information model data may also support the processes of operation of facilities [1]. Requirements on building information model data that can be
used during facility operation may be specific to the purpose of the facility. Based on these findings
may be expected that building information modeling principles and informatics knowledge connected
with an understanding of IFC data structure may have an important role also in education for chemical
engineers especially with the connection to the development of the implementation of building
information modeling principles in plant engineering. The importance of education in building
information modeling principles for chemical engineers is also one of the findings in [18].

5. Results and discussions
There were identified various fields of informatics knowledge that may be useful for setting
requirements on desired IFC data content. Because the setting of requirements on IFC data content is
usually made by users of the data that may be civil engineers or other professions that operate or
manage modeled facilities, education for these professions may be necessary. It was also found that
building information modeling principles and informatics knowledge connected with an understanding
of IFC data structure may have an important role also in education for chemical engineers especially
with the connection to the development of the implementation of building information modeling
principles in plant engineering. The question is how deep understanding is necessary and how to
educate these professions. Some of the identified fields of knowledge may also require more general
knowledge e.g. from the software engineering domain. Future research should answer these questions
and also set recommendations for establishing study plans. Inspiration from studies on topics of
teaching building information modeling (e.g. [24]) for civil engineers can be taken.

6. Conclusions
Identified fields of informatics knowledge are mostly concerning the EXPRESS data specification
language, but there are also fields of informatics knowledge concerning to STEP format and computer
graphics. There are fields of informatics knowledge related to the management of processes that use or
produce the data. Software engineers should be usually familiar with the most of specified fields of
informatics knowledge, but requirements on IFC data content and structure are usually set by data
users that may be civil engineers or other professions that operate or manage modeled facility.
Nowadays, there is a discussion on using building information modeling principles for storing data for
the design and operation of plants. It may be expected that building information modeling principles
and informatics knowledge connected with an understanding of IFC data structure may have an
important role also in education for chemical engineers, especially with the connection to the
development of the implementation of building information modeling principles in plant engineering.
Future research should answer the questions about how deep understanding is necessary, how to
educate professions that produce and use IFC data, if there is some more general knowledge, e.g. from
the software engineering domain required, and also set recommendations for establishing study plans.

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