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BIM BASED INTEGRATED ROAD ASSET MANAGEMENT

Stanislav Lenart[1], Veljko Janjić[2], Uroš Jovanović[2], Andrej Anžlin[1]
[1] Slovenian National Building and Civil Engineering Institute (ZAG), Slovenia,
e-mail: stanislav.lenart@zag.si, andrej.anzlin@zag.si
[2] BEXEL Consulting, Slovenčeva ulica 93, SI-1000 Ljubljana, Slovenia,
e-mail: veljko.janjic@bexelconsulting.com, uros.jovanovic@bexelconsulting.com

Апстракт

Мостовите и тунелите се изложени на различни видови процеси на влошување и на тој начин тие се предмет на набудување. Податоците обично се генерираат во текот на целиот животен век на средствата. Затоа, важно е да се соберат што е можно повеќе информации денес, со цел со сигурност да се предвидат нивните перформанси во иднина. Додека следењето е одговорно за собирање информации и податоци, дополнително управувањето со податоците е исто толку важно како и нивната генерација. Од клучно значење е сигурното средство за инфраструктура да биде свесно за постојните физички услови во инфраструктурата во секој момент од животниот циклус и затоа да се соберат и анализираат податоците за набудување од пост-градежниот модел и информации од мониторинг во реално време. Во документот е претставен концептот за ракување со набудуваните податоци со употреба на концепт за моделирање на информации за градење (БИМ).

Клучни зборови

БИМ, мост, управување со информации, инфраструктура, мониторинг, тунел

Abstract

Bridges and tunnels are exposed to various types of deterioration processes and thus they are subject of monitoring. Data are usually generated during the whole life cycle of assets. Thus it is important to collect as much as possible information today in order to reliably predict their performance in future. While monitoring is in charge of information and data collection, additionally data management is as important as their generation. It is crucial for the reliable infrastructure asset to be aware of infrastructure existing physical conditions at every point in the life cycle and therefore to capture and analyse monitoring data from the post-construction model and information from real-time monitoring. Paper presents the concept of handling with monitored data by the use of Building Information Modeling (BIM) concept.

Key words

monitoring, information management, BIM, infrastructure, bridge, tunnel

25. INTRODUCTION

Building Information Modelling (BIM) is model based process of generation and managing building data during building life cycle. The concept of BIM was first introduced by Eastman et al. [1] and explained more in details by Van Nederveen and Tolman [2]. Real implementation and popularity of BIM started at the end of the millennium with various commercially available solutions, which first extended traditionally building design from two-dimensional drawings to 3D modelling (ArchiCAD, AutoCAD, MicroStation). BIM augments spatial dimensions with time as the fourth dimension and cost as the fifth [3]. Thus, nowadays BIM is defined as a digital representation of physical and functional characteristics of a facility and a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle (6D); defined as existing from earliest conception to demolition [4]).

BIM concepts and workflows are accepted quite well in the AEC industry (Architecture – Engineering – Construction), while infrastructure managers have been initially less ambitious but try to catch up recently. Compared to finite area of average building, infrastructure assets can span several kilometres in one direction while only few meters in other dimension. Therefore 3D representation of engineering infrastructure seems less attractive and GIS asset data were transferred to asset management systems for operation and maintenance for long time [5]. Anyway, 3D virtual design, construction and facility management of civil engineering infrastructures is implemented into modern engineering practice with an aim to enhance collaboration of all involved stakeholders, resolve conflicts and improve cost-effective performance of infrastructure. Furthermore, a survey conducted by ASCE and associates reveals recent accelerated application of BIM for Infrastructure, i.e. Infrastructure Building Information Modelling (I-BIM). Engineering firms adopt technology from vertical buildings for infrastructure projects most quickly, but to extent they are waiting demand from their clients [6]. Although spatial visualization does not attract infrastructure owners so much as vertical buildings operators, it is evident [7] that infrastructure owners often tend to make far more effective use of the information once data is collected. In general, they increasingly recognize the benefits of 3D modelling using intelligent objects.

Globally, there are two major vendors; Autodesk and Bentley, and several minor vendors providing software solutions for infrastructure design supporting BIM workflows. Each provider has its own data format and object models that are not compatible. Industry Foundation Classes (IFC) is a platform neutral, open file format specification developed by BuildingSMART [8]. As such, IFC is most commonly used vendor-neutral format to allow BIM data exchange between different applications and disciplines in AEC industry. However, at its current state IFC mostly supports building information with IFC for infrastructure being still in development stages [9]. Nevertheless, bulk of object model data such as geometry, properties, relations etc. can still be transferred from I-BIM via existing IFC standards.

26. PERFORMANCE INDICATORS

The overall aim of asset management is to optimise the service level delivered by infrastructure over its life-cycle. The condition assessment of bridges and tunnels is namely performed through the visual inspection and destructive or non-destructive tests as well as, more rarely but of increasing importance, with the aid of monitoring systems. In order to simplify the communication between the consultants, owners and operators, the concept of performance indicator was introduced [10, 11]. According to Model Code 2010 [12], the performance indicator is defined as a superior term of an asset characteristic, which indicates the condition of the asset. It can be expressed in the form of a dimensional performance parameter or as a dimensionless performance index. The most widely used performance indicator is the condition index, condition rating, deterioration, index, …, or some other nomenclature used by different countries and operators, mainly obtained from visual inspection.

Defining and measuring of required service levels is nowadays a fundamental starting point for asset management. Performance indicators (PIs) for RAMS (reliability, availability, maintainability and safety), capacity, punctuality, etc., are continuously applied to support infrastructure managers (IMs) to identify performance killers and in making more efficient and effective decisions, but they are often ad hoc and seldom standardised [13].

Performance indicators, which are the most critical for the current and future performance of assets are called Key performance indicators (KPIs). They will make possible the monitoring of the data and the extraction from them of the relevant information for the decision process. Therefore, KPIs have to be [11]:

- meaningful to stakeholders and written in a manner which they can understand easily,
- transparent, giving a clear picture of performance,
- easily measurable in a cost-effective way or evaluated from several measurable data,
- useful as a strategic management tool.

Extensive expert systems exist at Slovenian National Building and Civil Engineering Institute (ZAG) regarding the bridge and tunnel performance monitoring. ZAG started to develop a bridge management system at the beginning of the '90s, and the system is in operation from 1996. It is based on defining the condition class of a structure by means of visual inspection of the bridge. The result of the visual inspection is the condition rating of an inspected bridge. Similarly, tunnel management system was developed in the last decade. They are both being upgraded with remote sensing data of various monitoring systems in the recent period.

27. SENSORING TECHNIQUES

Figure 1 presents various groups of monitoring techniques. Traditional infrastructure monitoring is based on contact sensing approach. Sensors are installed directly in contact with the structure in that case [14]. Thus, innovative infrastructure contact monitoring technologies are mostly based on various sensors, consist of data logger, which transfers data via world wide web to a database. Sensors, which measure various physical parameters (e.g. strain, moisture, temperature, etc.), can be installed on the surface or inside the structure. Although physical contact with the object of monitoring is needed, advanced sensors which allow wireless data transfer are sometimes named also remote or autonomous monitoring system. Various systems allow the interrogation of large numbers of sensors by dedicated data logging equipment.

On the other hand, based on the degree of interaction with the structure, there exist also non-contact monitoring methods [15], based on the analysis of various waves travel (e.g. visible, infrared, microwaves). Two types of sensors can be used. Active sensors emit a wave and receive the reflection of the emitted wave from the ground/structure (e.g. ultrasonic and electromagnetic pulse). Passive sensors receive the wave naturally emitted by the ground/structure following an emission from nature (e.g. photography and thermal imaging). To capture existing physical conditions of infrastructure, remote monitoring data can be successfully supported also by the use of simple web-cam for additional visual analysis

Using a I-BIM process infrastructure managers have access to very rich information streams. Information includes detailed data from the post-construction model and information from real-time sensors that continuously update the model during operation. For reliable infrastructure asset it is critical to capture real-time infrastructure existing physical conditions at every point in the life cycle. This can be done by traditional contact surveying and also from reality-based point clouds captured via non-contact methods (i.e. laser scanning, ground-penetration radar or digital photographs by photogrammetry etc.) briefly mentioned above.

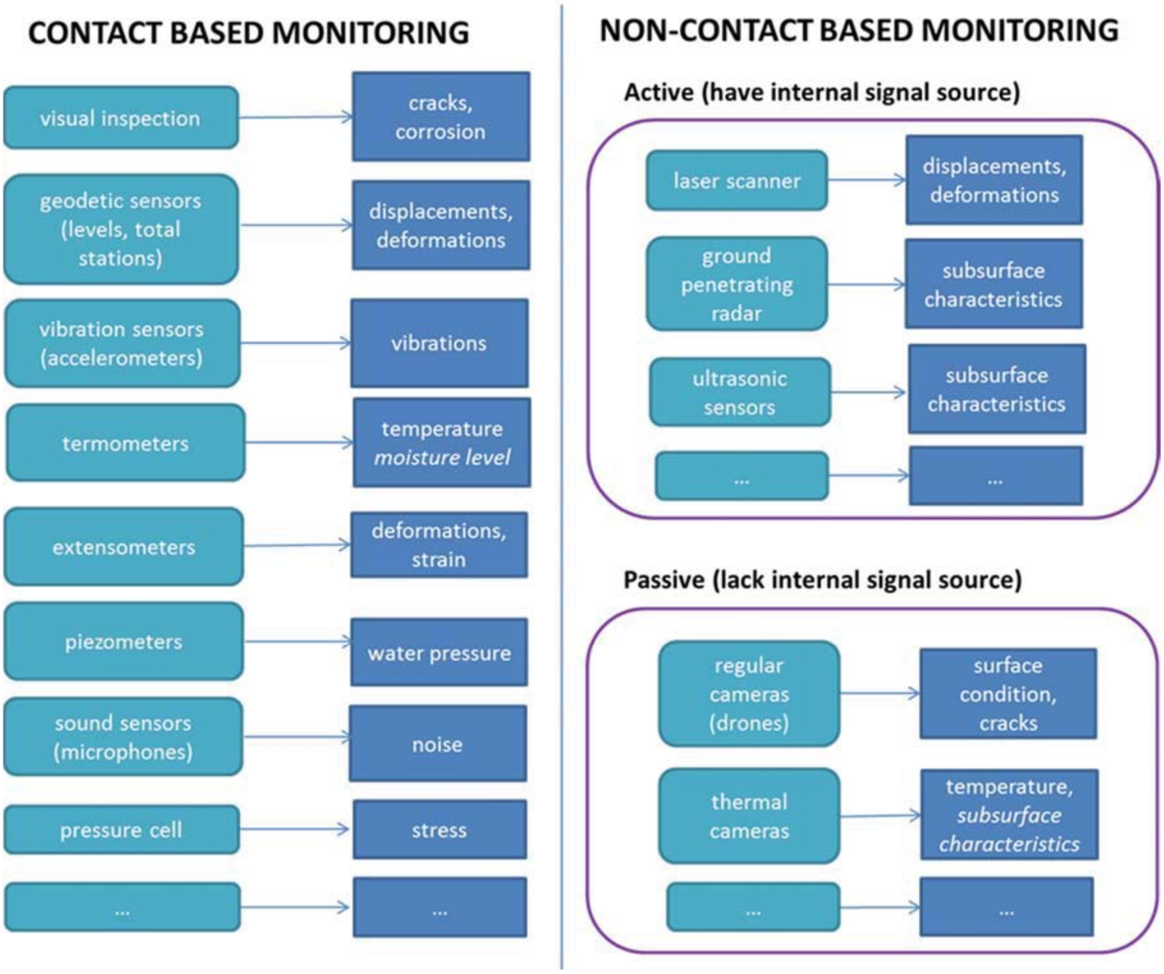


Fig. 1: Monitoring techniques

28. IFC FORMAT FOR INFRASTRUCTURE

As a neutral open file format platform, IFC is the most commonly used vendor-neutral format to allow BIM data (objects, geometry, associated properties and relationships) to be exchanged between different applications and disciplines in AEC industry throughout the whole lifecycle, from feasibility and planning, through design (including analysis and simulation), construction, to occupancy and operation. It is registered by ISO and is an official international standard under ISO 16739.

Throughout the years there were many iterations of the IFC standard (Figure 2), the most prominent being IFC2X3 TC1 and IFC4. The latest recommended version is IFC 4.1 (published 2018-06), although software adoption is still in early stages.

The main goals IFC aims to achieve are:

- cross-discipline coordination of building information models, including architecture, structural and building services,
- data sharing and exchange across IFC-compliant applications,
- handover and re-use of data for analysis and other downstream tasks.

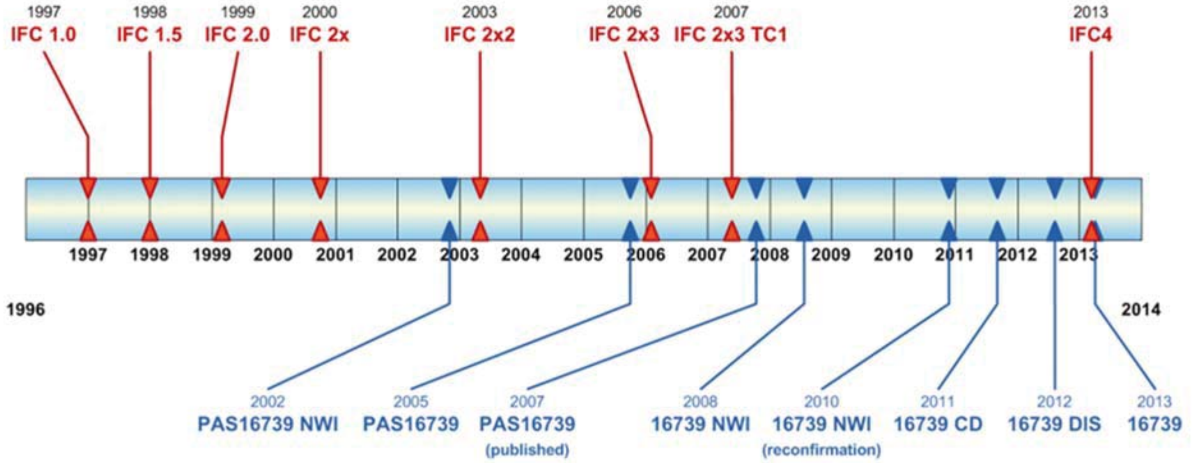


Fig. 2: The history of IFC development

The IFC specification includes terms, concepts and data specification items that originate from the use within disciplines, trades, and professions of the construction and facility management industry sector. Terms and concepts use the plain English words, the data items within the data specification follow a naming convention. The data schema architecture of IFC defines four conceptual layers. Each individual schema is assigned to exactly one conceptual layer. Figure 3 shows the schema architecture.

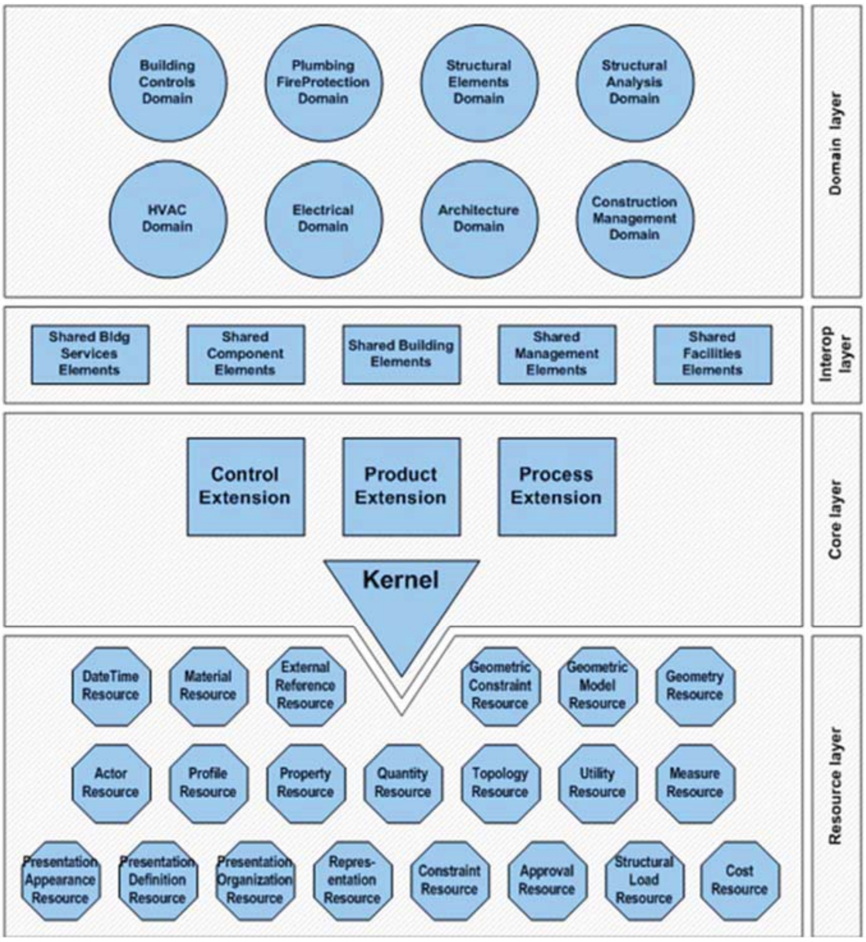


Fig. 3: Data schema architecture with conceptual layers

Resources layer - the lowest layer includes all individual schemas containing resource definitions, those definitions do not include a globally unique identifier and shall not be used independently of a definition declared at a higher layer. Basic properties such as geometry, material, quantity, measurement, date and time, cost, actors, roles are defined in this layer;

Core layer - the next layer includes the kernel schema and the core extension schemas, containing the most general entity definitions, all entities defined at the core layer, or above carry a globally unique id and optionally owner and history information;

Interoperability layer - the next layer includes schemas containing entity definitions that are specific to a general product, process or resource specialization used across several disciplines, those definitions are typically utilized for inter-domain exchange and sharing of construction information. For example, Shared Building Elements schema has entity definitions for a beam, column, wall, door etc.;

Domain layer - the highest layer includes schemas containing entity definitions that are specializations of products, processes or resources specific to a certain discipline, those definitions are typically utilized for intra-domain exchange and sharing of information.

IFC data schema is defined using EXPRESS data modeling language through several hundred entities organized hierarchically in an object-oriented fashion. The data schema is computer interpretable, which means software developers can write applications against the specification in order to read, process, analyse, modify and write IFC data. Figure 4 shows an example of object inheritance and relationship diagram in IFC.

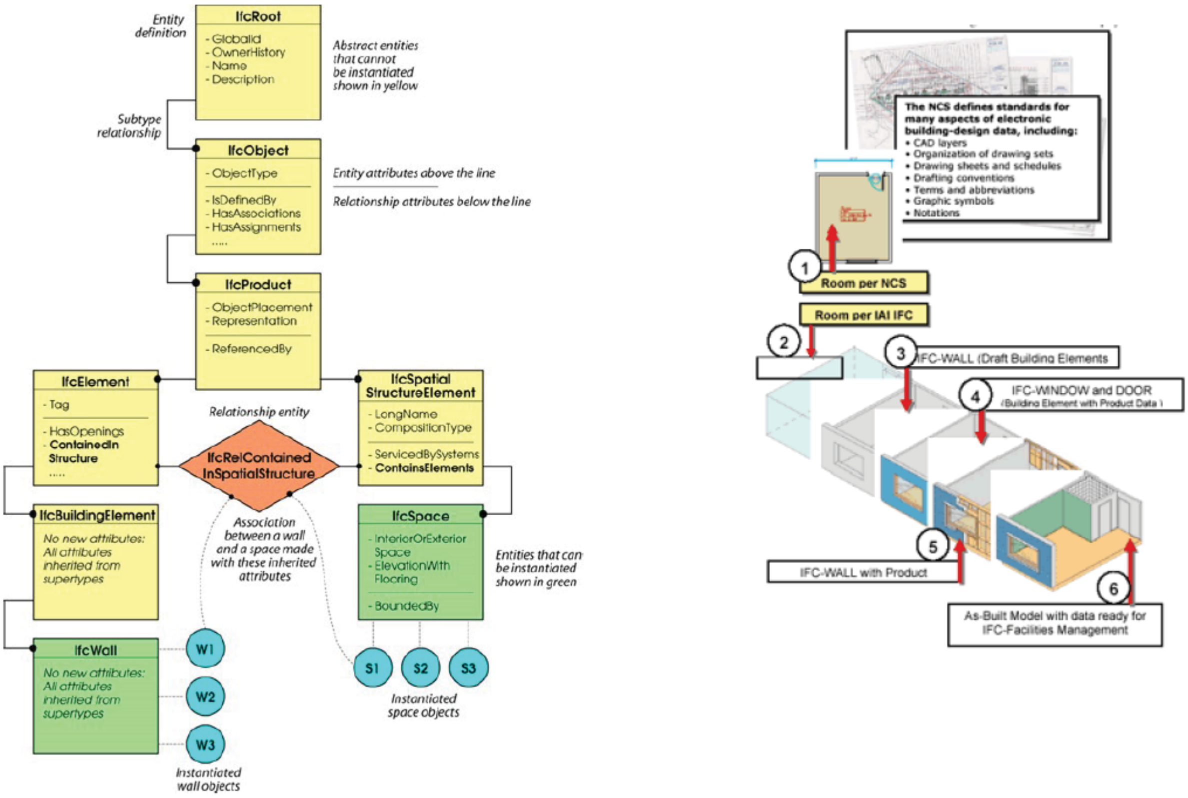
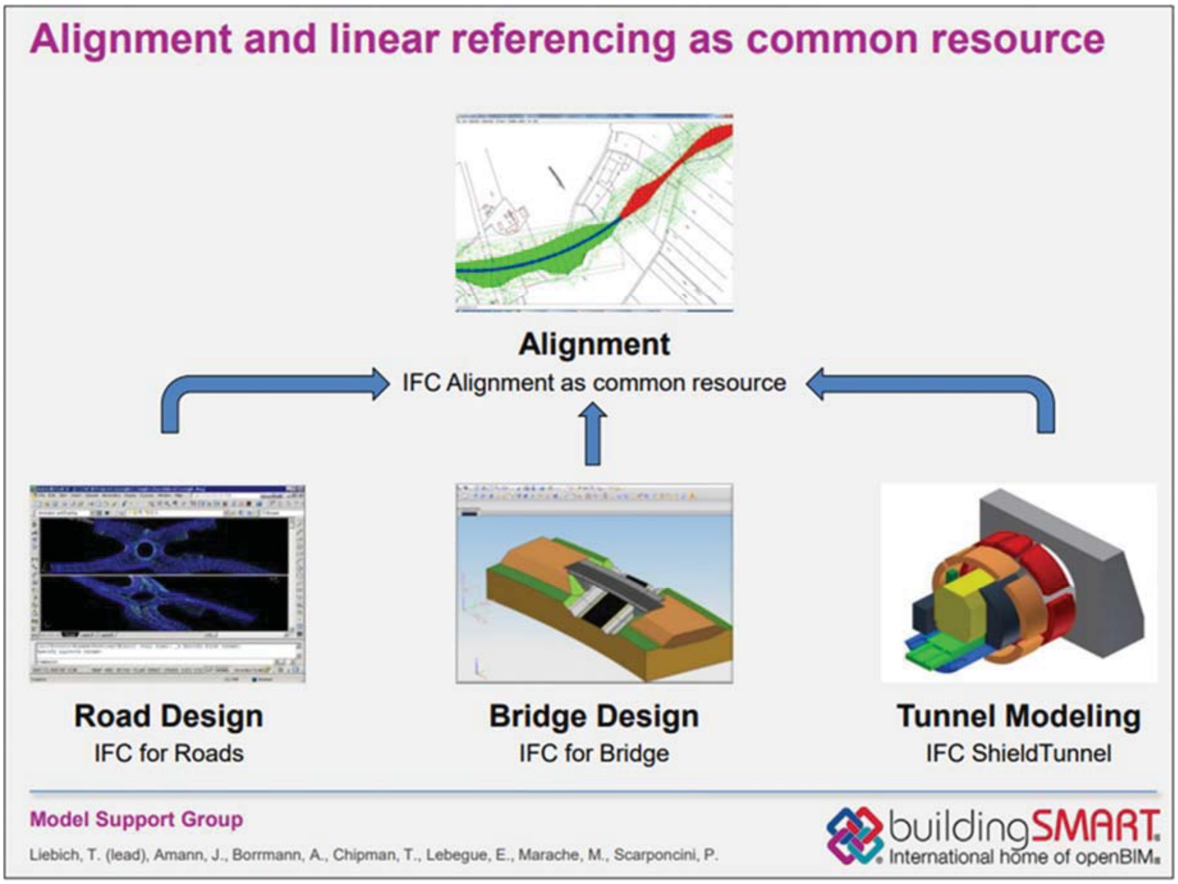


Fig. 4: Object inheritance and relationship diagram. Right-hand side shows the conceptual 3D model in BIM and left-hand side shows the object-oriented implementation of the model in IFC.

IFC may be encoded in various electronic formats, each having benefits and trade-offs of software support, scalability, and readability. As typical BIM model data can be quite large (i.e. gigabytes), the choice of format may have practical considerations. The officially supported formats are STEP, XML and ZIP.

At its current state IFC mostly supports building information with IFC for infrastructure being still in development stages [9]. IFC version 4.1 introduced the concept of alignment and linear referencing into the schema, providing the backbone for future infrastructural schema expansions (road, rail, bridge, tunnel) as shown in Figure 5.

Nevertheless, bulk of object model data such as geometry, properties, relations etc. can still be transferred from infrastructural BIM models via currently existing IFC standards. In such scenarios, due to lack of infra-specific domains and entities, infrastructural elements are usually represented using generic entities such as IfcBuildingElementProxy.



Alignment and linear referencing as common resource

Alignment

IFC Alignment as common resource

Road Design

IFC for Roads

Bridge Design

IFC for Bridge

Tunnel Modeling

IFC ShieldTunnel

Model Support Group

Liebich, T. (lead), Amann, J., Borrmann, A., Chipman, T., Lebegue, E., Marache, M., Scarponcini, P.

buildingSMART
International home of openBIM

Fig. 5: IFC 4.1 Alignment concept

29. SENSOR DATA APPLICATION

Examples of practical use-cases of IFC in sensor-based maintenance and monitoring are very scarce, existing only as a part of academic research papers [16], [17] and [18]. The underlying structure of IFC allows for a sensor to be defined using IfcSensor element of which specific types are defined using IfcSensorType entity. Both IfcSensor and IfcSensorType are new entities introduced in IFC4 and are defined in Domain layer (Figure 3), specifically under Building Controls Domain schema. As a rooted entity (inherits from IfcRoot), IfcSensor has associated GUID (globally unique identifier), name, description etc. By also being an IfcProduct, sensor can have geometric representation and object placement associated with it, as well as relations to other elements and numerous property sets attached. This means that data read from the real sensor can be processed and attached to it's digital twin in BIM model which is represented by an instance of IfcSensor.

The actual sensor data binding can be achieved in several ways through IFC format, generally by associating the sensor element (and/or the element(s) the sensor applies to) with properties and property sets. This includes entities defined in Resource layer such as:

1. IfcPropertySingleValue - Defines a property object which has a single (numeric or descriptive) value assigned. It defines a property - single value combination for which the property Name, an optional Description, and an optional NominalValue with measure type is provided. In addition, the default unit as specified within the project unit context can be overridden by assigning a Unit;
2. IfcPropertyListValue - Defines a property that has several (numeric or descriptive) values assigned, these values are given by an ordered list. It defines a property - list value combination for which the property Name, an optional Description, the optional ListValues with measure type and optionally a Unit is given. An IfcPropertyListValue is a list of values. The order in which values appear is significant. All list members shall be of the same type;
3. IfcTimeSeries - A time series is a set of a time-stamped data entries. It allows a natural association of data collected over intervals of time. Time series can be regular or irregular. In regular time series data arrive predictably at predefined intervals. In irregular time series some or all-time stamps do not follow a repetitive pattern and unpredictable bursts of data may arrive at unspecified points in time.

The specific choice of data type to be used may be subject to practicality, ease of implementation, software support, file-size differences etc.

With all of the above taken into consideration, IFC could be used as an output format, allowing the BIM model (elements, geometry, properties, relations) with all additionally integrated sensor data information to be accessible in an open, standardized, vendor-neutral way across all IFC supported software.

30. CONCLUSION

The presented paper focuses on the mechanisms needed to adequately integrate the data provided by the HSM sensing solutions identified for monitoring of bridges and tunels into a Building Information Model (BIM) environment. Specifically, the challenges of streaming the data output of the sensors into an existing BIM database. The proposed vehicle for this integration is an open Industry Foundation Class (IFC) format as defined in the ISO standard 16739. Different types of data flows, inherent to the different technologies considered, are analysed as well as the procedures to integrate the resulting information stream into the data repository in the BIM environment.

31. ACKNOWLEDGEMENTS

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