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TUM Open Infra Platform: an open source package for simultaneous viewing and analysis of digital models in the civil engineering domain

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Summary

The Architecture, Engineering and Construction (AEC) is in its transition from 2D design processes to 3D object-oriented modelling. Building Information Modeling (BIM) is steadily gaining importance, replacing the conventional Computer-Aided Design (CAD) practices and getting implemented in every aspect of the very complex software and stakeholder landscape (Jaud et al., 2019). As one of the main principles, BIM describes the idea of integrating all information relevant to the life cycle of a structure, such as a tunnel, bridge, building or road, in a digital (BIM) model. The digital model is to ensure, among other things (Amann, 2018):

- that all relevant data is available to all project participants;
- that all data is in a consistent state (data integrity should be guaranteed); and
- that the data can be used efficiently.

TUM Open Infra Platform (OIP) is an open source application for viewing and analysis of different BIM models used in the civil engineering field. OIP supports reading, visualization, navigating, and handling of:

- Industry Foundation Classes (IFC) models as specified in ISO 16739 (ISO, 2018); and
- Point Cloud Data (PCD) models as supported by the Cloud Compare library (*CloudCompare*, 2016).

Multiple models can be loaded at once and compared between each other (see Figure 1). Their absolute position is accounted for, so the models can be checked against one another for internal differences based on location of elements. Allowing a direct comparison between IFC and point cloud data is especially valuable in the context of ScanVsBIM approaches.

Additionally, OIP incorporates its own EXPRESS parser that consumes and evaluates data models (like IFC) specified with a schema following the ISO (2004) standard (see Figure 2). This enables automatic code generation for IFC early-binding library (Amann, 2018; Amann et al., 2018; Hecht & Jaud, 2019). As such, complete contents of IFC files produced following ISO (2016) can be interpreted and analysed. Moreover, type safety is guaranteed at compile time, thus reducing the risk for bugs and errors. This is achieved by a carefully designed schema-agnostic template library.

OIP serves as a prototypical playground for developments. The software architecture, features, and functionalities have been changed, added or removed as required along the way. Nowadays, OIP uses the IFC schema and CloudCompare's model as independent internal data models — explained in detail by Hecht & Jaud (2019). Major elements from previous developments were already realigned, while some (previously available) functionalities are still considered as work-in-progress.

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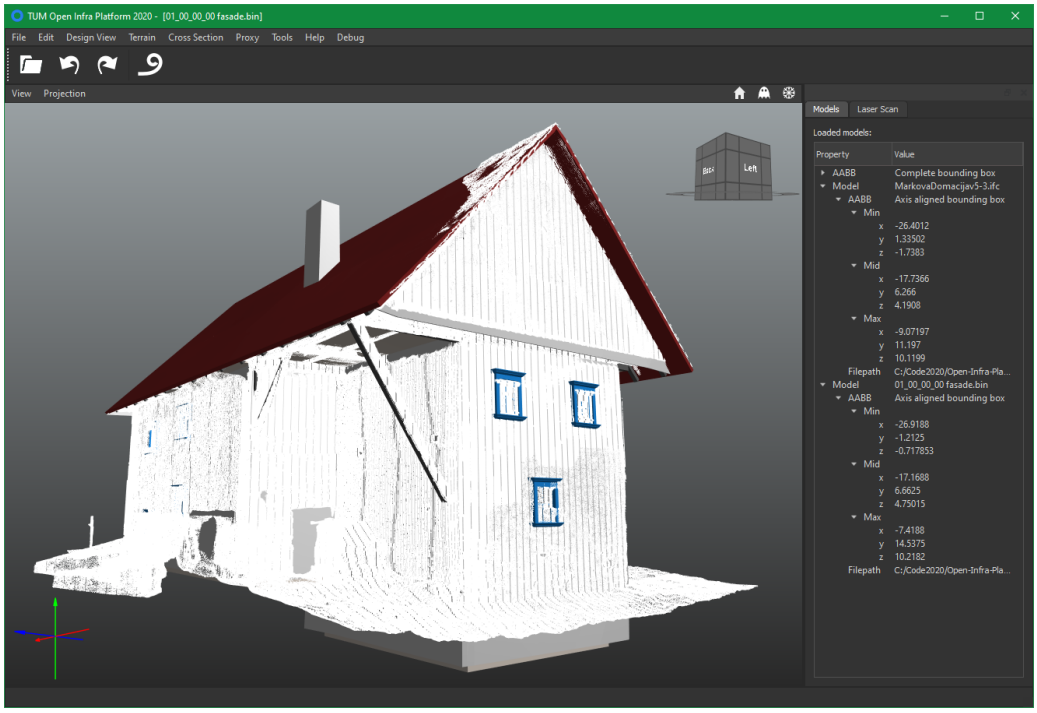

Figure 1: A PCD model together with an IFC model loaded in OIP. (PCD model courtesy of Grega Indof, IFC model courtesy of Laurens Oostwegel.)

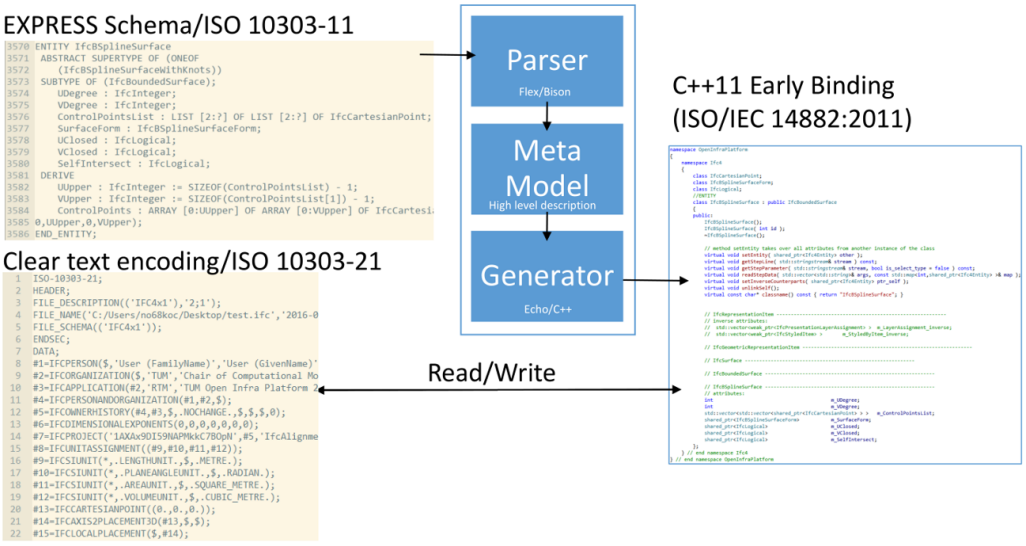

Figure 2: An overview over the EXPRESS parser's architecture (Amann, 2018).

Statement of Need

During the development of the IFC standard, a clear need for an independent software package capable of consuming and producing IFC files according to the newly developed schemas was determined. Additionally, an interface to other infrastructure data model standards like OKSTRA and LandInfra was needed (Amann et al., 2015; Amann & Borrmann, 2015a; BASt, 2021; OGC, 2016). OIP fulfils this role by being open source, using CMake as a

build system generator, and being based on well-known libraries (like Qt, Eigen, Carve, and Boost). Additionally, the provided EXPRESS parser proved useful for automatically producing source code and data models from newly developed schemas when needed (Amann, 2018; Vilgertshofer et al., 2017).

There are similar open source libraries and viewers available. As a matter of fact, the geometry handling of IFC content has been taken and improved upon from the versatile *IFC++* library (*IFC++*, 2021). Note that this is not an exhaustive list — a more thorough comparison has been conducted by Hecht & Jaud (2019) and Valero et al. (2020).

On the one hand, *IfcOpenShell*, *IFC++*, *IFC.js* and *XBim toolkit* focus primarily on handling IFC content and geometries (*IFC++*, 2021; *IFC.js*, 2021; *IfcOpenShell*, 2021; Lockley et al., 2017). They provide an API to implement against (in various programming languages) together with a viewer. However, they focus mainly on the stable versions of the IFC standard (like IFC2x3 and IFC4), while OIP focuses primarily on the newer developments. Additionally, OIP supports DirectX versions 11 and 12 simultaneously through the use of the BlueFramework open-source library that serves as a basis for the rendering engine.

On the other hand, *ParaView*, *Point Cloud Library* and *CloudCompare* focus on handling PCD (*CloudCompare*, 2016; *ParaView*, 2021; *Point Cloud Library*, 2021). These provide more functionality for PCD analysis than OIP, but cannot handle BIM models. With the emergence of the Scan2BIM and ScanVsBIM research field (deriving from or merely comparing PCD and BIM models), a tool that supports both PCD and IFC data is a welcome addition to the research processes. Valero et al. (2020) selected OIP among many other software solutions as best suitable for the development of a Scan+BIM platform.

Recently, Blender received a *BlenderBIM Add-on* and can now support both IFC and PCD models, using *IfcOpenShell* and *ParaView* as supporting libraries, respectively (*BlenderBIM Add-on*, 2021). The add-on currently supports only the IFC4 version of the IFC data model, which is a major drawback if one wishes to compare PCD and IFC data of infrastructure objects. OIP bridges this gap by providing a viewer for both recent IFC versions and PCD (Valero et al., 2020).

Research Projects

The origins of this software date back to the first projects expanding IFC for infrastructure at the Technical University of Munich (Amann et al., 2014, 2015; Amann & Borrmann, 2015a, 2015b; Singer & Amann, 2014). There, first implementations of roads' geometric concepts and interfacing between multiple standards (like IFC, OKSTRA, and LandXML) were explored (see Figure 3).

Further on, many functionalities were added during the course of these projects:

- support for first experimental IFC schema additions for tunnels (Vilgertshofer et al., 2017);
- support for PCD and their analysis (Hecht, 2018);
- support for IFC Programming Language (IFC-PL) (Amann, 2018);
- support for linked data approaches (Beetz et al., 2019); and
- support for IFC4x1, IFC4x2, and IFC4x3 candidate versions of the IFC standard during their development (Jaud et al., 2020).

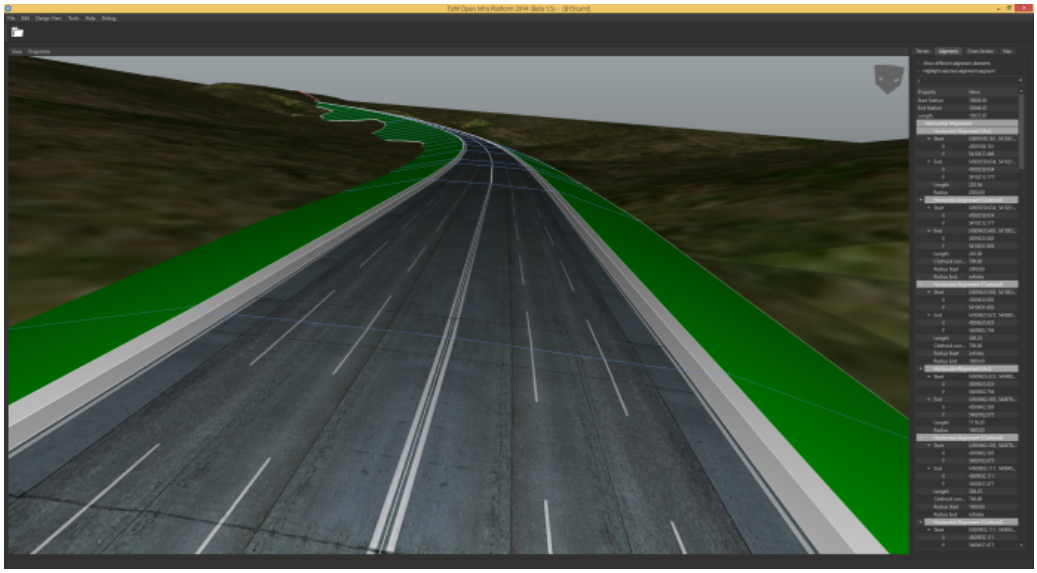

Figure 3: A perspective view of road geometry on terrain's surface with clearly marked fills.

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