

## BSPRO COM-Server—interoperability between software tools using industrial foundation classes

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### Abstract

The continuing development of the Industry Foundation Classes (IFC) standard by the International Alliance for Interoperability (IAI) creates new possibilities for achieving interoperability for design software through the use of a common object model of the building and its open data transfer standard. Several architectural CAD tools are already IFC-compliant. However, in-depth knowledge of the highly complex IFC object model is required to develop IFC-compliant software. It has proven quite difficult to read the huge amount of building data stored in an IFC file, extract the information needed by a particular application, and correctly update the IFC file with new data. To make this work easier for developers not familiar with the IFC, Olof Granlund Oy has developed a new development tool, BSPRO COM-Server for IFC Files. Using this tool, a software developer of new or existing tools can achieve IFC compatibility with a quite reasonable amount of work.

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### 1. Introduction

The major constraint on the everyday use of powerful calculation tools at different stages of the building design process has been time consuming manual data input, especially related to the building geometry data. However, the continuing development of the Industry Foundation Classes (IFC) standard by the International Alliance for Interoperability (IAI) creates new possibilities for achieving interoperability for design software through the use of a common object model of the building and its open data transfer standard. Several architectural CAD tools from all the leading CAD vendors (e.g. AutoDesk, Nemetschek, Graphisoft, Visio) are already IFC-compliant. So, the geometry model can already exist as a base for the building process.

However, software development experience has shown that an in-depth knowledge of the highly complex IFC object model is required to develop IFC-compliant software. It has proven quite difficult to read the huge amount of building

data stored in an IFC file, extract the information needed by a particular application, and correctly update the IFC file with new data.

To make this work easier for developers not familiar with the IFC, Olof Granlund Oy from Finland has developed a new development tool, BSPRO COM-Server for IFC Files. Using this tool, a software developer of new or existing tools can achieve IFC compatibility with a quite reasonable amount of work. BSPRO COM-Server is a so-called “middleware” solution, based on Microsoft’s COM technology, that can link new and/or existing software tools by allowing them to exchange IFC-compliant building data. BSPRO COM-Server uses a language-independent architecture that can be used in any programming environment within Windows<sup>TM</sup>. The methods offered in the BSPRO COM-Server interface enable easy access to IFC classes and their properties without a deep understanding of the IFC standard. BSPRO COM-Server has its scope in the Building Services (“BS”) domain (e.g. HVAC and electrical). Currently, BSPRO handles building geometry and thermal data for the building envelope. It can be used in different tools throughout the BS implementation process (design, manufacturing, contracting and facilities management).

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When using the IFC standard, the work of manual data input required by end users diminishes because the data can be imported directly from the IFC file created by other applications such as CAD. This has tremendous benefits, especially when using thermal and CFD simulation programs. The simulation tools can be made interoperable with the IFC model. This enables, for instance, dimensioning and performance comparisons of design alternatives beginning in the early stages of the design process. The easier handling of IFC files provided by BPro also enables updating and adding information to an IFC project file during the whole design, delivery, and operation process. In the future, the IFC model of the building, containing data from thermal simulations, offers many possibilities for data reuse in other IFC-compliant programs, such as HVAC CAD. For example, the sizing of terminal boxes and ventilation system ductwork can be based on loads simulation data from a different tool that are imported from the IFC file.

This paper describes the experiences of several international software developers, when testing and demonstrating the use of BPro in their IFC interface development.

## 2. Experiment

The trend in building environment simulation has been towards linking several tools together to make mutually beneficial alterations in designs over several metrics. This trend is being accelerated by joint industry operations, such as the development of IFC. Examining the logical conclusion of this trend suggests that all simulation tools will run in the same design environment, which is achieved with interoperable tools. Recognising the need to bring together existing CFD and HVAC analysis technologies, AEA Technology Engineering Software, Olof Granlund, Halton Group and Lawrence Berkeley National Laboratory (LBNL) in collaboration with Massachusetts Institute of Technology (MIT) and the International Facility Management Association have engaged in Project Bild-IT to develop and evaluate a prototype software tool for integrated building HVAC

design. Fig. 1 shows how different software tools can share information via IFC using BPro COM-Server.

## 3. Case MIT

As a subcomponent of the Bild-IT project, the MIT has recently developed a Simplified CFD Interface (SCI) [1], a public domain program that allows architects and building engineers to use CFD without excessive training. SCI provides service of pre- and post-processing for a CFD simulation. It uses a standard data interface structure to communicate with different CFD programs. SCI current serves for two CFD programs, one simple zero-equation program developed for ASHRAE [2] and another more general CFD program for EnergyPlus [3]. The interface can be easily used for other CFD programs, even those of large eddy simulation.

Although a sufficient model geometry can be constructed in SCI through the Windows interface without importing files, this requires tremendous effort in the data input. It has been estimated that a CFD simulation for built environment modeling requires 80% of effort for the data input and 20% for the computing. Therefore, the use of standard data format such as IFC and STL reduces the redundant work from the designer. In our experience with the architecture design students, it can be concluded that the data input effort can be reduced as much as 80%.

The success is partially attributed to the use of the boundary manager to keep track of the model layout in SCI. The special feature allows the data to flow from geometry file importing classes like IFC and STL into the boundary manager. The organisation behind IFC files made importing them into the SCI data framework very simple. SCI uses an IFC component object model server, BPro COM-Server for IFC Files. The server acts as like a snap-in subsystem. When an IFC file geometry is needed, SCI creates an instance of the IFC server class and connects it to the file. Once connected, the file acts like an instantiated object. The program requests a list of geometry objects from the file and uses it to create SCI boundary conditions. The

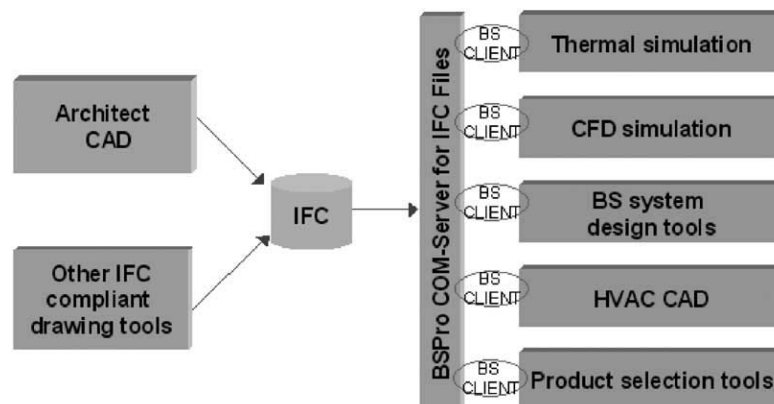


Fig. 1. Linking of IFC-compliant software tools using BPro COM-Server.

objects are specified as rectangular shapes, which match SCI's geometry primitives, and therefore require no transformation work.

The simplicity of the IFC system suggests that more and more building environment simulation codes will be utilising it as the substrate of choice for model geometry. Incorporating its use into SCI will be beneficial to the system for years to come.

#### 4. Case AEA

As a subcomponent of the Bild-IT project the AEA Technology Engineering Software is also developing their CFD calculation software CFX to be IFC-compliant. The usage of BPro COM-Server enables easy access into the building geometry within IFC files. Without this link to IFC

geometry model, the drawing of the needed geometry for CFD calculations would take typically one day's work. Fig. 2 shows the CFX user interface with IFC import panel and the imported IFC-geometry of a building storey. Shown is also IFC geometry after diffuser and exhaust boundary conditions have been automatically applied, and room objects and associated boundary conditions (lights, computers, tables, etc.) have been manually created. The automatically applied boundary conditions took on the order of 3–5 min to setup, whereas the manually created additions took on the order of 1–2 h!

#### 5. Case Halton

Halton Group is implementing IFC via developing software named as Halton Designer (previously Help 2000) [4]. This software has several modules:

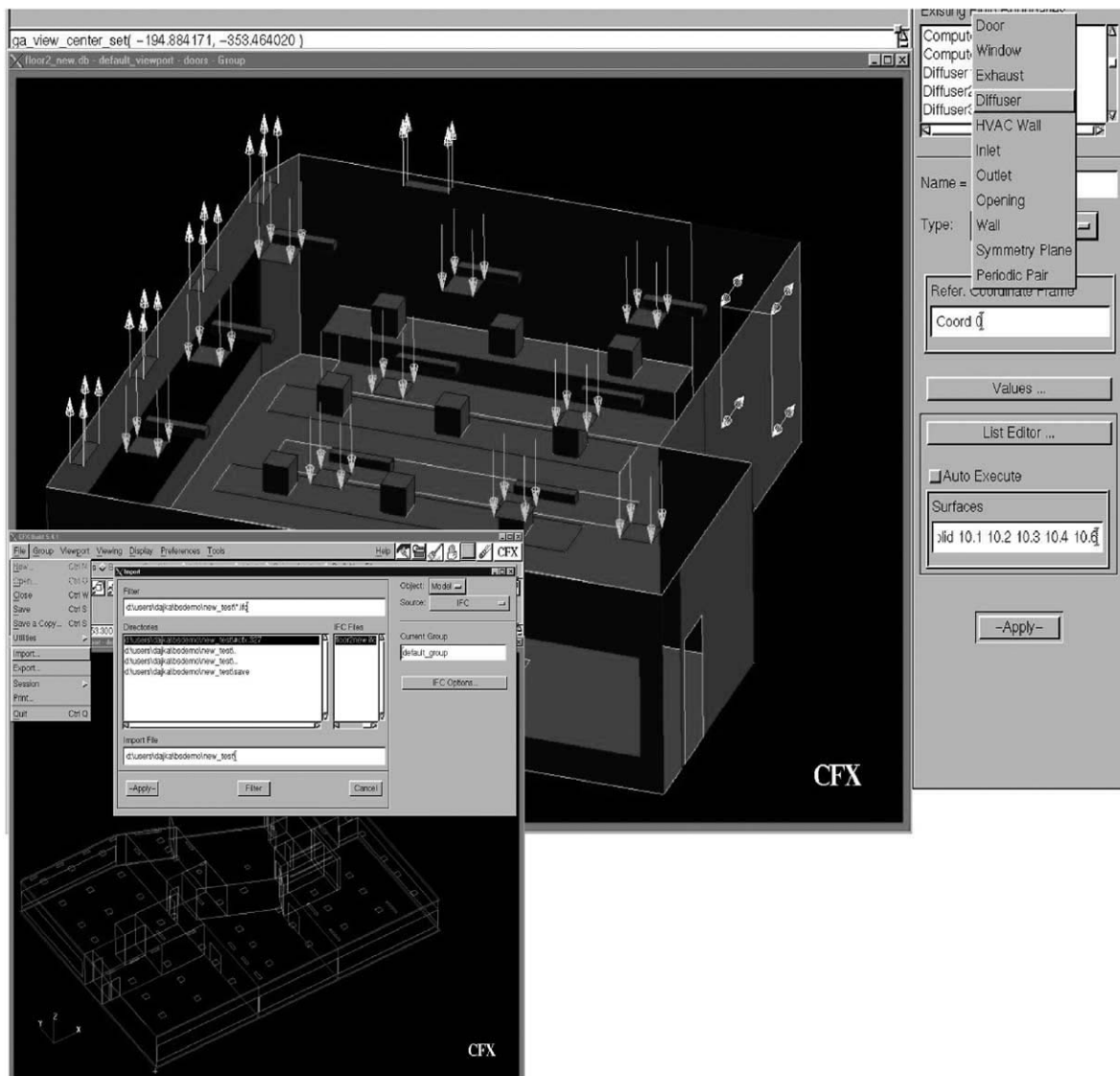


Fig. 2. CFX user interface showing the IFC import panel and the imported IFC geometry (below); IFC geometry after diffuser and exhaust boundary conditions have been automatically applied (top).

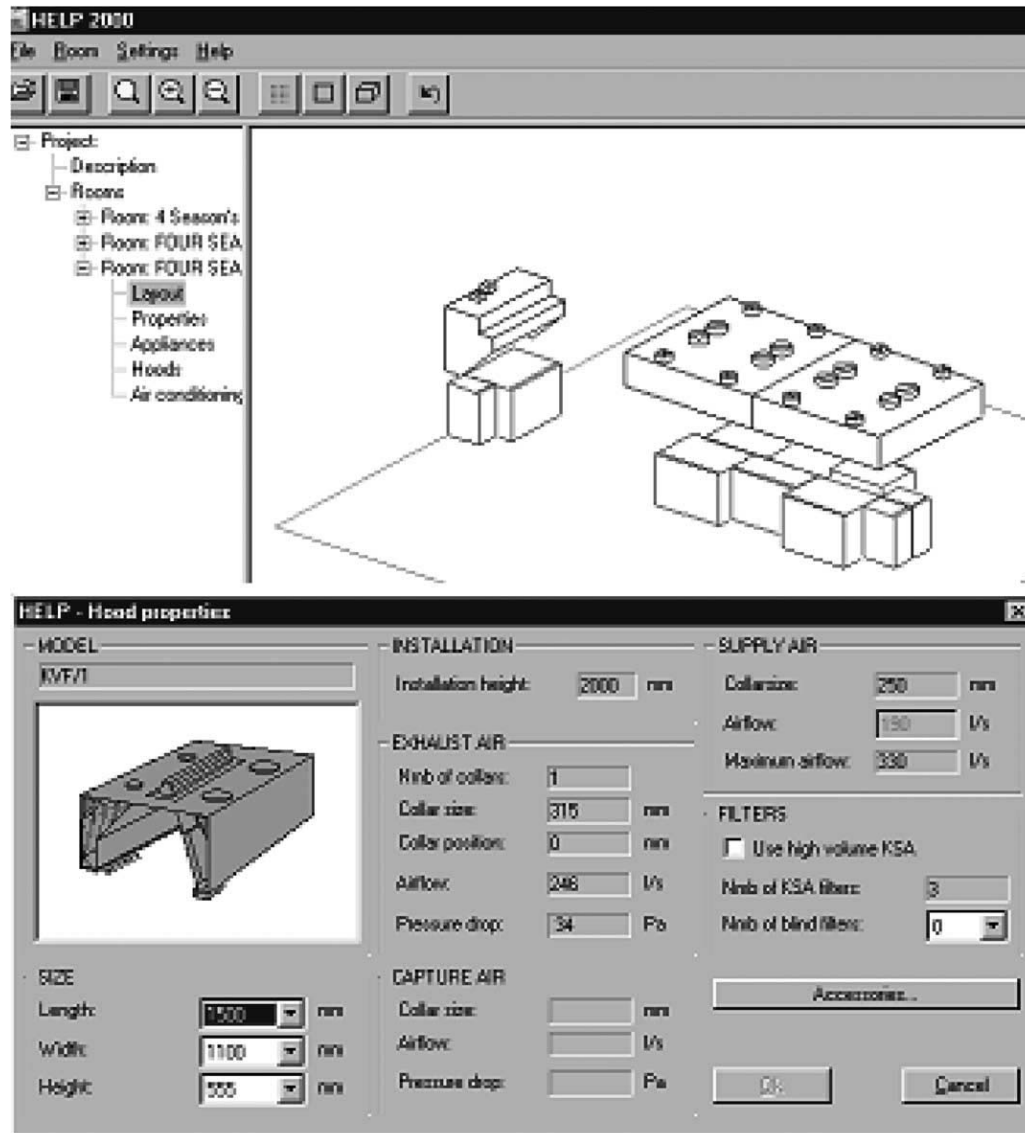


Fig. 3. Geometry of kitchen canopy units.

- Kitchen ventilation design and canopy selection.
- Air distribution design of mixing and displacement ventilation.

Halton will integrate the BPro COM-Server into the Halton Designer to achieve the IFC compliance. IFC is used to import/export the space and canopy geometry data. Also the geometry data of mixing ventilation and displacement ventilation units is imported from IFC. Other possible IFC based HVAC design data via BPro will also be imported in the future software versions (Fig. 3).

## 6. Case LBNL

LBNL has created a BPro Client Module for EnergyPlus. One of the issues that has limited the use of energy

simulation software in support of building design and operations activities has been the time required to accurately input a building description. To address this issue, the LBNL, with support from the US Department of Energy and the California Energy Commission, has developed a utility that implements an initial level of interoperability for EnergyPlus based on the IFC standard. The utility, which is named IFCToIDF, imports data from an IFC data file created by any IFC-compliant software tool (e.g. CAD) and creates a corresponding input data file (IDF) for EnergyPlus.

The initial implementation of the IFCToIDF utility focuses on extracting the geometric representation of building, space, and envelope surface and opening object instances contained within an IFC data file and mapping this geometry to the EnergyPlus Input Data Dictionary (IDD). As more software tools become IFC-compliant, and as the existing IFC-compliant software supports additional data that are

relevant to energy simulation (e.g. material characteristics), the utility will be enhanced to transfer these data from IFCtoIDF. It is also anticipated that as more IFC-compliant software tools become available, the capabilities demonstrated in the IFCtoIDF utility will be incorporated into a variety of software developed by others, including specialised user interfaces for EnergyPlus.

### 6.1. Implementation details

The IFCtoIDF utility has been developed using Visual C++ 6.0™ as a Windows™ dynamic link library (DLL) that is a client to the BPro COM-Server. A simple host graphical user interface (GUI) application has also been developed that allows an end user to specify the IFC data file to be read, and the IDF to create. The GUI and the DLL run on the Microsoft Windows 95/98/NT/2000 platforms. The utility requires the installation of the BPro COM-Server software package, which Olof Granlund Oy is making available free of charge to registered users of EnergyPlus.

The relationship and the flow of data between various software modules is illustrated in Fig. 4. Note that there is a two-way flow of data between the IFC data file and both the BPro COM-Server and a fully IFC-compliant tool. At this point, however, there is only a one-way flow of data from the BPro server through the IFCtoIDF utility, into an IDF, and then into EnergyPlus. In the future, a two-way flow could be developed in which output from EnergyPlus (e.g. end-use energy predictions) are stored back into the IFC data file for archiving and sharing with downstream applications (e.g. commissioning and operations).

The IFCtoIDF utility currently extracts only the geometric description of specific building elements contained in an IFC data file using the COM methods provided by BPro. Geometry is extracted for the following IFC classes: IfcProject, IfcSite, IfcBuilding, IfcBuildingStorey, IfcSpace, IfcWall, IfcWindow, IfcDoor, IfcFloor, IfcRoofSlab.

There is not a one-to-one correspondence between object classes in the IFC data model and the EnergyPlus IDD. Therefore, the object data that are extracted from an IFC file must be mapped to their IDD counterparts. The geometric representation of objects also differs between IFC and the IDD, requiring a transformation between the two representations. The resulting objects that are written to the IDF include building, zone, heat transfer surface (wall, floor, and roof), and heat transfer sub-surface (window and door). A minimal set of library objects for material and construction types is also written to the IDF for reference.

The BPro server greatly reduces the effort required in mapping the geometry of these objects by simplifying the potentially complex geometric representation of the IFC to the more restrictive three or four vertex planar surfaces required by EnergyPlus. For example, an instance of IfcWall, which might have been created as a curved surface spanning an entire exterior façade (i.e. the wall spans and bounds multiple IfcSpace instances), is simplified by the BPro server by returning only three or four vertex faces that bound a single IfcSpace. This capability of simplifying geometry is even more critical for floor and roof surfaces that bound L-shaped or other non-rectangular space floor plans.

### 6.2. Current limitations

There are some outstanding issues that are being addressed as development of all of the software modules shown in Fig. 4 continues. We are working with software vendors to address these issues.

As previously mentioned, only geometry is passed from the IFC data file to EnergyPlus, with simple defaulted material characteristics. This is not a consequence of the IFC data model, which includes material related class definitions, but rather of the user interfaces of currently available IFC-compatible tools that do not provide any means of inputting these data.

EnergyPlus requires input of whether a surface is interior or exterior. This can be difficult to determine based solely on the geometry of surfaces and may require direct user input, either within the software that creates the IFC data file, or within the IFCtoIDF utility itself, which is not currently interactive.

The correct geometric mapping of openings that may span multiple spaces (e.g. strip windows in a façade wall) is still being developed. This mapping is particularly tricky for curved and sloped host wall surfaces.

Few of the available IFC-compliant CAD tools provide a mechanism for identifying thermal zones within a building. For this reason, the IFCtoIDF utility currently maps each instance of IfcSpace to its own IDF Zone. This means that objects that were most likely created as individual rooms in a building story become individual thermal zones. The IFC data model provides classes for grouping spaces into zones, so this is another user interface issue rather than a data modeling issue.

As indicated in Fig. 4, the current IFCtoIDF utility is a standalone, non-interactive, one-way transfer of data from

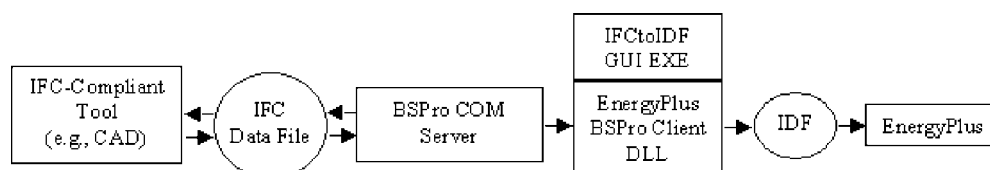


Fig. 4. Flow of data between software modules.



IFC to EnergyPlus. However, the BPro server supports two-way data transfer. It is therefore possible to enhance the utility so that it transfers EnergyPlus output back to the IFC data file. It would also be possible to embed such a utility within an environment that supports interactive user input to provide additional data required for energy simulation as part of the process of creating an IDF and post-processing EnergyPlus output.

### 6.3. Distribution

The IFCtoIDF utility is being distributed free of charge along with EnergyPlus. The distribution package consists of the utility DLL, the utility host user interface, a sample IFC file, user documentation, and a user license. Registered EnergyPlus users can download a runtime version of the BPro COM-Server from Olof Granlund Oy free of charge.

## 7. Case Granlund

For couple of years Granlund has been developing a building energy simulation interface, RIUSKA, which is currently using DOE-2.1E as a simulation engine. Earlier the building three-dimensional-geometry used in simulations had to be drawn in a separate AutoCAD™ based drawing

tool, and then imported into RIUSKA with help of special API-functions. Drawing of the building geometry again on top of the architect's two-dimensional-drawings was in many cases time consuming. This is one reason why Granlund got interested in handling building geometry in IFC format. IFC standard creates new possibilities for achieving interoperability for design software through the use of a common object model of the building and its open data transfer standard.

For easier handling of IFC files, Granlund developed a new development tool, BPro COM-Server for IFC files [5]. Using this tool, a software developer of new or existing tools can achieve IFC compatibility with a quite reasonable amount of work. BPro COM-Server is a so-called “middleware” solution, based on COM technology of Microsoft™, that can link new and/or existing software tools by allowing them to exchange IFC-compliant building data. BPro COM-Server uses a language-independent architecture that can be used in any programming environment within Windows™. The methods offered in the BPro COM-Server interface enable easy access to IFC classes and their properties without a deep understanding of the IFC standard. BPro COM-Server has its scope in the “BS” domain (e.g. HVAC and electrical). Currently, BPro handles building geometry and thermal data for the building envelope. It can be used in different tools throughout the

The screenshot shows the RIUSKA software interface. At the top left, a window titled 'Import geometry' is open, showing a file list with columns for Storey, Building, Site, and IFC file. An arrow labeled 'Import IFC geometry for thermal simulation' points from this window to the main workspace. The main workspace has a menu bar (File, Databases, Reports, Information, Tools, Help) and a toolbar. Below the menu bar, there are fields for 'Building: B1 Building1' and 'Case: (2002) Basecase'. A 'Thermal zones/Storeys: All' dropdown is also present. The main area contains a table of room properties:

Code	Name	m2	m3	Infiltration...	Temp. gr...	Type
R201	R201	137.4	494.6	0.10	0.0	Office room
R202	R202	32.6	114.1	0.10	0.0	Office room
R204	Office room R204	27.0	91.8	0.10	0.0	Office room
R205	R205	10.0	34.0	0.10	0.0	Office room
R206	R206	2.8	9.2	0.10	0.0	Office room
R207	R207	11.5	38.0	0.10	0.0	Office room
R208	R208	15.0	49.5	0.10	0.0	Office room
R209	R209	130.5	469.8	0.10	0.0	Office room
R210	R210	139.4	487.9	0.10	0.0	Office room
R211	R211	154.0	554.4	0.10	0.0	Office room

Below the table, there are controls for 'Space cooling: 1350.0 W (= 50.0 W/m2)' and 'Air flow rate: 40.6 l/s (= 1.5 l/s/m2)'. There are also 'Load levels' (Other, High, Normal, Low, No load) and 'Space type: Office' and 'Indoor air quality level: Norm' dropdowns. An arrow labeled 'Export thermal data to IFC for re-use in HVAC CAD' points from the main workspace to a detailed view of room R204. This view shows a 3D floor plan of the room with a ducting system. A 'ROOM' properties panel is open, showing:

- GUID: 3A82575CDFA2C2150533
- Code: R204
- Name: Office room R204
- Floor: Floor-1

The 'PROPERTIES' panel for room R204 includes:

- T for cooling [C]: 26.0
- T for heating [C]: 21.0
- Supply airflow [l/s]: 40.6
- Exhaust airflow [l/s]: 40.6
- Total heatgain [W]: 1350.0

Fig. 5. Thermal simulations can be performed for the imported IFC geometry and resulting data exported back to the IFC file. The geometry and thermal data can then be used for example for designing and sizing of the ducting system.

“BS” implementation process (design, manufacturing, contracting and facilities management).

When using the IFC standard, the work of manual data input required by end users diminishes because the data can be imported directly from the IFC file created by other applications such as CAD. This has tremendous benefits, especially when using thermal and CFD simulation programs. The simulation tools can be made interoperable with the IFC model. This enables, for instance, dimensioning and performance comparisons of design alternatives beginning in the early stages of the design process. The easier handling of IFC files provided by BSPro also enables updating and adding information to an IFC project file during the whole design, delivery, and operation process. In the future, the IFC model of the building, containing data from thermal simulations, offers many possibilities for data reuse in other IFC-compliant programs, such as HVAC CAD. For example, the sizing of terminal boxes and ventilation system ductwork can be based on loads simulation data from a different tool that are imported from the IFC file.

Granlund has written new program code into their building energy simulation software, RIUSKA, to act as a client for the BSPro COM-Server. With the help of BSPro navigating through the IFC file was easy without any deep knowledge of IFC standard. BSPro makes it easy to write the program code for reading the spaces related to the building, walls related to the space, etc. Granlund has used IFC based building geometry import in its simulation projects, whenever the IFC model has been available from the architect.

After performing thermal dimensioning simulations in RIUSKA, it is possible to save the dimensioned values back to the same IFC file, where the geometry was imported from. Currently these values include space air flow rate, space cooling capacity and design temperatures for heating and cooling. This IFC file updated with the thermal data from the simulations can then be re-used for example in a air duct design software (Fig. 5).

## 8. Conclusions

BSPro COM-Server allows easier implementation of IFC standard for existing and new software tools. When using the IFC standard, the work of manual data input required by end users diminishes because the data can be imported directly from the IFC file created by other applications such as CAD. BSPro is currently used by several software developers, when they are developing clients for handling the IFC files.

BSPro focuses currently only to the geometric description of specific building elements contained in an IFC data file. The BSPro server greatly reduces the effort required in mapping the geometry of these objects by simplifying the potentially complex geometric representation of the IFC to the more restrictive three or four vertex planar surfaces. Also, some thermal simulation softwares require input of whether a surface is interior or exterior. This may be difficult to determine, if it is not specified in the IFC file by the software that created the file. HVAC system modeling is currently being improved in IFC, and BSPro will be further developed to implement also this field of IFC.

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