# COUPLING CAD TOOLS AND
# BUILDING SIMULATION EVALUATORS

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## SUMMARY

The ISE (Intelligent Simulation Environment) concept, developed by CSTB since the early nineties, has been applied to the development of various Simulation Environments (such as IISiBat III for TRNSYS or IISiBat II for COMIS). This concept has also been used to develop a prototype which aims at helping researchers to document their models and to store them in a neutral way, within structured model libraries [1].

The Simulation Environments developed are very often seen by the users as "only" user-friendly interfaces, whereas they are more than that. Whatever, the schema-blocks front-ends are appreciated and widely used worldwide (there are more than 300 institutes and consulting companies, worldwide, which are equipped with the latest version of TRNSYS). Nevertheless this kind of front-end (schema-blocks) is still too much abstract, too much technical for users such as architects which are more used to work with CAD tools.

Coupling CAD tools and Simulation Environments such as IISiBat represents a significant improvement both for the user-friendliness and for the efficiency of use. Geometrical data can be automatically re-exploited (less errors due to re-keying), additional geometrical data, such as HVAC system pattern, can be added through the CAD tool.

At this time most of the CAD tools can export DXF files. At the international level, the IAI (International Alliance for Interoperability) is leading the development of the IFC (Industry Foundation Classes) which are expected to replace soon the current DXF files (allowing to store more "semantic" within the files).

After introducing briefly the ISE concept, this paper focuses on the coupling between CAD tools and Building Simulation Evaluators (such as TRNSYS). The prototype of a tool called "SimCAD" is described. This tool enables the users to read DXF or IFC files, to add information and to translate the geometrical information into the data usable by the targeted Simulation Environment.

## THE ISE CONCEPT

Building Performance Evaluators such as TRNSYS or COMIS make use of complex data structures. The data structures embed geometrical data and all the physical data necessary to describe the Building envelopes and the HVAC system components' characteristics. It becomes more and more difficult and inefficient to try to use these simulators without a user interface to enter and process the data. Moreover, such an interface is not only dedicated to the easy entry of data but it is also intended to help the user all along the simulation process.

Developing user-friendly and efficient Simulation Environments is a time-consuming, then very expensive, process. On the other hand, most of the Building Performance Evaluators share a common data structure and common data. These factors led to the concept of ISE. The concept of ISE aims at producing a generic tool to facilitate the development of specific simulation environments. These various simulation environments make use of a common core of functions (such as "store a model in a library", "retrieve a model from a

library", instanciate a model on an assembly panel", etc.). Being generic and once developed, the ISE reduces the cost of developing specific simulation environments such as IISiBat III for TRNSYS or IISiBat II for COMIS. The specific simulation environments make easier the use of the complex Building Performance Evaluators encapsulate, and, because of that, enables their dissemination towards practitioners.
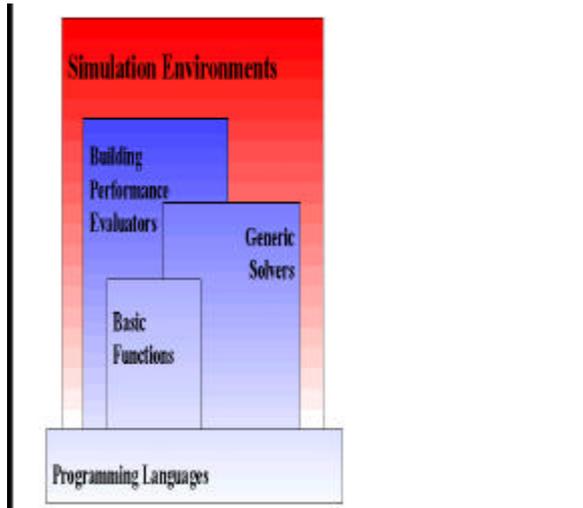


*Figure 1: Simulation Environments*

Concrete implementation of the ISE concept, is the Simulation Environment called IISiBat. IISiBat II is developed is Lisp and has been used to encapsulate TRNSYS and COMIS (TRNSYS 14.2 w. IISiBat and COMIS 3.0 w. IISiBat). A new version of IISiBat (IISiBat III) is in the process of being released and will encapsulate the brand new TRNSYS 15.

The IISiBat environment is an open environment. This means that, with reasonable human resources, it is possible to derive from the generic IISiBat environment specific front-ends dedicated to specific Building Performance Evaluators. Moreover, the Simulation Environments developed can be customized to fit the needs of an organization (such as a big consulting company with many users) or of a specific user.

These tools (ie. the Simulation Environments such as IISiBat) have enabled to transferring complex Building Performance Evaluators to practitioners.

In addition, the Simulation Environments developed allows inclusion of new numerical models either imported from various libraries (very often public users' libraries) or developed by the user himself. Due to this functionality, the wide use of Simulation Environments such as IISiBat enables to disseminate stand-alone models. This possibility can in the future lead to the development of Model Servers accessible via the Internet.

So far, IISiBat II has been used to encapsulate TRNSYS and COMIS. A brand new version of IISiBat for TRNSYS is in the process of being released. This new version is written in C++ and runs only on PC platforms (Windows 95, 98, NT) whereas the previous version ran also on Unix machines (but it was very complex and expensive to maintain and in fact, almost never used on Unix machines).
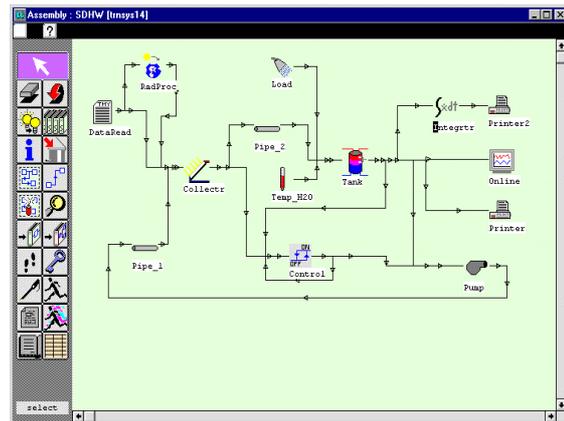


*Figure 2: IISiBat Assembly Panel*

More recently, the ISE concept has been used to develop a tool dedicated to the researchers (ie.: "Model Developers"). This project (called MSN: Model Server Network) aims at developing a software to facilitate the development of numerical models, with all the necessary documentation, their storage in and retrieving from a structured library of models (ie.: object oriented), their translation into the targeted simulation environments and, eventually, their use coupled to other numerical models.

Whatever the improvements made, there is still a lack in the Simulation Environments developed: the description of the building geometry requires an excessive amount of time

and effort (without speaking of the risks of errors due to data re-keying).

## ABOUT CAD-LIKE FRONT-ENDS

Even if the recently developed Simulation Environments are assessed by their users as "very user-friendly", they still need a certain period of time to be mastered and used with efficiency. The graphical language is often based on the "Schema-blocks" approach. And even if drawing blocks and connecting them together is relatively close to the way engineers model, this is not necessarily adapted to any user especially to architects. Buildings are first designed by architects who draw them using CAD tools. Even the engineers, who intervene afterwards, do also make use of CAD tools to draw their "layer" (ex.: HVAC system). Both architects and engineers are used to use CAD tools. Moreover the engineers must re-key into their tools, geometrical data already entered by the architects via the CAD tools. This is a waste of time and a source of errors which contribute to diminishing the quality of the whole project.

Using CAD tools in tandem with Building Performance Evaluators will certainly constitute a significant improvement in the way architects and engineers work together. In this context, "in tandem" means either that data can automatically be passed from a CAD tool (which exports data in DXF or IFC files) to a simulation tool, or that data can be added to the initial drawing by the engineers via CAD tools.

These possibilities have become a reality in the case of TRNSYS, thanks to the extension of the ISE concept to CAD tools. A specific, stand-alone, module has been developed, called **SimCAD**.

**SimCAD** can read DXF files and IFC files. DXF stands for Drawing eXchange Format, DXF is a proprietary format from Autodesk. IFC stands for Industry Foundation Classes. The IFCs are developed by a consortium called IAI (International Alliance for interoperability). This consortium gathers CAD developers such as Autodesk, Intergraph and Nemeschek and users. The IFC are

intended in the mid-run to replace the existing DXF files providing a new way of storing the geometry of a building. The main advantages of the IFCs are that, being object oriented, a higher level of semantic (eg.: two parallel lines can be explicitly stored as a wall) can be embedded into the files and the files are more compact.

## INTRODUCING SIMCAD

SimCAD is a piece of software dedicated to TRNSYS w. IISiBat. SimCAD allows users to draw the building shape, including its various zones, and to add information about the materials used, including some of their physical characteristics (such as U values, or thermal conductivity). DXF files, produced by any CAD tool, can be imported into SimCAD. Thanks to SimCAD, semantic can be added to the original DXF file in such a way that the building component of TRNSYS (ie.: TYPE 56) will be able to understand, and therefore use, the geometrical data. Examples of added semantic are walls limits, thermal zones definition, materials. SimCAD can also read IFC files[1].

Once the building shape is drawn, the geometrical data are defined (lengths, widths, heights, thicknesses), and the physical characteristics are entered, SimCAD generates the input file needed by the TRNSYS subroutine called PREBID. Using PREBID remains a necessary step to generate the .BUI file which can eventually be used by the TRNSYS building model (ie. by TYPE 56).

## COUPLIG CAD TOOLS TO BUILDING PERFORMANCE EVALUATORS

**An old story …**
In the seventies the first dynamic simulation tools such as TRNSYS have been developed and very rapidly the developers and the users have felt the need to couple CAD tools to these simulation tools. Many experiments [5] have demonstrated the usefulness of electronically exchanging data between CAD tools and

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[1] The next AutoCad release will be IFC compatible.

simulation tools, but they also demonstrated the complexity of the problem.

As today, have significant progress been made since that time? The answer is not so obvious. As a matter of fact both architects and engineers make use of computers and ad hoc software. Drawings are very often exchange as DXF files. But the time needed to exploit the data contained in the DXF files is almost equivalent to the time needed to re-key in the data from a paper-based drawing.

Even if a DXF file is well structured (ie. drawings are organized in layers, each layer gathering all homogeneous components such as walls, zones, HVAC equipment, dimensions, electrical wires, etc.), this does not solve all the problem when connecting this file to a thermal code such as TRNSYS. The main reason is that a thermal simulation code needs to know more about the building that only the name of the zones and their dimensions. What is needed are the relationships between "objects" [6], [7]:
- relationships between a zone and the walls that delimit this zone;
- thermal zones (how are physical zones grouped together with respect of thermal considerations);
- adjacent zones;
- apertures (thermal programs must understand that window A or door B belongs to wall C or wall D);
- junctions between walls, between walls and ceilings and between walls and floors (this is needed to compute thermal losses through the thermal bridges).

SimCAD allows definition of all these relationships.

## The "long march" towards interoperability …

### From data modeling to STEP (STandard for the Exchange of Product)

The scientific community, involved in the field of Information Technologies applied to the AEC (Architecture, Engineering and Construction) sector, acknowledged, for a long time, that object oriented modeling was the way to follow ([8], [9], [10], [11]).

The STEP initiative (standardization work for the technical data) was launched in 1984 as a subcommittee 4 of the ISO TC 184. It took 10 years to the experts to release the first version of the STEP standard.

Developing STEP is a very slow process not only because this is an ISO process but also because the initial ambition was very wide. STEP intended to cover all the domains: automotive, space industries, oil platforms, AEC, naval industries, etc. Nowadays, after 15 years of work, the results are there; especially the language used to describe abstract objects (EXPRESS) is recognize as being adapted to the needs of the various activity sector initially targeted.

STEP technologies have been widely experimented [12] [13] including in the framework of European projects such as ATLAS [14].

But, despite of all the technical advantages, as a matter of fact STEP technologies are not used in the AEC sector. The reasons are complex, not only technical but also, as often, commercial: from the beginning, there was a lack of involvement of the main users of the main software developers.

### IAI an International Alliance for Interoperability

Autodesk initiated this movement. But nowadays there are   than 600 members Worldwide including all of the main Autodesk competitors. The IAI is structured in regional chapters (Australia, France, Germany, Japan, North America, Scandinavia, Singapore and UK). The IAI aims at defining a simple common language to exchange technical data related to the AEC sector. Version 1.5 of the IFC contains about 200 entities. This version is based of some of the STEP concepts and formats. Version 1.5 has already been implemented in various prototypes of new generation CAD tools.

There is a whole volume of the IFC dedicated to HVAC systems. This volume is implemented in SimCAD.

## HOW TO USE SIMCAD IN PRACTICE

Modeling and simulating a building with a tool such has TRNSYS can be split in three different phases:
- gathering, completing and processing the geometrical data
- modeling from a thermal point of view the building and its equipment
- running the simulations (including the choice of the meteorological data, the choice of the variables to be computed, etc.).

In this process SimCAD is used in the first phase (gathering, completing and processing the geometrical data). The main functions of SimCAD are:
- reading of the DXF or IFC files;
- definition of the thermal zones;
- definition of the relationships between the zones and the walls (which are the walls that delimit the zones);
- 3D representation (this function is to help the user to visualize the building he or she is working on);
- to generate the .BUI file: data ready to be processed by PREBID (PREBID is a module used by TRNSYS to add information, such as thermal properties of the material used, to the geometrical data)
- writing of the DXF or IFC files;

### An example of the use of SimCAD

During the Beta tests of SimCAD, Laurenti, a engineering company based in Toulouse (France) used SimCAD on a 20 000 m$^2$ project.

The architect sent the drawings to Laurenti in DXF format. The drawings was correctly structured in layers. SimCAD has been able to retrieve all the data contained in the DXF files and has added some semantic to these data. The .BUI file has been generated by SimCAD, completed thanks to PREBID and used with

success by the TYPE 56 which computed the dynamic thermal behavior of the building.
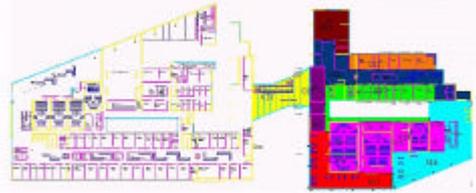


*Figure 3: the drawing of the building as displayed by SimCad*
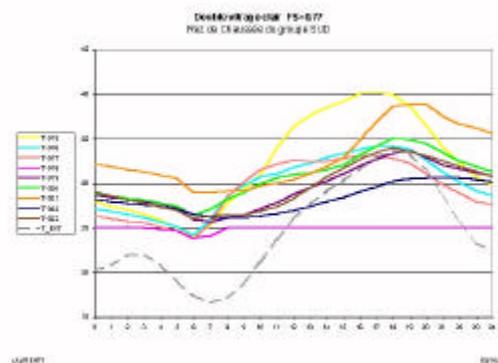


*Figure 4 : Temperatures vs time computed by TRNSYS in the various thermal zones defined with SimCAD*

The use of SimCAD has allowed to automatically re-exploit the DXF files sent by the architect. Defining the thermal zone through the SimCAD interface was easy and fast. All the same, defining the relationships between the zones and the walls and between the zones them-selves was not very time-consuming. In addition to this, SimCAD allowed to color the zone in such a way that the same colors were used to print the temperature curves thus simplifying interpretation of the results.

## CONCLUSION

Coupling CAD tools and thermal simulation codes is not an easy task mainly because the level of details required by the simulation code is very high. SimCAD is without doubt an answer to this concern. Developed with STEP technologies, SimCAD is already capable to read IFC files which should be the next generation format used by CAD tools worldwide.

As a matter of fact SimCAD makes much easier the retrieving and use of geometrical data. The time saved can be used to better design the HVAC system.

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