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Information interoperability and interdisciplinarity: the BIM approach from SEEMPubS project to DIMMER project

Parole chiave: BIM, Interoperability, Augmented Reality, Virtual Reality.

Abstract Design, implementation and management constitute the cornerstones of the building process and the current trend, albeit still at an embryonic state in Italy, is represented by the application of a problem-solving approach combining integrated analysis and research between interdisciplinary professionals able to integrate their know-how and experience.
The project SEEMPubS (*Smart Energy Efficient Middleware for Public Spaces*), which ended in August 2013, investigated the theoretical and operational possibility of using a network of sensors to monitor energy consumption and raise awareness of this issue among end-users in academic and working places. The project DIMMER (*District Information Modeling and Management for Energy Reduction*), that kicked off on October 01st, 2013, represents its evolution, as the research extends from buildings (building scale) to the neighborhood (urban scale), simultaneously expanding the areas of study.
Data and information to be processed and analyzed call, in this case, for a reconsideration of the activities to be carried out, through the use of innovative instruments and procedures to ensure correct information flow and optimal data management. For this purpose, we adopted the BIM methodology (Building Information Modeling) for digital representation and modeling of our case studies, facility management and analysis of interoperability between different software applications, investigating how the tools currently available on the market and the interdisciplinary collaboration between professionals from different areas may constitute the standard for tomorrow's communication.

INTRODUCTION

The need for specific aggregations of data and information has been increasingly pressing for a number of years. In the Web 2.0 era, the amount of data and information available has steeply increased, facilitating their access but also creating confusion, encouraged by redundancy and lack of a monitoring and verification system.
Designing, building and facility management all involve considerable amounts of data and information shared and exchanged; moreover, during the lifecycle of a building or a neighborhood, in addition to specific information on construction, we must consider also data and information derived from interactions with other areas, such as transportation, rents, utilities, security, entertainment, etc.
Computer science can help us to properly manage all these interdisciplinary actions and activities,

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by providing the professionals involved with effective and innovative tools to manage and monitor the flows of information.

The project SEEMPubS allowed experimenting practical interdisciplinary collaboration between professionals working in different areas, through the involvement of different scientific disciplines.

As described in detail in the following chapter, a number of experimental activities were carried out to examine how the professionals involved could benefit from practical collaboration. Construction was related to the energy sector in order to integrate building modeling with lighting and thermal analysis. Likewise, construction was linked to facility management and IT (developing a tablet app to support facility maintenance).

The project SEEMPubS enabled (as DIMMER will) to practically apply the above theories to a number of case studies. Through the use of software available on the market or apps specifically created by our research group, we investigated possible future developments for data and information management in several areas, such as energy consumption, facility maintenance, installations, etc. both at building and neighborhood level.

THE PROJECT SEEMPubS

Smart Energy Efficient Middleware for Public Spaces (SEEMPubS)[1] is a STREP project (*Small or medium-scale focused research project*) with a duration of 36 months (started on September 01st, 2010 and ended on August 31st, 2013), funded with 2.9 million Euros by the European Commission within the Seventh Framework Programme.[2] The project was aimed at reducing energy consumption and carbon dioxide emissions in existing buildings (including historical buildings), by monitoring physical variables (temperature, humidity, lighting, presence of people, CO_2 emissions, etc.) of the environments chosen as case studies through the use of ICT (Information and Communication Technology) and without carrying out any construction work.

Monitoring was performed by an integrated network of sensors and the “middleware”[3] software LinkSmart for the management of “embedded”[4] systems. The middleware software acted as a “translator” for the various languages used by the sensors installed to communicate with each other, manufactured by different producers, thus allowing for uniform data monitoring, collection and analysis.

A number of premises of the Polytechnic University of Turin were chosen to implement and demonstrate the project; specifically, 6 pairs of rooms were identified, with one room working as testing facility and the other one, similar in size and type, as reference room.

Contrasting pairs of rooms were needed in order to clearly show the benefits obtained through monitoring as well as to verify energy savings achieved in the long-term.

The rooms selected are located in the Castello del Valentino, the headquarters of Corso Duca degli

1 http://seempubs.polito.it/

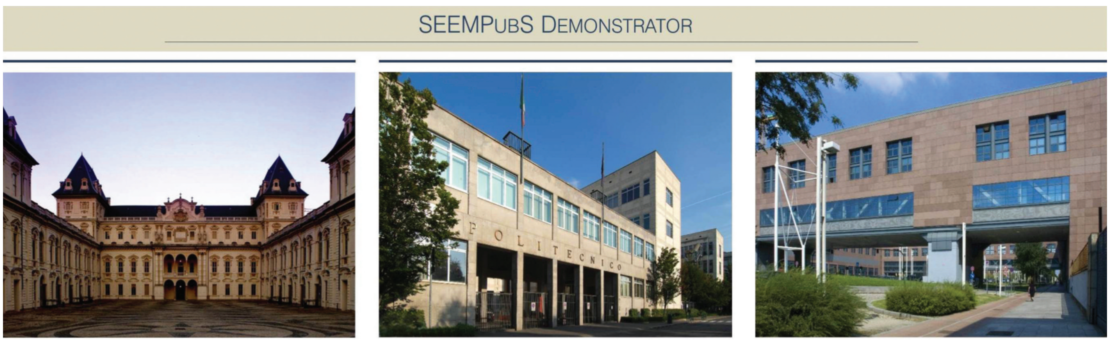
2 The EU Framework Programme is the main instrument used by the European Union to fund research in Europe during a fixed period of time (5 years). The Programme is designed to provide funds to universities, research institutions and SMEs that participate in a call and are selected (http://cordis.europa.eu/home_it.html). The Seventh Framework Programme is due to expire this year (2007-2013).

3 A *middleware* represents a set of computer programs or apps whose objective is to enable communication and management of data in distributed applications. For instance, sensors for energy monitoring communicate with each other using their own computer languages, often created or implemented by different manufacturers. Consequently, the *middleware* works as a “translator”, thus allowing the sensors to communicate with each other.

4 An *embedded* system is an electronic system for data processing provided with a microprocessor, developed to perform specific operations or activities. Home automation sensors such as thermostats or anti-intrusion system control panels are classic examples of *embedded* systems, as they are developed to manage and monitor specific operations.

Abruzzi and the Polytechnic Citadel. These premises were strategically chosen as the buildings all have different construction characteristics - related to the period they were built in - and, consequently, specific energy issues.
Different types of sensors were installed according to the characteristics of the above premises. For the Castello del Valentino, built in the first half of the seventeenth century and featuring frescoes, stucco and high-quality materials, we could not carry out any construction work to reduce energy consumption; therefore, we installed wireless sensors. In the other two premises, two modern buildings, wired[5] sensors were installed instead.

Figure 1 The premises chosen to demonstrate the project SEEMPubS

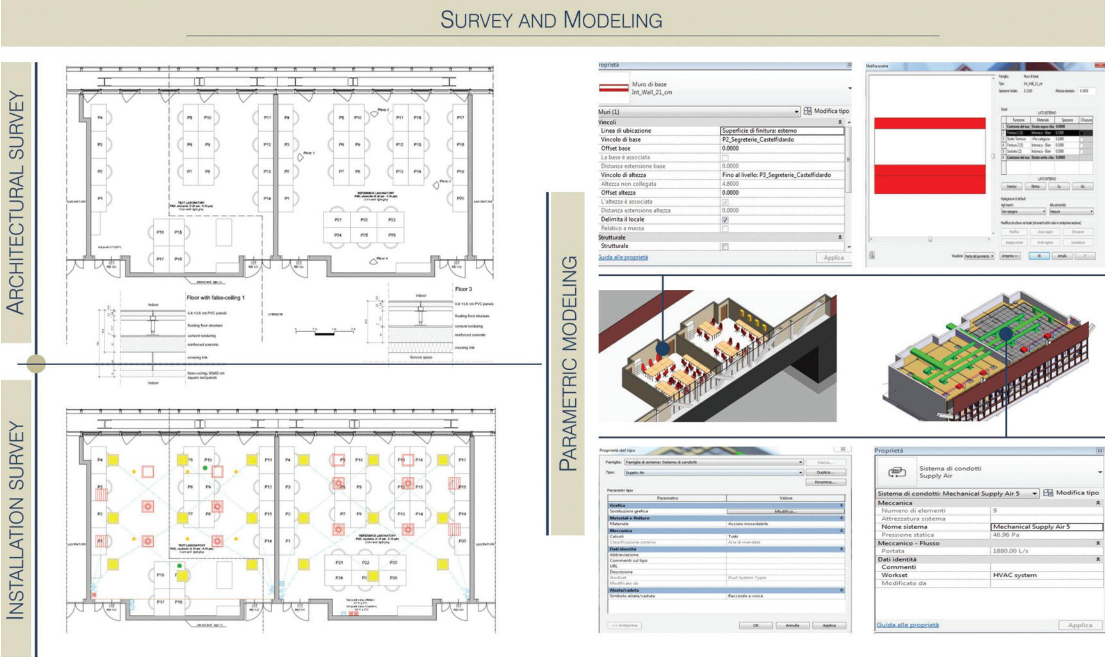


Following the selection of the physical spaces to demonstrate the project, the initial phase of the project consisted in modeling the premises with BIM parametric applications. Thus, three-dimensional models of the premises were obtained, which were then used for energy simulations and the development of an Android app for maintenance management.
The starting idea was to apply the paradigm of the BIM methodology, according to which any object or artifact only needs to be modeled once and then it can be used to support other activities through appropriate data export or import.
During the preparatory phase for modeling, we carried out an in-depth survey of the rooms, a key starting point to collect and implement information; in particular, we measured the dimensions of the rooms and checked the positioning of the installations, including any other additional equipment, such as computers. Modeling was created using the software Revit Architecture 2011 and the results obtained can be classified as a bim model instead of proper BIM modeling.
There is a substantial difference characterizing the whole methodology here. BIM (Building Information Modeling) is intended as a **parametric information model**, that is a model containing not only graphic information but also other kinds of information in its internal database, including data on thermal characteristics of materials, costs, technical specifications or others. This information can be integrated and shared by a variety of professionals (interoperability) in their respective areas of expertise. On the other hand, a bim (building information model) model simply represents a three-dimensional geometrical model devoid of any other information; a bim model, therefore, is nothing but a three-dimensional model, which differs from a classic 3D CAD model as it can be implemented with additional information and, therefore, become a BIM model.
This first three-dimensional model was needed to start energy and lighting simulations and that is

5 A *wired* system is an electronic system requiring a wire for data transmission. *Wireless* systems do not need wires instead.

why it can be classified as a bim model; as our research continued and extended into new areas, we also had the opportunity to implement three-dimensional models of the premises tested and, therefore, develop a more advanced and complex BIM model, integrated by alphanumeric information.

Figure 2 Graphic rendering of a plan (CAD) and BIM parametric modeling.
The images show the pairs of rooms named DAUIN Labs



Parametric models, therefore, provided the graphic/information support for a number of complementary research activities to the project SEEMPubS, in which we were able to test interoperability between different software apps and between databases.

The research covered the following topics:
- Use of the bim model for lighting simulations
- Use of the BIM model for facility management
- Use of the bim model for the development of an Android app

Bim for lighting simulations

Within the preliminary analysis on the possibility of improving energy efficiency, a number of lighting simulations were carried out to assess availability of natural sunlight in the environments tested in order to establish the best technology to monitor and adjust artificial lighting according to the amount of natural sunlight available. As simulations usually require the creation of 3D models for calculations purposes, our lighting experts were able to develop this model independently according to their requirements. Following the afore-mentioned interdisciplinary cooperation between professionals from different areas, we decided to integrate modeling and simulation activities, trying to optimize the latter.

Below are the procedures adopted to transfer the three-dimensional model from the design environment to the apps for the simulations.

Application

As previously mentioned, the premises chosen for our project were modeled using BIM parametric modeling (Revit Architecture 2011).

In order to perform a correct simulation, it was essential to provide the model with a high level of detail, especially for the geometry of the rooms. Such characterization was achieved through the internal logic of the parametric application, which provides for the hierarchical creation of the model by using the types of generic families available and parameterizing the elements needed from time to time. Each constitutive element of the rooms (walls, ceilings, doors and windows, etc.) was modeled according to their surface materials. This strategy proved highly effective since lighting simulations are strictly related to the surface characteristics (color, roughness, etc.) of the materials that come into direct contact with the light.

A detailed modeling type was chosen also for the environment outside the rooms tested, in order to ensure correct simulation.

Once such operations were completed, we transferred the model from the parametric application to the software used for the lighting characterization of the elements, Ecotect Analysis[6]. Three different export files formats were tested (.IFC, .gbXML and .FBX) in order to identify which one would provide the best results. The first two formats did not achieve the expected results, in particular .IFC was affected by a number of import errors of some essential elements needed for the simulation, such as the uprights of doors and windows; moreover, we observed discrepancies between the elements imported and the original model. Files exporting, and subsequent importing, via the .gbXML format also revealed a number of critical aspects, the most significant being the transformation of all solids into surfaces. Correct file exportation was achieved instead with the .FBX format. Here, the model is exported from Revit Architecture in .FBX format, and then imported into another app acting as a "bridge" and thus facilitating the data transfer; this app was identified in 3dsMax. By performing additional file exporting in .3ds format, we were finally able to import the three-dimensional model into Ecotect Analysis.

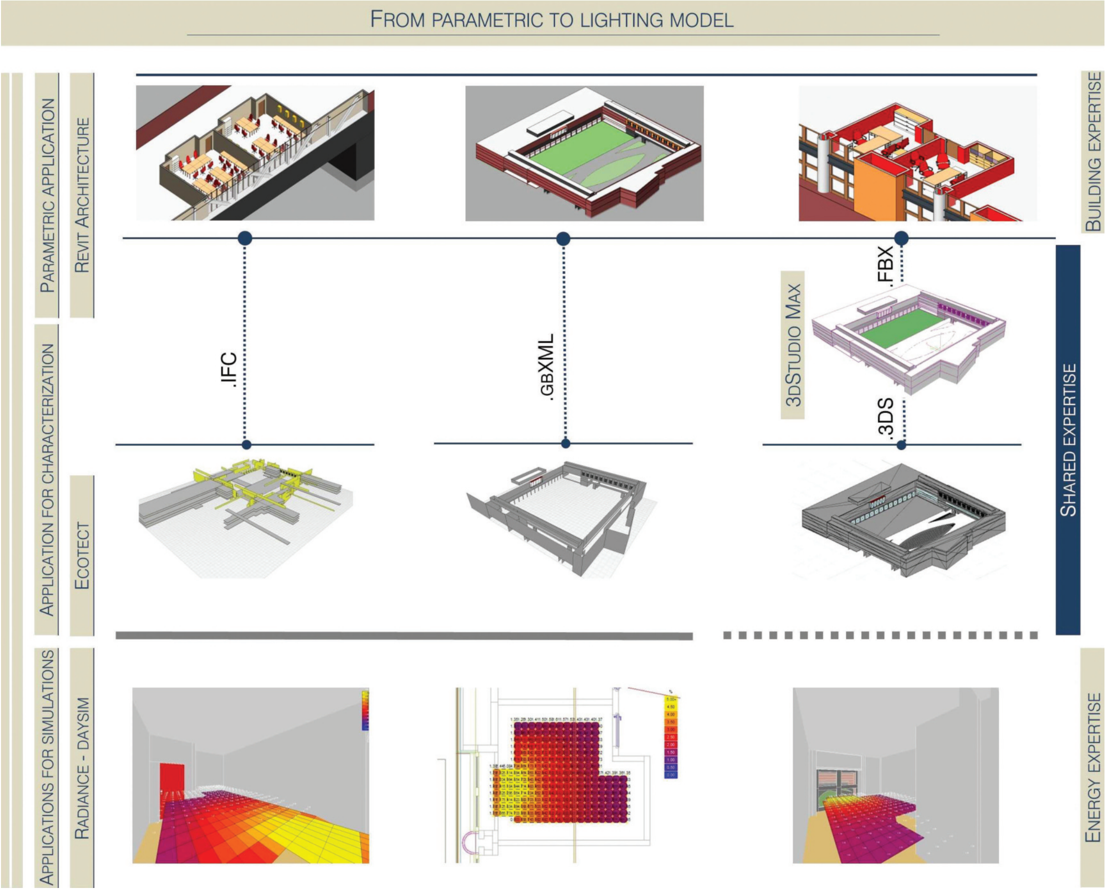
This long and complicated procedure (not entirely logic in terms of software interoperability) allowed preserving the original model in its entirety, without incurring into any data or geometry losses.

In Ecotect Analysis, the model was integrated by adding information on the lighting characteristics of the rooms, including the characterization of different surfaces, then exported once again to the apps for lighting simulations, Radiance and Daysim.

The use of the above "bridge" app was an example of effective collaboration between different engineering areas, following the afore-mentioned interdisciplinary approach; this operation highlighted, once again, the positive results that can be achieved by sharing and integrating information from different areas of *expertise*.

6 http://www.autodesk.it/adsk/servlet/pc/index?id=15078641&siteID=457036

Figure 3 Representation of the export/import procedure of the three-dimensional model from the parametric application to the apps for lighting simulation



BIM for facility management

Facility management plays a fundamental role in the construction process, due both to its duration - a percentage higher than 70% of the buildings' lifecycle - and the consistent number of activities, operations and professionals involved. In addition to this, facility management represents a key area especially in times of economic crisis, as it can help achieve significant savings in terms of cost and time.

In 2010, the Polytechnic University of Turin, started purchasing and using a CAFM (Computer Aided Facility Management) app called ArchibusFM[7]. Structurally, this software consists of an alphanumeric database containing information and data entered by authorized users, and a graphic interface, represented by CAD plans. The software integrates alphanumeric data entries and graphic interface to ensure constant facility management in real time. This application is being currently used to manage facilities as well as cleaning and maintenance services on demand.

While the above app was being used by several offices and department of the Polytechnic University of Turin, we carried out a parallel research aimed at replacing its CAD graphic interface with the BIM model.

7 http://www.archibus.com/

Our objective was to investigate how the parametric modeling apps used by the University could be implemented for facility management. The issue here revolves around the necessity of having common interpretable software for graphic representation which provides data accuracy and updating at the same time.

Application

The Polytechnic University of Turin currently uses Archibus Version 18.2, which for the first time allows for the possibility of using Revit 2009 for facility management through a specific *overlay*, that is an upgrade of the original version.
For modeling purposes and with the aim of supporting the management activities carried out by the University, we were able to achieve a satisfactory level of detail for the parameterization of the building components. Our objective, in fact, was to create a model that could support facility management while analyzing limitations and opportunities for improvement; consequentially, our priority was obtaining a model displaying correct spatial arrangement rather than one containing other kinds of information.
From an operational point of view, facility management should be carried out since the designing of a building and, consequently, a parametric model (**as-built**[8]) containing all information needed should be made available upon completion of construction. However, we decided to develop a specific model for research purposes. The overlay provided by Revit 2009 consists of an *add-on*, that is a number of additional commands compared to the standard version. The Revit overlay for Archibus, in fact, shows a number of additional buttons in the commands menu that allow for an exchange of information between the alphanumeric database and the three-dimensional model.
Once the model is implemented, another essential step is needed to ensure correct facility management; this operation consists of placing the object "room" within the rooms constituting the model. The object "room" is a specific request by Revit, as it is used to compute a number of information related to room surface, perimeter, name, type or others.
Each room physically modeled within Revit can be associated to an object "room" that will acquire and visualize the afore-mentioned information. So far, we have worked exclusively inside the Revit environment by exploiting the potential offered by this application, hence the main potential users in this case would be professionals, such as architects or civil engineers, who need to design buildings and obtain a digital representation of their relevant data. The next operations allow instead also other professionals, such as management engineers or professionals, to interact with data and information contained in the model.
Once the model is populated with the objects "room", we can use the commands provided by the overlay to connect data and information in the Revit model with the Archibus database.
It is then possible to update information on the rooms, such as surface, category and type, building location, personnel and equipment associated to them, by operating both on Revit and Archibus.
However, the procedure tested raised a number of issues, first of all the impossibility to change some parameters contained in the overlay, which resulted in an error in the count of areas; as this is the first version of the overlay and is designed only for the American market, we could not change the units of measure from square feet to square meters, and, consequently, all areas shown in the database were incorrect. The second main issue was that, although it was possible to link graphic and alphanumeric elements, we could not observe a bi-directional flow of information. In fact, while

8 An "as-built" represents the entire design updated according to the actual execution of a building. An "as-built", therefore, is the closest representation of a building to reality.

the Archibus database can be directly accessed by sending a query to the Revit graphic model, you cannot do the opposite; in fact, while navigating inside CAFM, the graphic model cannot be displayed. Although the test did not achieve the expected results, we investigated the possibility offered by the interaction of the two apps, which target professionals working in different areas, yet feature intrinsically connected and parallel procedures. The path we tested is potentially feasible, provided that the afore-mentioned issues are solved.

Seeking a remedy to the above problems, we tried an alternative way, which does not involve the use of Archibus; instead, we only used Revit in *stand alone* mode.

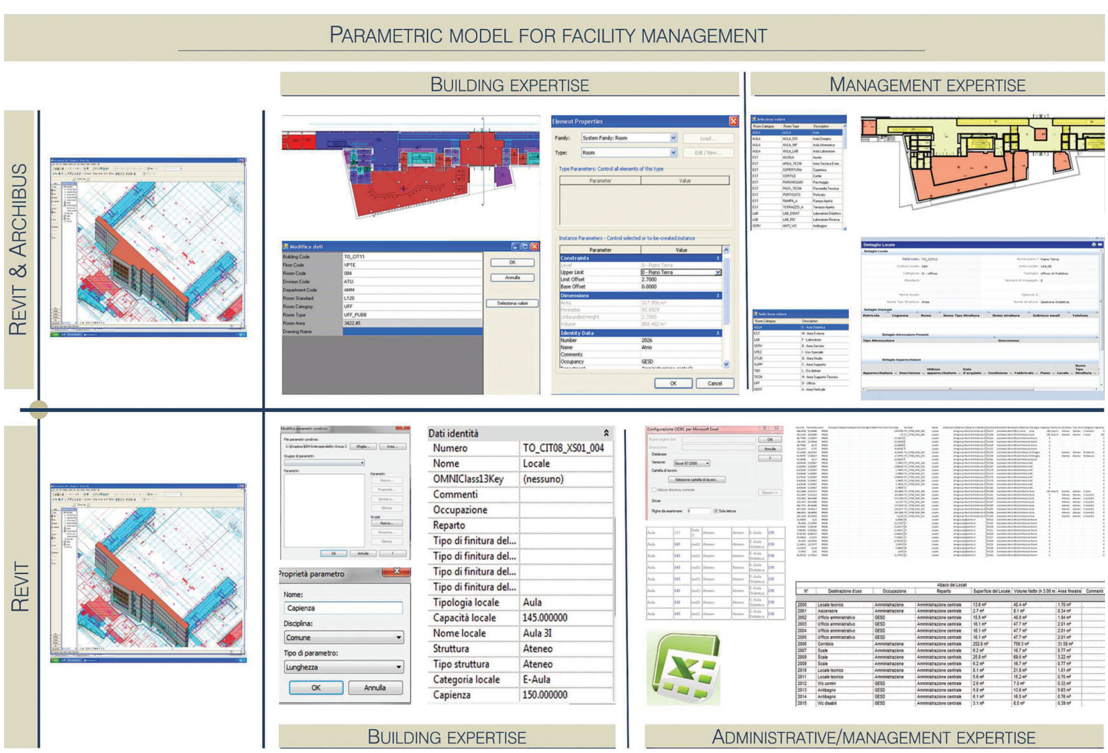
This strategy relied on a specific command offered by Revit and called “shared parameter”. A shared parameter is a specific parameter which can be totally customized by users who create it. It is mainly used to elaborate all those characteristics not offered by the standard application.

With regard to facility management, we then entered the shared parameters for the characteristics associated to the rooms, such as their type or the buildings they are located into. As information needs to be continuously updated, which is key for correct facility management, this task should be carried out by different professionals in their areas of *expertise*.

For this purpose, we decided to provide all users involved in the updating process with an easy-to-use and common format; through Revit Dblink, we were able to export the whole internal database of the parametric model to an Excel file. By interacting with this file, each user can thus enter any updates and then re-import the Excel file into the model, so that the latter is always updated.

Compared to the previous path, here we could observe perfect bi-directional flows of information while maintaining a strong control over updates and users. Both procedures involve the collaboration between professionals operating in different areas and are aimed at facilitating data exchange and integration.

Figure 4 Representation of the procedures tested on integration between BIM and Facility Management



Bim for the development of an Android app

All buildings, whether modern or historical, are characterized by a number of complex and different issues related to the time of their construction and the technology adopted; moreover, all buildings must undergo maintenance interventions that further highlight their criticalities.

Within the project SEEMPubS, we developed an Android app for building maintenance based on virtual and augmented reality.

While the technical description of the application is not within the scope of this study, we will illustrate the steps and operations we carried out to use the 3D model in the app for tablets.

Application

The first task was to create the three-dimensional and parametric model of the building with BIM modeling tools; after the architectural and structural parts, we modeled all installations by entering information on mechanical parts, electricity system and HVAC (Heating, Ventilation and Air Conditioning), so that the model could be used not just for analysis and simulations but also, and mostly, to be displayed on the tablet. The model was integrated also by introducing models of the sensors installed under the project or those already installed. The sensors are used for monitoring temperature, humidity, CO_2 concentration, human presence, etc. These operations were carried out through Autodesk Revit and in accordance with the "as-built" (if applicable) and our investigations/findings.

Once the parametric modeling was done, the model was exported to 3dsMax 2013, using both .FBX[9] (FilmBoX) and .DWG[10] (DraWinG) file exchange formats, in order to export as much information as possible from the original model. The .FBX format allows exporting the model geometry, while .DWG helps solve a number of issues related to the complexity of the geometries modeled; in fact, this format allows users to choose what kind of solids to export; moreover, thanks to the use of ACIS[11] geometries, we were able to considerably reduce the numbers of polygons constituting the surfaces of the model.

Using the .DWG format, we exported then the geometries of the building and the installations, while the models of the sensors were exported with .FBX.

The different files exported with Revit 2013 were then assembled in 3dsMax 2013 to create the original model. Also imports followed two different methods: firstly, we linked the 3dsMax environment to the files through the command Manage Links; the second instead consisted in importing directly from the original file. Using the first procedure, you can choose the recognition method of the elements imported (type of material, type of element, identifier, etc.); with the second procedure, file 'weights' can be reduced.

The next step was to export the model from 3dsMax to two different formats, .OBJ[12] (OBJect), for geometries, and .MLT for materials. The last operation consisted in importing the model and its information to the Bonzai Engine[13], which is used to export the model to .JMF format[14] (Java MultiFile). The latter is the format used by the Android app for display and browsing.

9 http://www.autodesk.com/products/fbx/overview

10 http://usa.autodesk.com/adsk/servlet/pc/index?id=6703438&siteID=123112

11 http://en.wikipedia.org/wiki/ACIS

12 http://people.sc.fsu.edu/~jburkardt/data/obj/obj.html

13 http://bonzaiengine.com/index.php

14 http://dotwhat.net/jmf/7232

Finally, in order to make these models in .JMF format available for browsing on the tablet, they were uploaded, through a BIM Manager application specifically created by the research group, to the online storage BIM Server. Online storage ensures usability and accessibility to the model at any time and from any tablet. Model navigability is provided by virtual and augmented reality.

Virtual reality allows accessing the model at any time, even when users are not in proximity of the room to query, since the application directs to the virtual model provided by the storage and then, browsing through it, users can send queries.

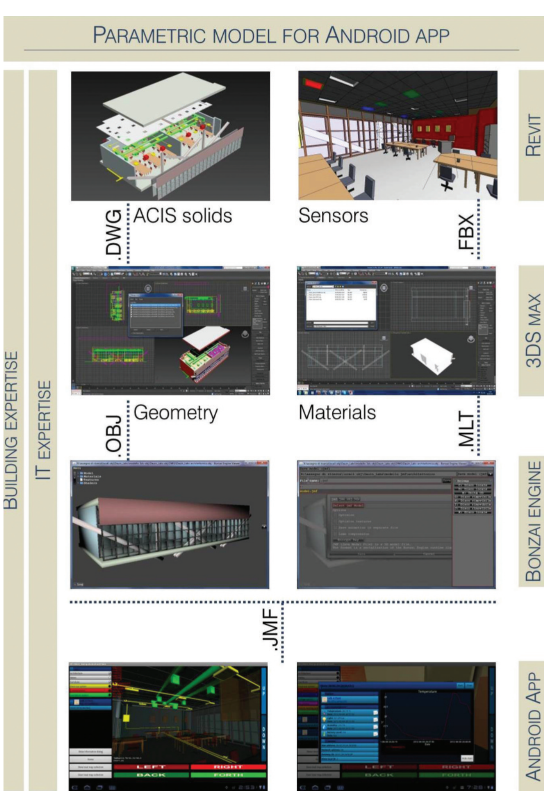
To query the model, you just click on an item, for instance a sensor, and visualize the information recorded by the device, then processed by the middleware and a dedicated Web Portal in real time. For example, you can click on a sensor monitoring temperature and visualize the trend in the short and long term.

The other feature developed in the application was the transparency of the building elements modeled, so that all of them can be read correctly (architectural elements, furnishings, installations, etc.). This function is extremely useful whenever users need to visualize installations covered by internal partitions.

Augmented reality, instead, is helpful any time users are in the proximity of the room they intend to query. The procedure here provides for the scansion of a specific QR code which refers to the online storage and thus allows visualizing information on the environment at issue.

Information and data visualized by the Android app come from a variety of sources and are taken from specific databases created in real time. In particular, information on monitoring performed by the sensors is taken from dedicated databases, while reference data on the premises are taken from the Archibus database used by the University for facility management.

Figure 5 Representation of exporting procedures of the parametric model for the Android app



THE PROJECT DIMMER

The project DIMMER (District Information Modeling and Management for Energy Reduction) represents the natural evolution of the project SEEMPubS, its objective being to extend the ideas and analysis tested on buildings to a neighborhood level.

It involves the participation of public authorities, research bodies and partners from Italy, Germany, England and Sweden.

The project moves from the basic concept that today ICT technology is essential to improve energy efficiency of any urban community. Technology for energy monitoring has been developed in conjunction with specific campaigns to raise awareness of energy-related issues among end-users, as we have seen in the project SEEMPubS. And yet, we can observe that such technology innovations are still scarcely used both by households (housing unit level) and plant operators (neighborhood/city level).

ICT technology can be extremely useful by providing and facilitating access to information on buildings and their environmental and energy characteristics in real time. Likewise, on a wider urban scale, it can provide access to information on heating/air-con systems, power supply network, etc. Opportunities offered by ICT are exemplified by the middleware software, an interface able to detect different languages used by sensors to communicate with each other, usually produced by different manufacturers, and translate them into a common language thanks to a centralized decision-making system.

Our project envisages a combination of ICT technology and Building Information Modeling as the ideal platform to create a digital organization leading to the development of the District Information Modeling (DIM).

The basic concept behind DIM, introduced by this project for the first time, is to implement the BIM philosophy and extend it to a neighborhood level. This approach will allow examining several issues shared by any neighborhood, which go beyond the typical engineering and scientific elements of buildings, as they are influenced by social aspects involving a plurality of users. The project's ultimate goal is to create a web-oriented interface able to collect data and information on the single buildings and the neighborhood as a whole, including data and information on their energy requirements.

This project offers multiple advantages to professionals operating in different areas; for instance, energy carrier suppliers could use the digital platform to identify potential new customers, while facility managers could access aggregated information to obtain an overview on specific issues.

The most advanced use of the platform is on public buildings, where users can, for instance, provide feedback on the services offered or the comfort of the premises.

The tool developed to access the platform is essentially a web portal. Nevertheless, to facilitate interacting with it, users are encouraged to access it also through augmented reality, such as QR Codes. QR Codes are placed in the proximity of the buildings whose data and information are to be disseminated, so that users can visualize them on their tablets or smartphones.

From an operational point of view, the project provides for the creation of a graphic model of the neighborhood through BIM parametric applications, whose database will contain data and information on architecture, structure and installations of the buildings, both public and private buildings, that will be chosen for testing.

The parametric model will constitute the starting point for developing the information platform, which will collect also other types of information on the neighborhood, such as utility networks, flows of people or rents.

The middleware software and the network of sensors installed will perform data monitoring, collection, analysis, elaboration and dissemination.

The final objective is to create a parametric digital model to manage all information on a given neighborhood, including visualization of energy consumption trends and feedback from end-users, who could benefit from information on energy-saving opportunities.

Figure 6 Diagram of the *concept* behind the project DIMMER

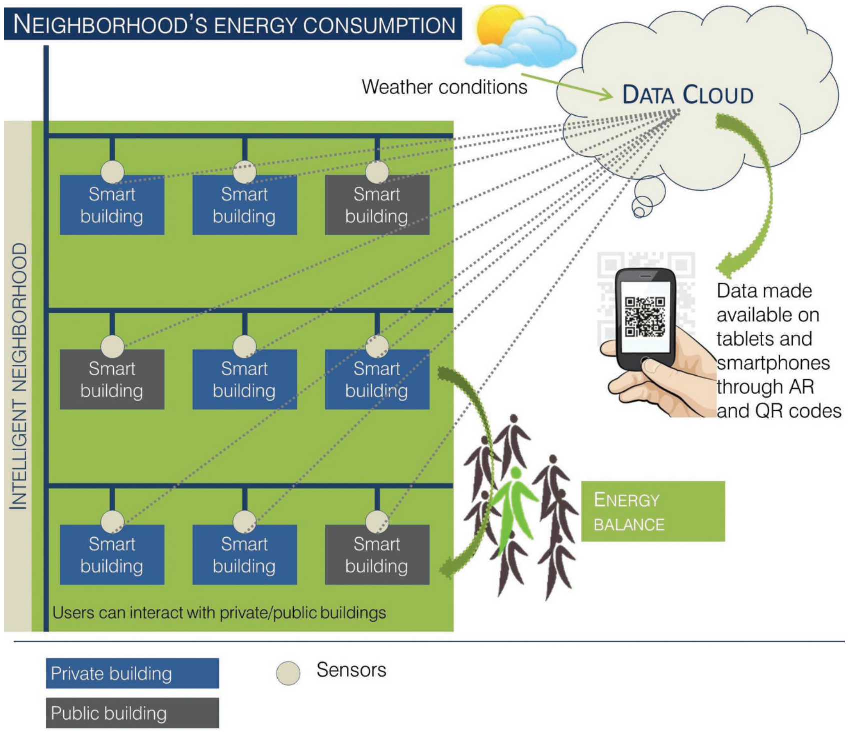
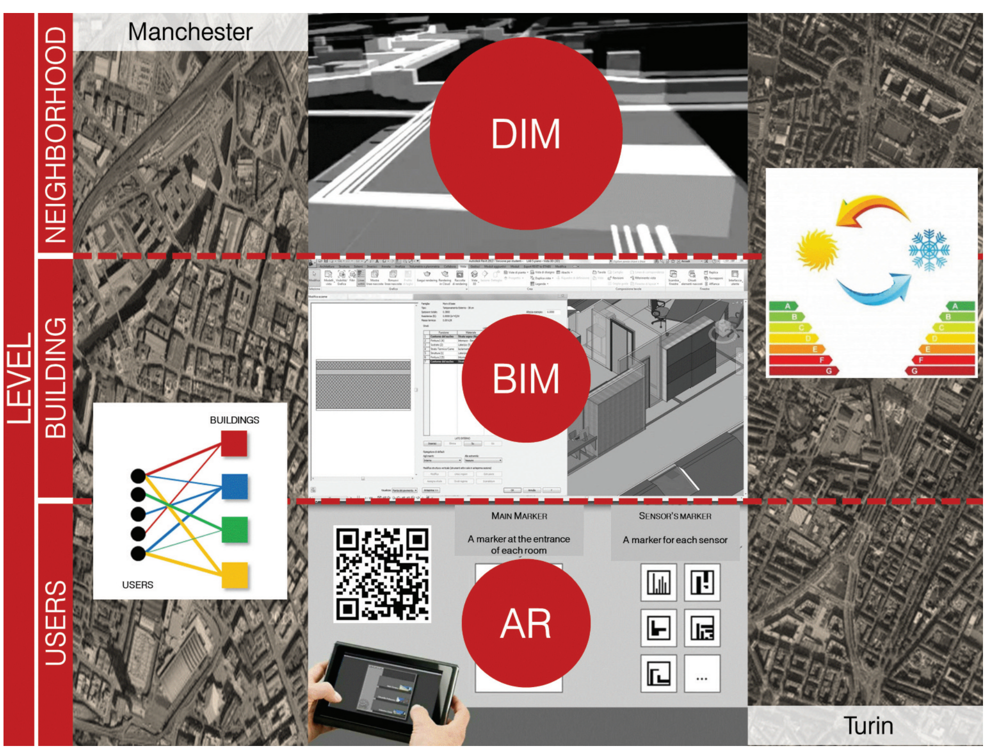


Figure 7 Diagram of interaction levels involved in the project DIMMER



CONCLUSIONS

Both project SEEMPubS and its natural extension DIMMER intend to raise awareness of energy-related issues, by involving users through a differentiated use of ICT technology. As such technology is now deemed essential in all areas, these projects aim at showing the benefits of exploiting its potential to reduce energy consumption. Both projects are based on significant use of the BIM methodology, not just to digitally represent existing buildings but also for simulations and facility management.

BIM tools, in fact, offer a great support to integrate information and optimize the management process. Yet, there is still a number of issues to be solved, such as those mentioned in the previous paragraphs. In particular, the analysis of the formats used by different apps to exchange information is key to define common, interpretable and safe processes.[15]

A full and effective collaboration between professionals from different areas must be supported by perfectly functioning tools, technology and formats to exchange data and information, in order to avoid slowing down and jeopardizing analysis and simulation activities. One of the main issues here, in fact, is related to the transfer of information between different areas of expertise. Our case studies involved a considerable number of professionals and skills; the availability of a single information model undoubtedly offers advantages which were unthinkable until a few years ago. Critical aspects emerged though when transferring the graphic model to the different apps. Despite the use of different formats, such as IFC or gbXML, the expected results were only achieved through alternative methods, with a consequent waste of time and energy. Use of common data exchange formats (IFC and gbXML) is not straightforward and requires advanced IT skills to export a graphic model correctly. As we observed when transferring the model from design to lighting simulation environment, the optimal path identified cannot be classified as standard, representing instead a specific procedure to obtain a model containing all data and information entered in the designing phase. In short, the use of common data exchange formats showed a number of functional impairments, instead of being easy to use and immediately applicable.

Despite the above criticalities, our project successfully demonstrated that different skills and interdisciplinary cooperation can help achieve correct, updated and functional data exchange. This is highlighted also by the results of the project SEEMPubS, which should be consulted for more details.[16] In particular, the use of a single BIM model, specifically created for our case studies, was effective to carry out lighting simulations, as it allowed installing the network of sensors in the most appropriate way. At the same time, the BIM model provided the graphic/information support, along with the facility management application, needed to develop the afore-mentioned tablet app.

The analysis conducted so far represents the starting point for the project DIMMER, (due to start October 2013), where our study will be extended from buildings to a neighborhood level.

15 In the book *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors*, published in 2008, Eastman offers a series of tables showing a number of data exchange formats between different apps. However, the formats proposed did not always work correctly on the totality of data exchanged. This is due to many reasons, mostly the fact that the complexity of the model and the app updates, now on an annual-basis, often lead to the necessity of testing data exchanged, including, as in our case, new formats.

16 http://seempubs.polito.it/

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