A new computational model: G.E.A.R. Graphical Expert Analytical Relations

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Abstract

In recent years, there has been a gradual growth in the adoption of the new EU directives related to different topics in the field of construction. Consequently, professionals are forced to take care of different aspects in projects, which are related to limit performance requirements that the new buildings must ensure from the points of view of energy, acoustics, lighting and more in general of environmental and economic impacts. The present work deals with a new computational model (GEAR) dedicated to the multi-task simulation of buildings. GEAR is integrated with ARCHLine.XP (3D architectural cad) so that the several configurations encountered are more easily implemented.

1. Introduction

The European board has recently issued the EU directive "roadmap for moving to a competitive low carbon economy in 2050"[15,16] which lays down recommendations to achieve the reduction of greenhouse gas emissions under 80 per cent of the 1990 level by such a date. The directive gives a very important role to the efficiency enhancement in the building sector. Both new and upgraded buildings will have to achieve a higher energy performance but this has to be considered as just one of the design items for buildings even though energy and energy efficiency play an increasingly central role in the building industry. In this regard, the EN 15251 standard provides information for room design and for energy assessment of buildings, taking into account other performance requirements that the new and upgraded buildings have to fulfil, for instance:

- interior air quality;
- thermal environment;
- lighting;
- acoustics.

Following on from that, buildings will need to state their performance from several different points of view, in order to be put on the market [2,3,4,5,6,7). Procedures which enable us to rate together the different performance aspects are useful to gain an overall index.

Procedures for the indoor quality classification have been proposed taking into account different parameters i.e. comfort aspects [1]. Here the G.E.A.R. (Graphical Expert Analytical Relations) software is presented and discussed. It aims to evaluate the different building outputs by a unique procedure, taking advantage of interfacing with the Architectural 3D CAD modeller ARCHLine.XP. Details concerning the components of the model and its operation are provided.

2. Calculation method and software

The present calculation method is capable of managing the different physical aspects that the design of buildings involves at the same time. One of the basic requirements that the method fulfils, also as solicited by Cadline Software Ltd, consists in carrying out the calculations included in the procedures EN and ISO to which laws in force refer directly or make reference [8,9,10,11,12,13]. Another honoured requirement is the capacity of

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interfacing and inter-operating with the three-dimensional models generated by the 3D Architectural CAD “ARCHLine.XP” by Cadline Ltd.

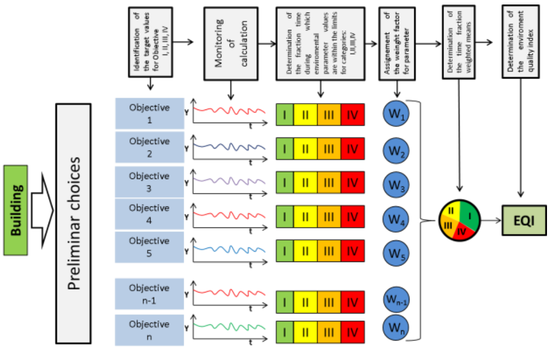

Fig. 1-Example of classification according to different goals [1]

The computational model has been developed within the environment Visual Studio by Microsoft, using C# and C++ as programming languages. Here below the main components of the GEAR model are shown (figure 2) and the user interface (figure 3) is sketched to remark its significance.

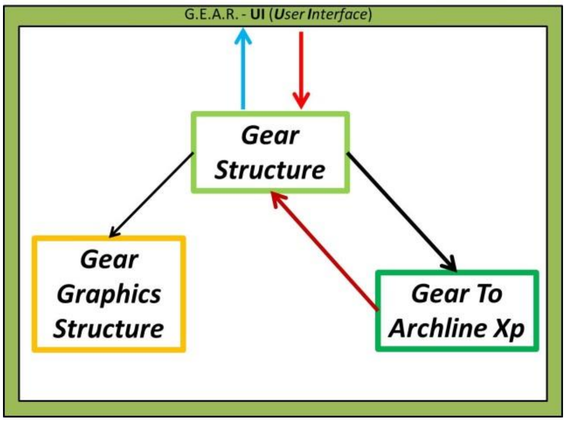

Fig. 2 – Main components of the computational model

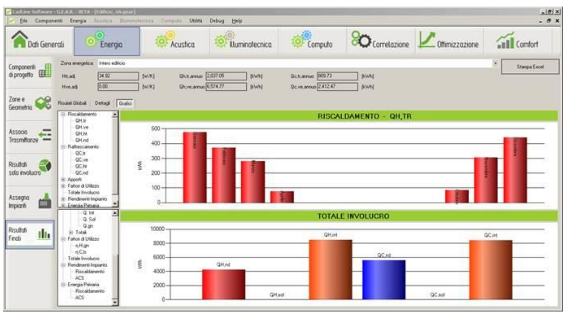

Fig. 3 – Screen results and user interface for G.E.A.R.

In writing the code, the different menu items have been split and several projects have been developed; their features have been linked by generating from each of them their own “dll library”. This option proved to be essential in the testing stage, in correcting the detected errors and in the algorithm optimization since each time we operated on a specific section of the code (component).

3. Structure and main components

The main components that form the model can be listed and analysed as follow:

Gear Structure

Gear to ARCHLine.XP

Gear Graphics Structure

3.1 Gear Structure

The most demanding task concerned the component that organizes all the data that the computational model has to manage. GEAR Structure includes such a management system: the various functions developed and implemented are expounded in the following.

3.1.1 ClimateData

The “ClimateData” name space (such a term of information technology denotes “a group of classes”) includes all the classes and advanced methods to manage climatic data. It has been conceived with four classes (in figure 4 the UML diagram for these classes) which are named as follows:

ClimateData

The aim of this main class is to process the climatic data according to the selected calculation methodology. It enables the processing of e.g. the external monthly average temperature according to the location coordinates or the daily hourly average temperature profile calculated on a monthly basis. With this class, one can access the data loaded for each province and for the municipalities of each province; besides this, it enables the user to manage the data concerning the indoor conditions and to manage the constants database.

Constant (shared at design stage)

Inside this class, all constants used in calculations are recalled. The same constants can be modified by the operator and made serial within the data flow or within the project backup.

InternalClimate

The class for the internal climate includes right inside the variables and the methods to obtain all the parameters the calculation needs. In detail, this class can be used to define the fixed (or calculated) climate for an entire zone or for a single room. All quantities which define the thermal, hygrometric and acoustic features of the inner environment as well as the daytime lighting, are included in such a class.

Province (provinces)

The object province checks on the list of municipalities of a specified province, but also all the data available for the province's capital (for instance the climatic data included in UNI 10349 norm).

Common

This part of the structure manages all data concerning the specific municipality. It includes the various methods that enable us to modify default settings such as changing of temperature as a function of a.s.l. elevation; such a function can be started also by interacting with external applications, i.e. Google Earth, from which coordinates, orientation, etc… can be drawn.

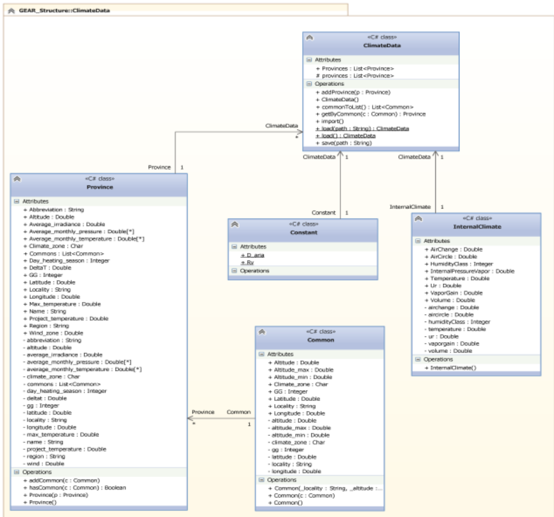

Fig. 4 – UML diagram for name space Climate Data

3.1.2 Gestore_Materiali (material manager)

The name space "Gestione Materiali" is devoted to single materials and architectural systems management. It stands for the heart of the computational model, in some way, as all the name spaces and classes refer to it in order to carry out their various functions This name has been conceived and developed taking into account the different physical and architectural properties that materials and architectures can possess. Such a manager is made up of five main classes and different codifications (formulas, reference month, type of material/layer). Classes have been arranged as follows:

Material

Such a class is about the different physical properties of materials. Variables such as vapor permeability, thermal conductivity and dynamic stiffness are defined within it. Moreover different methods are implemented which allow to set or give back values as heat transfer coefficients, for instance for a homogeneous insulating board, mass for a frontal unit area and thermal diffusivity. All these data are uploaded in order to manage the various features of materials or architectural systems.

Stratigraphy

The component stratigraphy can manage many compound materials. Namely, its purpose consists in managing the assembly of the different materials used to define the various building components both for interior partitioning and the exterior envelope. Various methods are implemented inside it, which allow the class to give back the different performance indices for the building component; if experimental values from laboratory tests are available, their input and setting is possible. For instance the following are given back or set:

- Thermal transmittance;
- Sound reduction index (curves for the frequency ranges 50-5KHz/ 100-3150Hz/ 100-5KHz);
- Permeance;
- thermal conductance;
- Reference sound reduction index
- Frontal mass
- Thermal capacity;
- Latent heat
- Cost;
- Areal heat capacities
- Periodic thermal transmittance

- Thermal admittances
- Periodic thermal conductances

Summarizing, the present component allows the user to set, calculate and manage all the physical/economic parameters that characterize the various building components.

Glaser

The class Glaser deals with the evaluation of vapor pressure trends inside construction elements. Computational procedures for vapor migration are mainly based on class EN 13788 which implements the norm with the same name.

Category stratigraphy

It manages a list of stratigraphic items that can be entered by different selection criteria. This class is very important for interactive research as it allows us to investigate all components included in the file archive and pick out just those which comply with the set up selection criteria.

Category material

It is similar to the previous class and manages the lists of specific materials (or architectural systems that can be assumed as "layers", both homogeneous and not homogeneous). This class can also be accessed by interactive research procedures in order to select the most suitable materials for a given background, among those available.

Below can be seen the diagram of the name space called "Gestione Materiali". The main links among the different components are drawn as well as associations, dependencies, aggregations among classes.

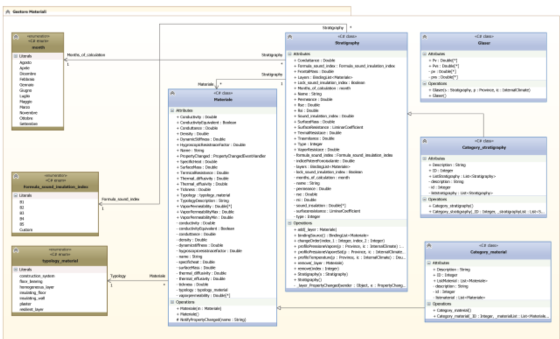

Fig. 5 – UML diagram for Gestore Materiali name space

3.1.3 Geometry

The framework of the name space called "Geometry" is shown in the following figure 6. In this section the adopted model deals with the management of "geometries"(narrowly and broadly speaking); indeed it includes the different classes for the management of zones (for energy, acoustics and lighting applications) which in turn are formed by lists of Roombooks (rooms).

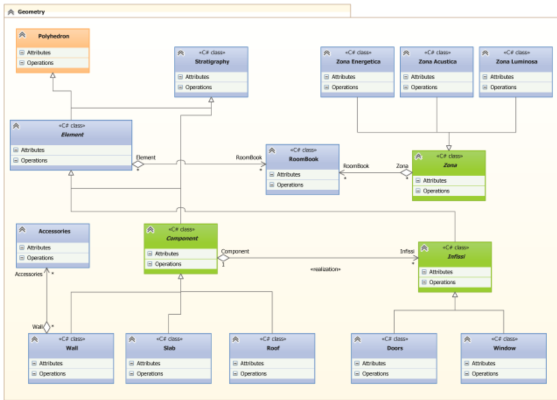

Fig. 6 – UML diagram for name space Geometry

As shown in the above UML diagram where the abstract classes are shown in green, the following main classes have been established.

Zona (Zone)

The abstract class "Zona" is needed to have a common basis for the three zone typologies that the model can manage. It recalls the properties that are included in the classes "Zona Luminosa", "Zona acustica" e "Zona Energetica" (for lighting, acoustics, energy calculations). It is able to manage all the typical setting parameters, such as winter temperature of the internal zone, intended use for acoustic purposes or design day light factors, features of the plants on duty.

Component

This other abstract class manages all the methods and the basic variables of the different building components (walls, floors, roofs, windows and door fixtures). The calculation procedure included in the EN-ISO-Calcoli class is recalled inside such a class.

Roombook

This represents one of the most relevant classes of the model, and it is the class where the data about the single rooms that form the different zones are included, developed and given back. This class can manage several other lists of objects, such as lists of elements. It can belong to different zones like the acoustic and the energetic zones. Moreover, the class includes a series of geometric data as areas, volumes, orientations and exposures of the different surfaces that define the room.

3.1.4 Space System

The name space system, for which the UML diagram is depicted in figure 7, includes classes, methods and databases to assess the yields of plants both from the energetic and from the acoustic points of view. Such a name space includes three main classes which in turn manage subclasses of plant subsets such as heat generation, distribution etc. In the following, the framework of the main classes which form the "System" name space can be seen.

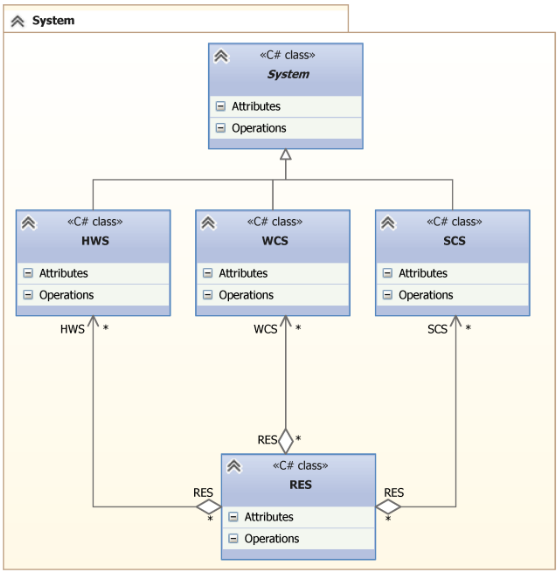

Fig. 7 – UML diagram UML for System name space

The main classes of the name space system implement the calculation methods for winter and summer air conditioning, production of household hot water etc. including plants exploiting renewable sources, following the main rules in force for building sector.

3.2 Gear To ARCHLine.XP

The dll library component Gear To ArchlineXp is the section of the model devoted to interfacing with the three-dimensional CAD Archline XP; it is one of the most innovative parts of the computational tool expounded here and deals with the geometry management. Interaction with CAD takes place through a dll library called ADE.dll. It has been assumed as a focus within the computational model in order to be used properly.

Hereinafter three excerpts of the code, written in the programming language C# that deal with: referencing the dll library ADE, transferring parameters to a dll library and generating the needed parameters to a given procedure (in the present case the conception of a stratigraphy)

1. Uploading of the dll library to get in touch with ArchlineXP
2. Feeding in of parameters to ArchlineXP
3. Generating the parameters to define stratigraphy

The example of sequence of instructions here shown illustrates how the transition to the class stratigraphy (str) is realized and how this is visited and then drawn in the ArchlineXP environment.

By means of the three strings of instructions shown above, a bidirectional dialog with CAD and a management of all geometrical properties and of the zoning for them is possible.

3.3 Dynamic partialisation of surfaces

One of the most innovative features of the model which is managed by the component *GEAR to ArchlineXP*, it is named "dynamic partialization of geometries"; such a function enables the user to partialize in an interactive way the geometric data for the building elements according to the zoning of reference.

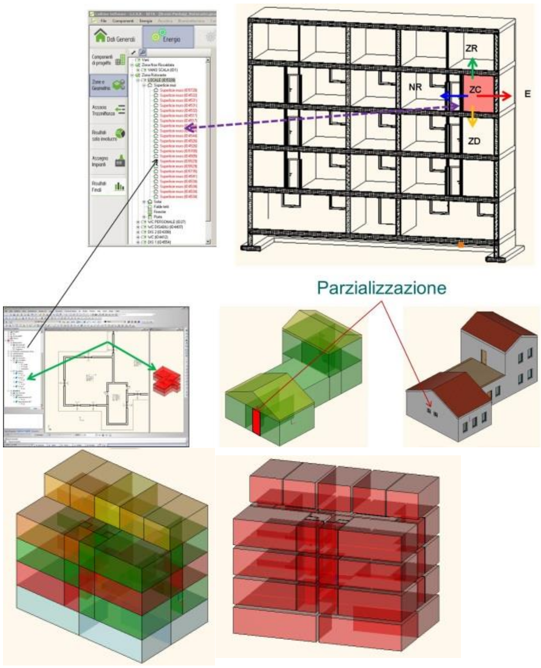

Fig. 8 - Example of partialization of surfaces

3.4 Gear Graphics Structure

The component Graphics Structure is committed to drawing in the guise of diagrams or sections (for instance the contour of the temperature trend inside a wall) all the results produced by the model. It is fully integrated and allows the user to implement several adjustments about results displaying. Here a figure (figure 9) with achievable results is shown.

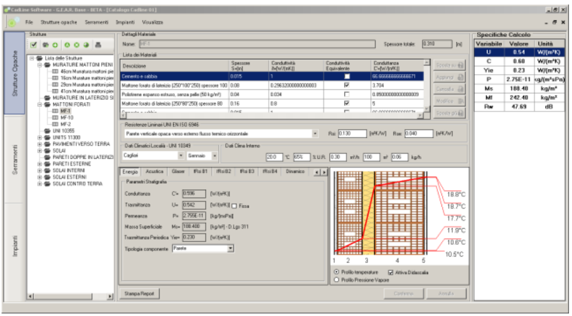

Fig. 9 – Screen displaying the calculation results

4. Application: example of zoning

The computational model constitutes a unified procedure for building design which deals with different sets of problems together This result is obtained by logging on in a bidirectional way to the architectural cad Archline XP which forms the geometrical/graphical basis to enable the interactive operations of the model.

Among the features of the model the most innovative is called “dynamic partialization of surfaces”; it enables the user to divide the geometrical data of the building elements into parts in an interactive way as a function of the considered zoning.

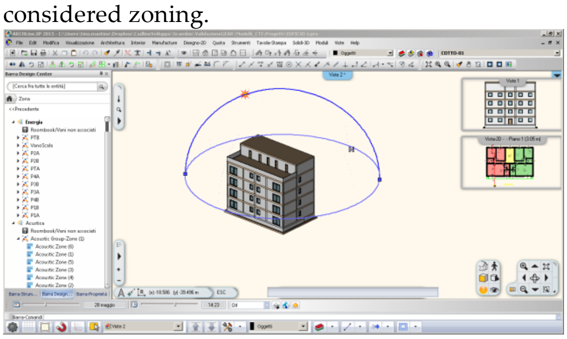

Fig. 10 – Model example

Hereinafter an application example, concerning the use of the model to implement the energy and acoustic zoning and the input of the physical properties of building components, is referred to. The starting point is modeling the considered building by using the cad Archline Xp v.2015 (figure 10)

Then the subdivision into zones of the different rooms of the model is carried out in a graphical way (or after on GEAR tool) as a function of the physical problem examined (in the present example acoustics and energy are the matters).

After accomplishing the geometrical development with cad, the computational model GEAR is started including the geometrical modeling within it. In the following figures two screen shots concerning the energy and acoustic zoning are shown (figure 11 and figure 12)

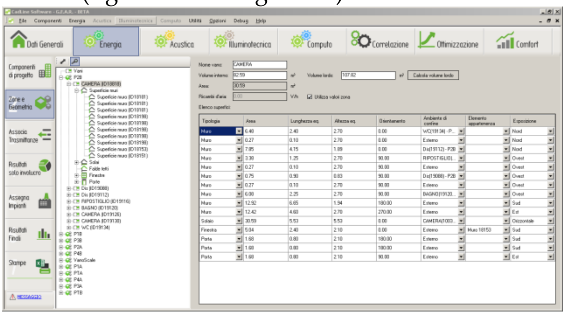

Fig. 11 – Energy zones

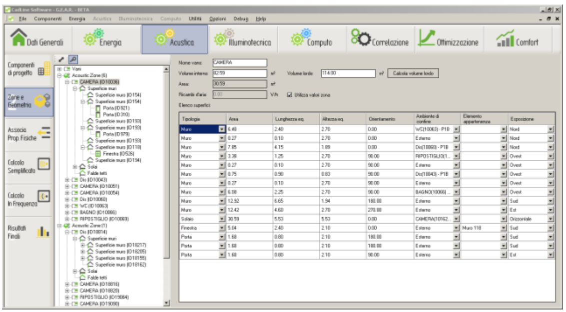

Fig. 12 – Acoustic zones

It is worthwhile noting that the above two zonings have been generated in the meantime by the same model keeping in such a way the uniqueness of rooms and constructive elements but analyzing them from different points of view.

For instance in the energy zoning, windows are grouped within the room while in the acoustic zoning windows belong to the wall where they are included. It is necessary to input all the physical properties into the correspondent elements in order to carry out the calculation for the present case. Such properties concern the set of problems to be analyzed (GEAR takes into account just the properties defined for a single element; for instance if only the energy properties and not the acoustic one, are defined for a wall, GEAR will run just the energy calculations, pointing out the lacking acoustic data for some elements). Such an event can occur indiscriminately in the energy or in the acoustic sections as the constructive elements are unambiguous; Fig. 13 shows this, when the selected element receives in input its properties it is highlighted

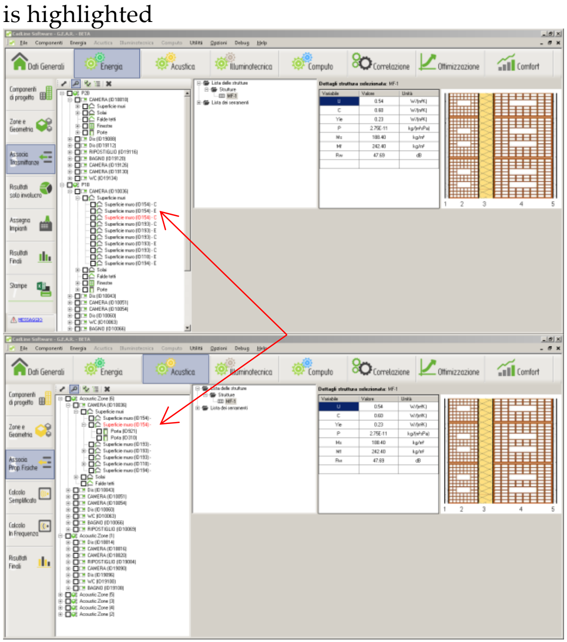

Fig. 13 – Assigning physical properties to the same element

When the input of the physical properties to the elements is carried out, further parameters that are specific of that kind of analysis can be defined (for instance thermal bridges for the energy section and connections between elements for the acoustic section). Finally, it will be possible to display the calculated predictions for the entire building or for the single room.

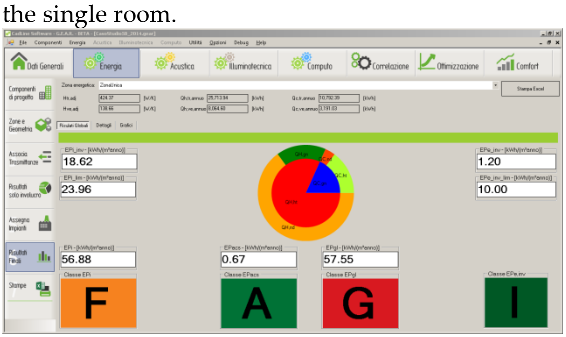

Fig. 14 – General results example of energy calculation

5. Conclusions

The unified handling of a set of physical problems can be seen as an innovative aspect of the developed model presented here that integrates effectively with the three dimensional architectural CAD. The model does not need any ad hoc three dimensional geometric modelling, but can make use of the same model developed for the architectural project. Furthermore, a cutting edge function is represented by the option of dynamic partilization of surfaces. Since calculations are based on a 3D model the dynamic partialization of surfaces enables the user to carry out a much larger number of simulations in the design stage to find out the best configuration for the studied case.

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