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SOFTWARE FOR THE HEAT FLOW EVALUATION OF THE NEARLY-ZERO HOUSES

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Abstract

The windows in a building are the weakest part for energy saving and reduced consumption. In particular, the choice of window frames and glazing systems directly influences the amount of heat loss through a houses envelope. The paper will show the results of a work developed by PADesign srl company (Accademic Spin off of the Università degli Studi di Palermo). This is a software tool that allows a rapid comparison about the windows thermal performances, by calculating the global thermal transmittance and by showing the trend of the heat flow. The tool has a simple graphical interface that allows the users to select the climate data, the window typologies, the geometric features and the materials of window frames and glazing system. The tool calculates the global thermal transmittance and checks the compatibility with the limits set by Italian law. The possibility of immediately view the heat flow through an envelope of the selected combination allows you to identify the possible thermal bridges. It also allows to try out other combinations of the envelope stratigraphy, in order to optimize the choice of components providing the most suitable thermal performance.

The tool can be implemented for all typologies of frames and glazing systems. Moreover, the software tools for evaluating energy efficiency and sustainability in buildings are very important to meet the restrictive requirements of thermal transmittance, provided by national and international regulations, and according to the Europa 2020 goals. It was developed in Java language to ensure portability across platforms. It uses a software library split that implements a self-contained, server less transactional SQL database engine. To generate outputs, the tool uses data and results provided by "LBNL WINDOW" and "LBNL THERM" software, for which we hold the commercial license. The software is aimed at a wide audience cause it does not require specific technical skills.

Keywords

Energy-efficiency, sustainability, U-value, heat flow, energy savings, envelope.

Introduction

To achieve energy efficient buildings for a low-carbon energy system, is essential that the structures that mark its volume are properly insulated. The shell is the most sensitive part of the building in order to calculate the heat load and can be thought of as a dynamic system that, separates and connects the interior from the exterior. The efficiency of the building envelope is given by the ability to react flexibly to the variability of environmental conditions and the choice of its components - frames and coating systems - affects the energy performance of the construction and the internal environmental comfort.
In order to reduce heat loss and increase the efficiency of the building-service system, it is necessary to have instruments which are support to the optimal choices of the construction elements to be used in new buildings and in existing ones to improve thermal insulation. To choose the window frames and glazing systems it's important to evaluate some features on the thermal behavior as the global transmittance of both individual elements and of the "window" system, as the thermal transmittance and the heat flow, which shows the energy performance in specific points. Currently there are software that allow you to make the rigorous calculation of isotherms, but the use needs technical skills and the processing time is not short. PADesign srl Company has developed a tool that could allow the easy calculation of the thermal transmittance, showing the heat flow in order to facilitate the choice between several possible technological solutions.
This tool will appeal to a wide audience, because it does not require specific professional skills. It is an user-friendly tool that can be useful for designers, customers, employees to view the thermal behavior and take advantage of the incentives provided by the law.

Innovation of the system

To accurately assess the effect of thermal bridges in the vertical window frames, there are commonly in use specific software for finite element calculations. This involves the application of specific skills, as well as long times for the computation and for the changing, from time to time, of the flow diagram of the selected combination.
The proposed solution, however, is able to quickly view and compare the values of thermal transmittance and the isotherms of the heat flow of the chosen solutions, to compare the output data and to change the combinations so as to facilitate the choice of the best combination even by those who not have high skills in the use of specific software (Fig.1).

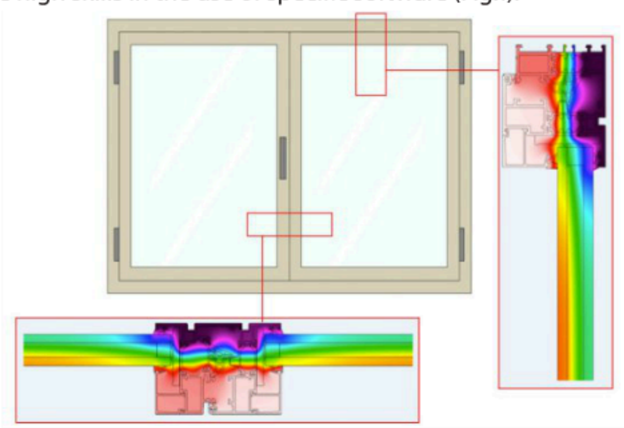


Figure 1: Demonstrative image of the flows calculated by the tool in the perimeter and in the central node of two-wing window

Many industries that produce windows systems provide tools that allow users to determine the overall transmittance of the selected component. Our tool, in addition to the above, displays the heat flow and the isothermal diagram, providing a tool that measures the transmittance with a certain rigor to assess the quality of the different choices unresectable, by using the best way to mitigate the effects of the thermal bridges.
The software, through a simple graphical interface, enables to select the climate data, the external frame typologies, the geometric features, the materials and the glass typologies. By starting the calculation, the instrument determines the thermal transmittance and checks the compatibility with the national regulations. The originality of this tool is that you can view the status of progress of the characteristics of the heat flow in a specific section, and immediately identify the possible points of heat loss (thermal bridges). In this way, the user can change the parameters to generate another solution that implements the overall performance of the exterior frame.

User interface

This tool is designed to be used by wide specialized users. After implementing the features of frame, the tool automatically generates the overall thermal transmittance and heat flow through THERM, a calculation software developed by the Lawrence Berkeley National Laboratory (LBNL), which analyzes the two-dimensional heat flows through different building components.
A mesh automatic generator, processing the calculations according to the Finite Element Method, defines the section. The results obtained are consistent with the evaluation process developed by the NFRC (National Fenestration Rating Council), a non-profit organization that manages the consistency of assessment and labeling system for the energy performance of building components.
The transmittance of the window is then calculated according to the following formula:

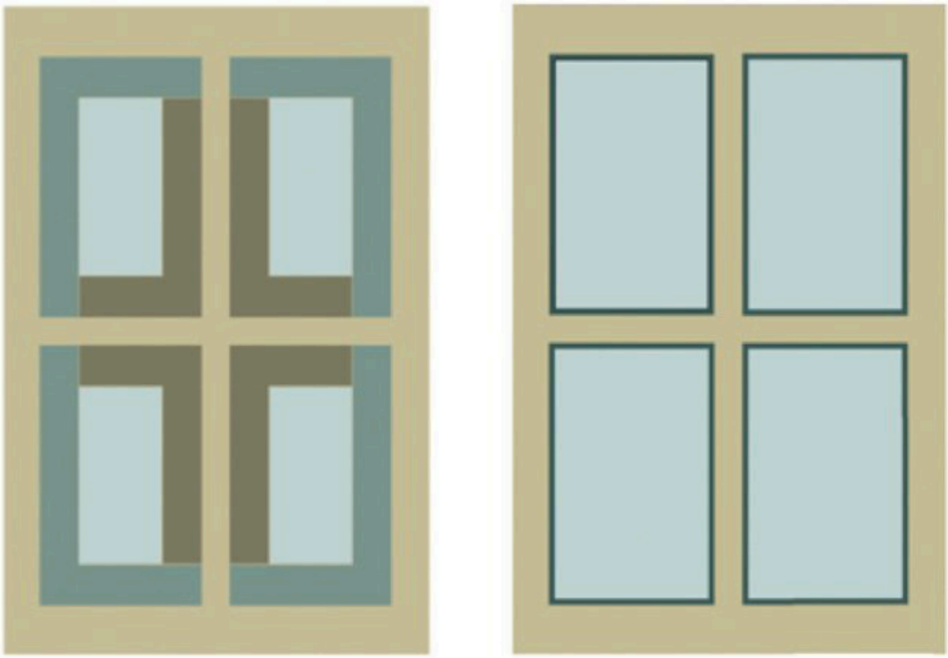
$$U_t = \frac{\Sigma\, U_c A_c + \Sigma\, U_{fr} A_{fr} + \Sigma\, U_e A_e + \Sigma\, U_d A_d}{A_t}$$

Uc, Ac: Thermal transmittance and projection of central glass area
Ufr, Afr: Thermal transmittance and projection of frame area
Ue, Ae: Thermal transmittance and projection of glass edge area
Ud, Ad: Thermal transmittance and projection of divider area
Ude, Ade: Thermal transmittance and projection of divider edge area

This method of calculation is considerably more detailed than the requirements of the UNI 10077-2, because are considered the mode of transfer of edge effects from the glass to the frame without resorting to tabulated values, often overestimated (Fig.2). As shown by the following formula (UNI 10077-2), in fact, the thermal transmittance of the glass edge is identified with the parameter ψ, *the linear thermal transmittance*, whose value, provided by the same law, is selected from a limited number of examples not always representing the real situation to be evaluated.

$$U_t = \frac{\Sigma\, U_g A_g + \Sigma\, U_f A_f + \Sigma\, \psi\, l_\psi}{A_t}$$

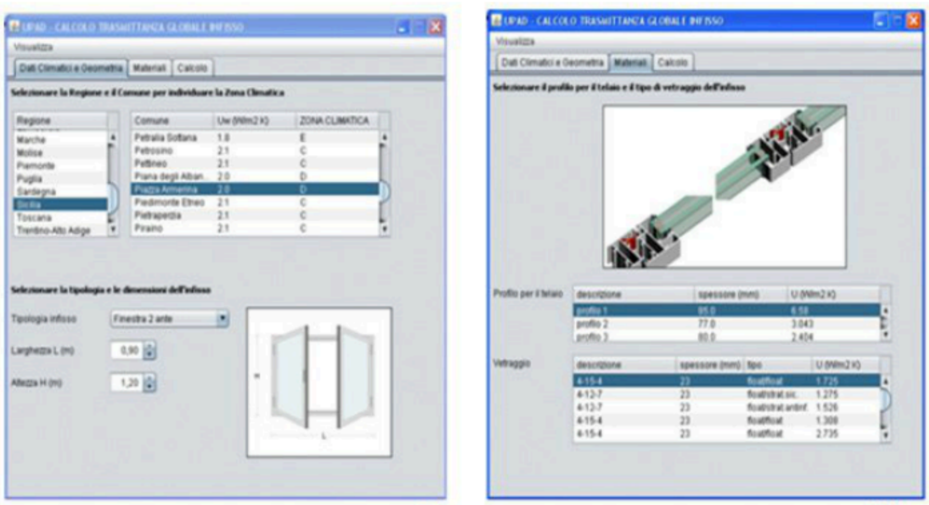
Climate data are set through a first drop-down menu that allows you to choose the region and a second one in which to select the city. The information is downloaded directly from the database file *insqllite*.



a) b)

Figure 2: In the diagram a) are highlighted various portions of the window (area frame, edge of glass, centre of glass and divider edge) that are considered in the calculation of the overall thermal transmittance, unlike the format b) in which are considered only the frame and glass portions and the edge line of the glass

The width and height of the window system are required by law to verify compliance with the limits of Uw for the standard frame. The setting is made through the required fields where to set the width and height of the compartment of the window (Fig.3).



a) b)

Figure 3: In the a) screen are set climatic and dimensional parameters while in b) are set the type of frame and glass

Through the next screen (Fig.4), you can check your input and start the calculation of transmittance, withdrawing from the database the information necessary to display the heat flow developed through the program THERM.

c) d)

Figure 4: The screen c) shows a summary of the input. The screen d) shows the heat flow and the thermal transmittance value

Subsequently appears the image of the heat flow with the relative temperature data. It also appears a red or green field depending on the compatibility of transmittance value achievable with the requirements of European legislation for the limit values of the transparent elements.

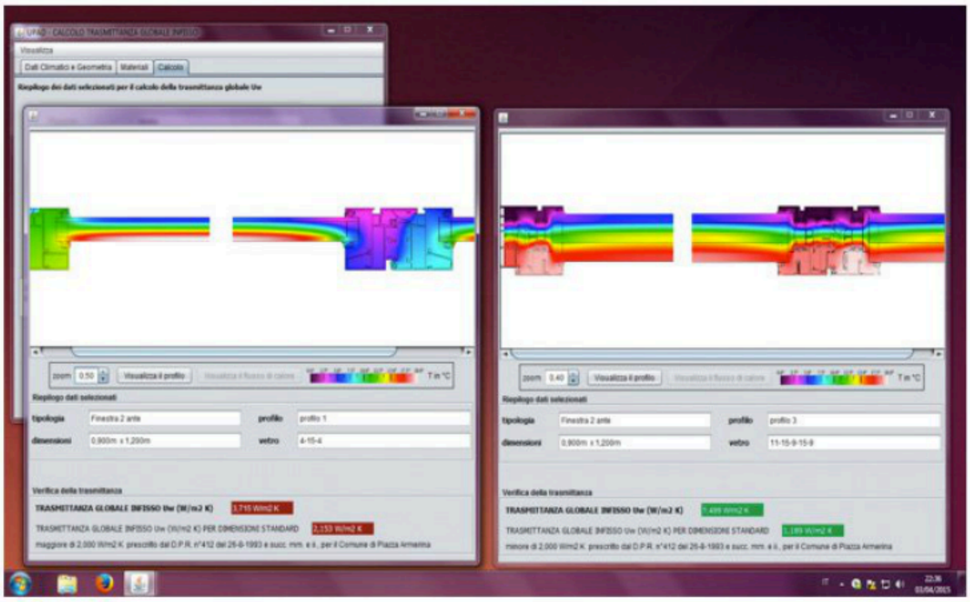


Figure 5: Comparison between two combinations where the second provides better performance than the other one

Is possible also allows a larger view of the profile and of the heat flow to provide better detail understanding of the temperature values obtainable.
To make a new search, or if the transmittance values are unsatisfied, you can reselect the main window, leaving open the output window previously generated, and change the combination of one or more elements rerunning "CALCULATE THE TRANSMISSION".
In this way, the tool will open a new output window and you can compare the results generated by combinations selected (Fig.5).

System operation

The tool has been designed using the software LBNL WINDOW and LBNL THERM. It was acquired authorization for the use of such software by asking the acceptance of their license by the user.
This option was included in the startup screen of the program. The tool can be downloaded to your computer from the www.padesignsrl.com website.
The application was developed in Java and uses the Swing library to create graphical components (windows, panels, frames, buttons, labels, text boxes etc.) which are used in the GUIs. *UpadMain* is the class that contains the main method that starts the application and instantiates the class *InfoLicenzaJFrame* (which extends the superclass *JFrame*) .This class creates a window that displays the text of the license terms and the buttons to accept ("I Agree") or refuse ("I Disagree") such conditions in order to be able to perform or not the application. If you accept the terms, it is instantiated class *StartJFrame*. This class has the task to display the main program window.
The default constructor *StartJFrame* first initializes the GUI components. Later calls *initDatiTabelle* that takes care of instantiating the class *DBManager*. *DBManager* manages the database containing the data used by the software. A SQLite library is used to integrate a relational database within the application.
A SQLite file contains the data of climatic zones, profiles of frames, glasses and the type of fixtures (Fig.6).

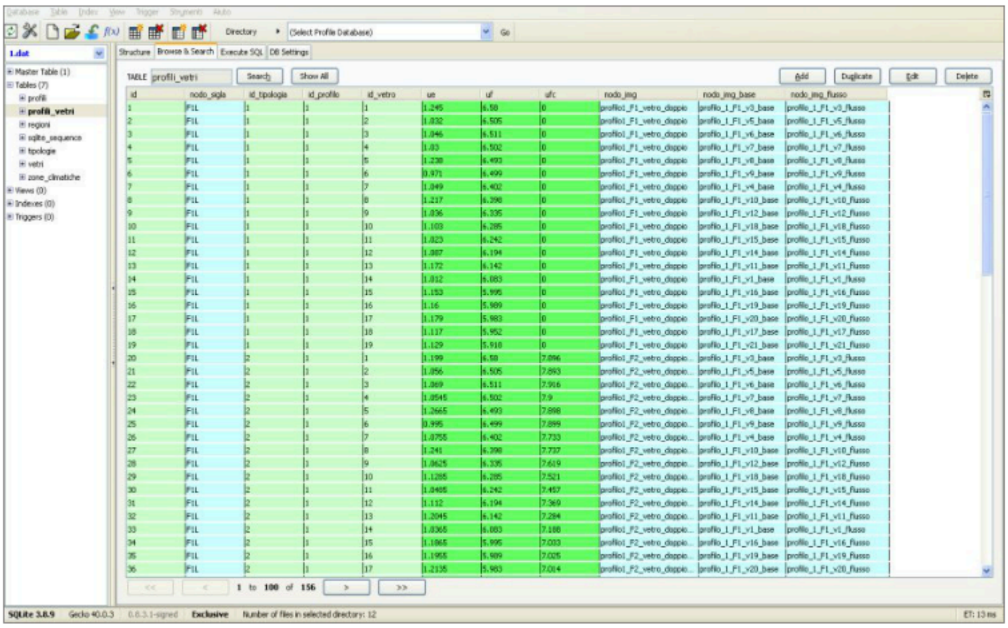
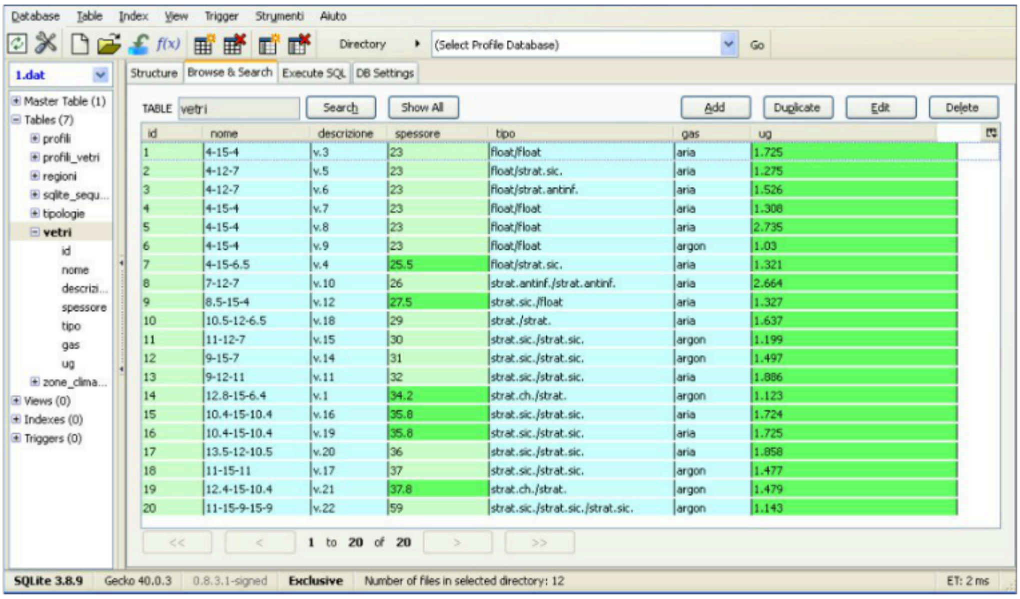


Figure 6: Profiles_glasses table data stored in the database (SQLite file)

The database consists of the following tables:

- profili (id, nome, descrizione, spessore_up, spessore_fc);
- profili_vetri(id, nodo_sigla, id_tipologia, id_profilo, id_vetro, ue, uf, ufc, nodo_img, nodo_img_base, nodo_img_flusso);
- regioni(id, regione);
- tipologie(id, nome, img_tipologia, numero_sezioni);
- vetri(id, nome, descrizione, spessore, tipo, gas, ug);
- zone_climatiche(id, codice_regione, codice_provincia, codice_comune, sigla_provincia, comune, altitudine_slm, gradi-giorni, zona_climatica, uw);



id	nome	descrizione	spessore	tipo	gas	ug
1	4-15-4	v.3	23	float/float	aria	1.725
2	4-12-7	v.5	23	float/strat.sic.	aria	1.275
3	4-12-7	v.6	23	float/strat.antinf.	aria	1.526
4	4-15-4	v.7	23	float/float	aria	1.308
5	4-15-4	v.8	23	float/float	aria	2.735
6	4-15-4	v.9	23	float/float	argon	1.03
7	4-15-6.5	v.4	25.5	float/strat.sic.	aria	1.321
8	7-12-7	v.10	26	strat.antinf./strat.antinf.	aria	2.664
9	8.5-15-4	v.12	27.5	strat.sic./float	aria	1.327
10	10.5-12-6.5	v.18	29	strat./strat.	aria	1.637
11	11-12-7	v.15	30	strat.sic./strat.sic.	argon	1.199
12	9-15-7	v.14	31	strat.sic./strat.sic.	argon	1.497
13	9-12-11	v.11	32	strat.sic./strat.sic.	aria	1.886
14	12.8-15-6.4	v.1	34.2	strat.ch./strat.	argon	1.123
15	10.4-15-10.4	v.16	35.8	strat.sic./strat.sic.	aria	1.724
16	10.4-15-10.4	v.19	35.8	strat.sic./strat.sic.	aria	1.725
17	13.5-12-10.5	v.20	36	strat.sic./strat.sic.	aria	1.858
18	11-15-11	v.17	37	strat.sic./strat.sic.	argon	1.477
19	12.4-15-10.4	v.21	37.8	strat.ch./strat.	argon	1.479
20	11-15-9-15-9	v.22	59	strat.sic./strat.sic./strat.sic.	argon	1.143

Figure 7: Profiles_glasses table data stored in the database (SQLite file)

The class *DBManager* then manages the connections and queries to the SQLite database file. When you start the program the method *initDatiTabelle* instantiates *DBManager* to call the get methods needed populate the tables displayed in the main GUI *StartJFrame*. Tables are populated in the following order: "Climatic Zones", "Regions", "Type of the frame", "Frame profiles", "Glazing". It is also populated the table "Nodes", not visible in the GUI, containing the data of the sections of interest for the combination calculation is currently selected. Table rows "Nodes" are obtained by querying the frames_glasses table stored in the SQLite file.

At startup it will already be selected all the elements needed to define a complete combination of calculation: climate data, type and size of the fixture, type of frame profile, glazing. A check is made to see whether the selected combination is allowable.

This check is also made during the selection phase of the elements (eg. glass selected may have a thickness greater than that allowed by the profile).

If the combination is possible, it is retrieved the list of the sections of interest in relation to the selected fixture type.

Each list item is associated with a pair of images: an image with the elements seen in cross-section and an image showing the evolution of heat flow.

This element is represented by an object from the class NodoInfisso. This is characterized by the attributes related to the constituent components of the selected combination.

For example in the case of two-wing window, the constructor for the class NodoInfisso has the following list of parameters:

- String nodo_sigla, // alphanumeric code assigned to the node
- int id_tipologia, // id of the selected type
- int id_profilo, //id of the selected profile
- int id_vetro,// id of the selected glazing
- double ue, // transmittance of the edge
- double uf, // transmittance of the side frame
- double ufc, // transmittance of the side frame
- String nodo_img, // name of the 3D preview section image
- String nodo_img_base, // name of the 2D section image
- String nodo_img_flusso // name of the 2D flow image

- The panels of the main GUI are grouped so as to allow you to select items without necessarily follow a fixed order.
- The event of the mouse click on this button executes the instruction sequence according to the following order:
- performs the query necessary to retrieve the data of building elements selected (profile frame, glazing);
- these data are stored in objects instantiated from classes Profilo_Infisso and Vetro_Infisso;
- depending on the type of the frame selected (one door window or two doors window) it is retrieved the list of nodes that represent the characteristic sections of calculation for the type of frames associated;
- the following values are calculated: the overall transmittance Uw of the frame built with the selected items and the total standard transmittance of the corresponding fixture UwStandard (current legislation assigns the values of standard width equal to 1230 mm and standard height of 1480 mm);
- an output window displays processing results.

The object of *InfissoCalcolo* class calculates the transmission value. In the case of window with one door , it is used the formula:

```
trasmittanza_totale=
    ((frame_trasmittanza*frame_area)+
    (edge_trasmittanza*edge_area)+
    (glass_trasmittanza*glass_area))/
    (frame_area+
    edge_area+
    glass_area);
```

While in the case of window with two doors it is taken into account the presence of the middle frame and its contribution transmittance:

```
trasmittanza_totale=
    ((frame_trasmittanza*frame_area)+
    (frame_centrale_area*frame_centrale_trasmittanza)+
    (edge_trasmittanza*edge_area)+
    (glass_trasmittanza*glass_area))/
    (frame_area+
    frame_centrale_area+
    edge_area+
```

glass_area);

At the end of the calculations, the window displays *OutputJFrame*:

- a summary of the values of the selected items (type, size, frame profile, glass, climate zone) in the main GUI *StartJFrame*;
- the value of the global transmittance for the selected geometric dimensions;
- the value of the global transmittance for the standard geometric dimensions;
- a message shows if you respect the limit of transmittance depending on the climatic zone selected;preview of 2D images of the sections of interest to the selected type of frame;
- a button to show the heat flow in sections of interest;
- a button that lets you adjust the zoom feature images;

The controls in the window object *OutputJFrame* and layout of the output window are managed using the class *ImageControls*.

Changing several times the combination of the selected items in the main GUI and starting the calculation again with the button *JButton calcola_UwActionPerformed*, you can simultaneously view *OutputJFrame* windows corresponding to different combinations in order to allow a comparison of the results of processing.

Conclusion: future developments

This tool has been currently developed for some types of door and window frames in combination with different types of glass.

Furthermore, the tool is designed to provide to the manufacturers of window frames an useful tool for the choice of the most effective components.

The research is still under development, to extend the processing of the heat flow to parts of shell containing also opaque elements.

To better understand the energy performance of a building the first step consists in the assessment of the features of the building envelope, both transparent and opaque, in order to obtain the global energy needs, useful to the choice of the action to carry out on the construction.

Another important result could be the development of a plugin that allows to evaluate the economic advantages associated to the better choice, through a cost-benefit analysis that takes into account both the initial costs and the obtainable energy savings.

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