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INTELLIGENT PRODUCT CONFIGURATOR - THE NEW APPROACH IN THERMO INSULATION OF BUILDINGS

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ABSTRACT
This paper presents the latest results of an undergoing project, which deals with the development of a specific on-line product configurator in the field of thermo insulation of buildings. The developed configurator gives a customized solution for thermo insulation of custom buildings. First, the main aspects of product customization in general are shown. Following that the needed project-specific input parameters and constraints are defined, based on which the suggested solution algorithm, as well as the developed architecture is presented. The case study shows the developed project. Based on the results, future research directions are suggested.
Keywords: Product configurator, Customization, Thermo insulation

1.INTRODUCTION

Global competition is forcing companies to change their activities from a seller point of view towards a buyer point of view, which results in a drastic increase of product variety offered by enterprises, which is one of the main characteristic trends of modern economic system [1,2].

To maintain their competitiveness, companies are modularizing their products and introducing platform concepts, and this transfer from no customizable products to modular products involving individual customer variants presents one of the most important industrial strategies nowadays.

The recent development of internet technology enabled the software based product configuration systems that support the process of customized product development. They compose customer specific solutions using the modules based on the customer's requirements.

Mass customization alters traditional product development and moves towards a two-stage model, the first, the realm of company/designer establishing the solution space and the second, that of customer as co-designer. This second stage fundamentally changes the role of the customer from consumer of a product, to a partner in a process of adding value [3].

The literature describes a spectrum of research in the area of designing for co-design and has identified a number of design considerations, which include:

- Minimizing the potential complexity experienced by the customer, keeping their expenditure in the buying process as low as possible, whilst providing clearly perceptible benefits [4,5];
- Reducing cognitive overhead, which lies not only in extent of choice, but also in areas such as lack of understanding about which solution meets their needs, uncertainty about the behavior of the supplier, and uncertainty regarding the purchasing process, ordering and paying in advance for something that's only been seen virtually [6].

1.1. Thermo insulation of buildings

Outer thermo insulation of buildings is becoming more and more important, since energy resource prices have raised extensively in recent years, and environmental issues have become more relevant than ever before.

Despite the widespread usage of thermo insulating materials in everyday practice, it can be noted that thermo insulation is often made self-initiated, without the proper knowledge about the materials, the technology, and the calculations needed to obtain the best results. This results in inadequate solutions, that can range from high installation costs and high consumption cost to short lifetime and insufficiency of the applied insulation. The ongoing project defines several goals for the developed configurator that can be stated as follows:

- The proposed configurator has to offer web based on-line instant results;
- The result should be based on the latest results in research and practice;
- The proposed solution should configure customized results, based on the specific characteristics of individual buildings;

- The proposed solution has to minimize the potential complexity experienced by the user, by reduction of cognitive overhead;
- The proposed solution has to be used both by retailers and customers as end users without specific technical knowledge about thermo insulation;
- The proposed solution should offer an accurate enough result, considering the nature of the research field.

2. PROJECT SPECIFIC INPUT PARAMETERS AND CONSTRAINTS

Research in the field of outer thermo insulation defines several rules that have to be considered when one wants to make the needed calculations. Those rules generally require knowledge about different parameters, such as:

- The overall position of the building;
- The building's characteristics such as structure, measures, materials, etc.;
- The conditions regarding the surroundings, e.g. weather data.

2.1. The overall position of the building, the building's structure, measures, materials and additional information

The necessary data about the overall position of the building requires the knowledge about the field location of the building, the position of the building and the type of the building.

The building's structure requires the following information:

- Information about the existence and position of cellar, as well as information about requirements considering the insulation of the cellar;
- Information about the number of floors;
- Information about the roof and loft type, as well as information about requirements regarding the insulation of the roof and loft and the envisaged purpose of them. Because in practice a huge amount of different roof and loft types can be found, based on field research, five different roof types and four roof-loft types are offered for the selection (Fig. 1), which covers most of the existing building types;
- Information about the ground plan form for each floor. Because in practice a huge amount of different ground plans exist, based on field research, five different ground-plans are offered for the selection, covering most of the existing building types (Fig. 2).

The building's measures require the following information:

- The lengths and heights for each floor of the building separately. Additionally, for each floor there is a correction factor for the floor area, the outer wall area, and the roof area;
- The total area and the number of the windows and doors for each floor;
- The number of wall layers (different materials) and floor layers (different materials), as well as layer's width for each floor.

The building's materials are defined in the following manner:

- Material types for floors and walls, for each floor of the building separately (thirteen different material types are defined and a maximum of five layers per wall);
- Prevailing window and door types for each floor of the building separately (ten different window and four different door types are defined).

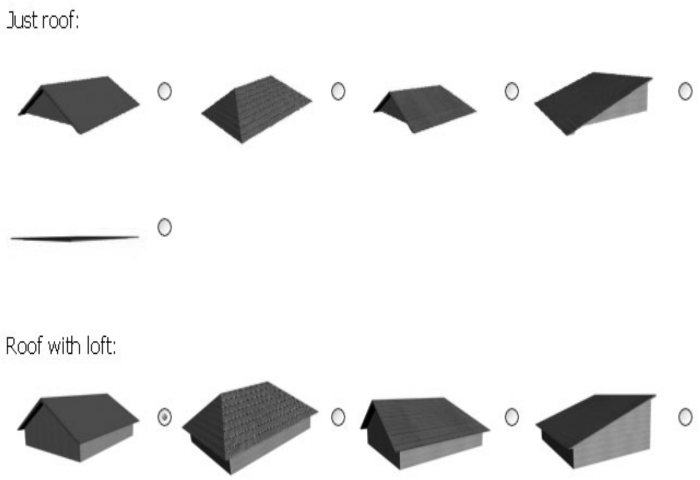

Fig. 1. Information about roof and loft types

2.2. The conditions regarding the surroundings

One of the project goals is that the proposed solution should offer an accurate enough result. Therefore the only required data considering the surroundings are outer average air temperature, average ground temperature, average cellar air temperature, the building's average air temperature and unused loft's average air temperature. Other parameters that influence the final results, such as thermal conductivity of different materials and heat transmission coefficient, etc. are considered as constant values.

3. PROPOSED ALGORITHM

Different structural parts of the building are taken into consideration separately by the proposed algorithm. The structural parts of the building are chosen based on necessary calculations and differences considering the choice of insulating materials defined by the manufacturer. These structural parts are: the floors in contact with the ground, the walls in contact with the ground, the walls in contact with external atmosphere near the ground, the walls in contact with external atmosphere away from the ground, the floors in contact with external atmosphere, loft's floor, roof, windows and entrance doors [7]. Based on input parameters and constraints, several input calculations are made:

- The total area of outer floors in contact with the ground;
- The total area of outer walls in contact with the ground;
- The total area of outer walls in contact with external atmosphere near the ground;
- The total area of outer walls in contact with external atmosphere away from the ground;
- The total area of outer floors in contact with external atmosphere;
- The total area of the loft's floor;
- The total area of the roof;
- The approximate circumference of windows and doors.

Based on these calculations, for each structural part of the building the heat transmission coefficients are calculated. The calculation results are used as inputs for the calculation of total energy loss of the building. The heat transmission coefficients of the defined structural parts are used by the algorithm to define the needed insulating materials. The algorithm also takes into consideration the manufacturer's advice and defines three levels of priority for initial choice of insulating materials, separately for every structural part of the building.

After the needed insulating materials are chosen, total energy loss of the building without proposed thermo insulation as well as with thermo insulation is calculated. Additionally the energy costs for different energy sources are calculated too.

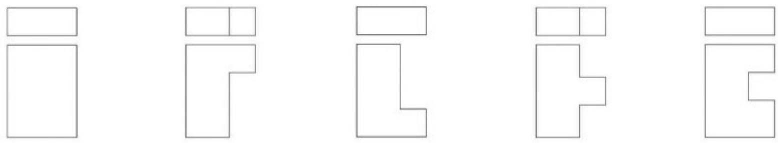

Fig. 2. Ground plans

The chosen insulating materials define the choice of additional materials such as the glue for the insulating material, screws, etc.

The algorithm also enables the hand correction of insulating and additional material types, measures and amounts, based on which the total energy loss with hand picked materials is calculated.

The result of the previously defined algorithm gives the calculated bill of proposed material types and amounts, as well as the hand picked material types and amounts with prices, what can be used for purchasing.

4. INTERACTION WITH END USERS

One of the main challenges that have been set for the developed configurator lie in the minimization of the potential complexity experienced by the user, by reduction of cognitive overhead. The other challenge is the fact that the configurator has to be used both by retailers who have successfully completed a training course about thermo insulation and customers who usually have little or no specific technical knowledge about it. Therefore the interaction with end users is defined in six levels.

The first level contains general information about thermo insulation on an encyclopedic level. It can be accessed during all phases of defining the parameters of the building. Their usefulness is multiple. They inform the customer with limited knowledge regarding thermo insulation about its benefits. They also give an overview of current trends in building insulation with results that can be obtained, thus raising awareness about environmental protection by reduction of thermal energy used for heating. Last but not least, these are popular science texts; therefore they are used to make the use of the configurator more interesting.

The second level contains specific instructions for filling in each form separately, as well as overall information about "things to do" for each page of the configurator. Specific instructions for filling in the forms can be accessed directly beside each form. They are presented in the form of direct instruction for use. Beside these direct instructions, each page of the configurator includes a specially designed portal for assistance that offers tips that should be provided by experts from the observed field.

The third level contains a number of forms to be completed. A huge number of required input parameters and constrains requires for the input fields to be defined in a way that is both easy and fast for manipulating instead of cumbersome for the user. Therefore, wherever it is possible the fields are defined visually, not textually. Beside that, the measures can be defined via drop down menus. Only a few input fields are used, where there is no possibility to define a predefined or offered result.

The fourth level of interaction is a possibility for the customers to analyze their individual projects - solutions by their retailer to obtain an optimal solution. One of the main problems for the customer who uses this kind of configurator is the lack of understanding about the whole aspect of thermo insulation. Therefore the customer has a possibility to analyze their individual projects - solutions, by a chosen retailer. The project can be accessed by the retailer, who can alter the project parameters, and modify the hand corrected result to achieve the desired solution. Based on the solution and the retailer's individual prices a purchase offer is automatically generated.

The fifth level of interaction is a possibility to read the answers for a set of frequently asked questions, given by an expert, while the sixth level of interaction is a possibility to ask a direct question via a set up form. The answer is given by an e-mail.

5. ARCHITECTURE

The architecture is a three-tier client server application (Fig. 3). On the client's side, only a common web browser is needed. The server side consists of an application server and a database server. The application server receives a request from the client, interprets it and performs the needed procedures. During the calculation process, the application communicates with the database. The result is passed back to the client.

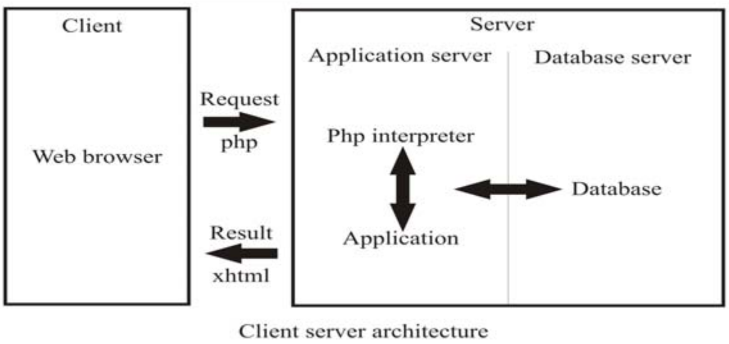

Fig. 3. Client server architecture

6. CASE STUDY

The developed configurator is tested configuring an existing building (Fig. 4), which simplified ground plans for cellar, 1st floor and roof are shown in Fig. 5. The building is detached, situated in a normal, protected area. It has a cellar approximately 40% underground, one floor and a roof with loft. Insulation is needed on the cellar's walls and floor, on all outer walls and floors, on the ceiling of the loft and on the roof. No loading of the attic is needed. All of the linear dimensions and heights are defined, as well as percentage of free surface areas of exterior walls, corrections of exterior surface of floors and walls, lengths of initial profiles and different edge protectors, number, types and thicknesses of walls and floors, window and door numbers, types and surface areas.

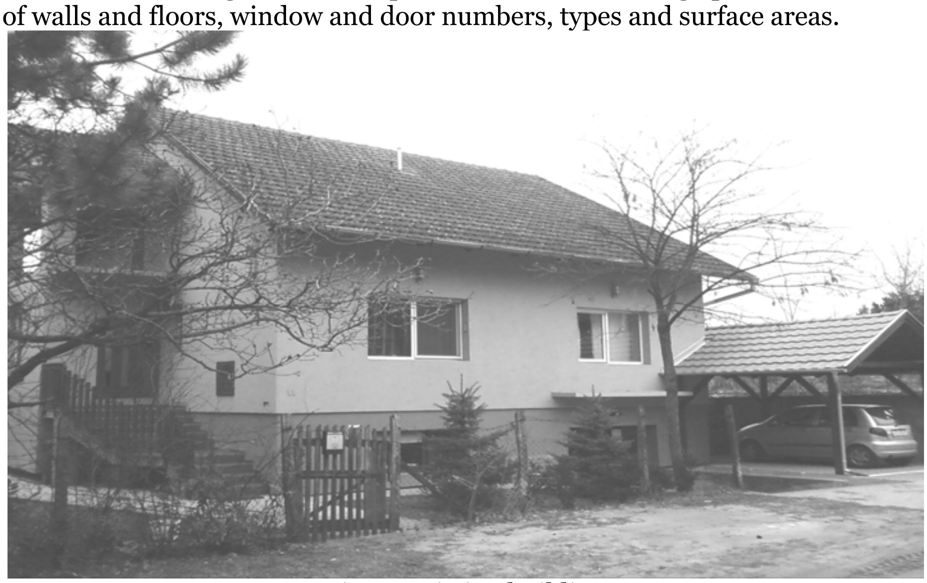

Fig. 4. Existing building

Outer average air temperature is set to -2 [°C], average ground temperature to 10 [°C], average cellar air temperature to 12 [°C], the building's average air temperature to 20 [°C] and the unused loft's average air temperature to -2 [°C].

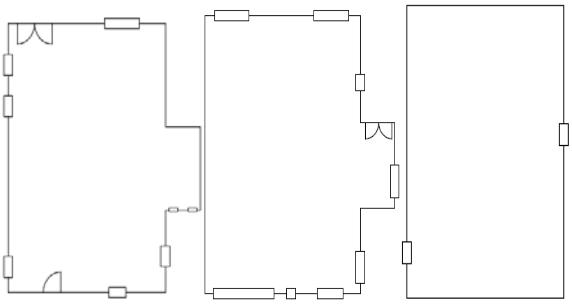

Fig. 5. Ground plans for cellar, 1st floor and roof respectively

Based on input parameters and calculations, heat losses as well as energy costs for building heating without insulation, with suggested and with chosen insulation for different energy prices are shown in Table 1[1].

Based on the performed calculations, the results show that the differences between the values calculated upon a simplified model of the building by using the configurator and the real values that are based on real data are acceptable if the nature of the research field is taken into consideration (Fig. 6)

Table 1 Prices

without insulation		with proposed insulation		with chosen insulation	
Energy loss	9081 [kWh/month]	Energy loss	3197 [kWh/month]	Energy loss	2503 [kWh/month]
Saving in percentages					
with proposed insulation 64%			with chosen insulation 72%		
Orientational price of electric energy: 0.05 [€/kWh]					
Energy costs (power)	454.05 [€/month]	Energy costs (power)	159.85 [€/month]	Energy costs (power)	125.15 [€/month]
Orientational price of wood: 0.032 [€/kWh]					
Energy costs (wood)	290.592 [€/month]	Energy costs (wood)	102.304 [€/month]	Energy costs (wood)	80.096 [€/month]
Orientational price of coal: 0.03 [€/kWh]					
Energy costs (coal)	272.43 [€/month]	Energy costs (coal)	95.91 [€/month]	Energy costs (coal)	75.09 [€/month]
Orientational price of gas: 0.049 [€/kWh]					
Energy costs (gas)	444.969 [€/month]	Energy costs (gas)	156.653 [€/month]	Energy costs (gas)	122.647 [€/month]
Orientational price of heating oil: 0.035 [€/kWh]					
Energy costs (heating oil)	317.835 [€/month]	Energy costs (heating oil)	111.895 [€/month]	Energy costs (heating oil)	87.605 [€/month]

Name	Code	Amount	Packaging
styrodur	0510-25006000	128.25 [m2]	37
isomaster	0501-08010000	259.52 [m2]	104
styrodur	0510-30010000	13.93 [m2]	7
styrodur	0510-30010000	48.56 [m2]	25
isomaster	0501-08006000	11.25 [m2]	3
isomaster	0301-07010000	53.18 [m2]	22
isover rio twin	0508-rt126000	77.06 [m2]	5
masterfix	0103-10001005	77.2 [l]	16
masterfix	0103-01101025	3230.5 [kg]	130
masternet	0101-117wh055	366.58 [m2]	7
thermomaster	0110-0z100000	92 [m]	46
ejot	0111-03000000	46 [pcs]	1
ejot	0112-03000000	92 [pcs]	1
ejot	0112-05000000	92 [pcs]	1
ejot	0112-10000000	92 [pcs]	1
thermomaster	0118-00150250	1038.06 [pcs]	5
plug dowel	0717-64002000	460 [pcs]	3
thermomaster	0105-10100000	24 [m]	10

Name	Code	Amount	Packaging
styrodur	0510-25006000	125 [m2]	36
isomaster	0501-08010000	248.77 [m2]	100
styrodur	0510-30010000	13.15 [m2]	7
styrodur	0510-30010000	46.08 [m2]	24
isomaster	0501-08006000	8 [m2]	2
isomaster	0301-07010000	43.11 [m2]	18
isover rio twin	0508-rt126000	85.6 [m2]	6
masterfix	0103-10001005	72.62 [l]	15
masterfix	0103-01101025	3087 [kg]	124
masternet	0101-117wh055	347.6 [m2]	7
thermomaster	0110-0z100000	92 [m]	46
ejot	0111-03000000	46 [pcs]	1
ejot	0112-03000000	92 [pcs]	1
ejot	0112-05000000	92 [pcs]	1
ejot	0112-10000000	92 [pcs]	1
thermomaster	0118-00150250	995.08 [pcs]	4
plug dowel	0717-64002000	460 [pcs]	3
thermomaster	0105-10100000	24 [m]	10

Fig. 6. Values obtained by using the configurator and real values respectively

[1] Prices are calculated, based on data that was current in Serbia on April 2009.

7. CONCLUSIONS

The fact that thermo insulation of buildings is often made elementally, without the proper knowledge about the materials, the technology and the needed calculations, usually results in inadequate solutions, that can range from high installation costs and high usage cost to short lifetime and insufficiency of the created insulation. Therefore, there is a need to have automated solutions for it. The developed configurator offers web based on-line accessibility for wide range of users, and gives instant results to be as attractive as possible to the public. The solution is customized for each individual building, but the user interface maintains as general as possible to minimize the potential complexity experienced by the user. The proposed solution is used both by retailers and customers as end users without specific technical knowledge about thermo insulation. The proposed solution offers an accurate enough result, which is acceptable in practice.

The case study shows that the results of calculations based on input parameters are acceptable. The final solution is given in understandable form, which can be directly used for ordering.

Initial experiences from end users of the configurator suggest that there is further need to make the configurator simpler and the configuration process less time-consuming, which may prove to be an insurmountable obstacle due to the complexity of the problem. Initial experiences from retailers on the other hand suggest that the idea of insulating a building is becoming more interesting and acceptable for the customers, when presented by using the configurator. These experiences point towards several future research directions:

- Simplification of user interface by using as many visual and interactive elements as possible with real time multimedia help;
- Testing the configurator on a significant statistical sample to get relevant information about deviations in calculated results against real values that are based on real data;
- Definition of rules for simple and accurate identification and interpretation of the user's profile (needs, wishes, limitations) and its incorporation into configurator;
- Definition of rules for taking into account the accepted solutions by previous users of certain profile and their incorporation into configurator;
- Development of an intelligent decision making algorithm that takes into consideration the input parameters and constraints, the user's profile, the previously accepted solutions and can automatically adjust the solution that can lead to suggested solutions, which correspond to a greater extent to finally accepted results.

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