Self-Adaptive Product Configurator for Thermal Insulation

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Abstract: The paper presents the latest results of an ongoing project which deals with the development of a specific on-line product configurator in the field of thermal insulation of buildings. The self adaptive product configurator proposes a definition of the customer profile that is relevant to the area of investigation. Based on defined customer profile, three levels of input information complexity are defined (for "dummy" user, intermediate user and professional user). The type and amount of input information on one level is defined by a set of initial questions, based on which the customer profile is defined. The proposed solution is generated based on input data and built in logic. The results show that different levels of input data produce different structure of the configuration process and proposed solutions, both qualitatively and quantitatively, but that the differences could be acceptable considering the field of thermal insulation. The results also show that different customer profiles lead to an improvement considering the simplicity of handling and understanding of the configuration process as experienced by the user.

Keywords: Self-Adaptive Configuration, Customer Profile, Product Configurator, Thermal Insulation

1 Introduction

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

technology enables 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 the 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]. This alteration of traditional product development through the involvement of the customer into the configuration of the final product faces some obvious problems. The fundamental challenge is to avoid the abortion of the configuration process by the customer. In many cases, the customer aborts the configuration process by himself. Major problem areas include the lack of a customer desired option value regarding a specific attribute within the system as well as the inability of the customer to create definite preferences between certain option values. As a result, the customer aborts the configuration process and does not come up to the sales phase [4]. Also if customers are overwhelmed by the configuration task, they may as well abort the configuration process. Customers usually only want the product alternatives that exactly fulfill their requirements. If too much of a choice is offered, customers can feel frustrated or confused and therefore incapable of making proper decisions. This overload of information is sometimes called external complexity. This external complexity is caused by limited information processing capacity of humans, lack of customer knowledge about the product, and customer ignorance about his or her real individual needs [5].

Based on problem analysis regarding customers involved in the configuration process, the main areas of investigation that should be considered are the minimization of the complexity experienced by the customers [6, 7] and the reduction of the cognitive overhead, considering not only the extent of choice, but also the lack of understanding about which solution meets their needs and also the uncertainties about the behavior of the supplier and the purchasing process [8].

1.1 Outer Thermal Insulation of Buildings

Outer thermal 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 insulating materials in everyday practice, it can be noted that thermal 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 configurator should configure customized results, based on the specific characteristics of individual buildings;
- The proposed configurator has to minimize the potential complexity experienced by the user, by reduction of cognitive overhead;
- The proposed configurator has to be used by professionals, retailers and end users without specific technical knowledge about thermal insulation;
- The proposed configurator should offer an accurate enough result;
- The configurator has to raise the awareness about the necessity and the advantages of proper thermal insulation.

2 Customer Profile Configuration

Based on the experience of a previous version of the developed configurator that was meant to be used both by users with average or no technical knowledge and by professionals with proper technical knowledge in the related field of investigation, it has been recognized that most of the problems had arisen because some of the previous non-professional users had found the product configurator too complex to use. On the other hand some of the professional users have found that the configurator lacked the possibility of defining exact and precise input parameters. Other problems included the need for more or less accurate results, as well as more or less time-consuming configuration. These problems were solved by identification of different customer profiles:

- "Dummy" user;
- Intermediate user;
- Professional user.

"Dummy" user is a customer without proper technical knowledge about thermal insulation, or maybe a user with no need for highly accurate results, or a user with a need of a fast enough result, etc. Intermediate user is a customer with average technical knowledge about thermal insulation, but can also be a customer without proper technical knowledge about thermal insulation but with more time for completing the configuration process or with a need for more accurate result, etc. Professional user is a customer with proper knowledge about the problem of

thermal insulation, can also be a customer with average technical knowledge about thermal insulation but with more time for completing the configuration process or with a need for more accurate result, etc.

To configure the appropriate user profile, three initial questions are asked before the start of the configuration process:

- What is your estimate about your knowledge about thermal insulation?
- What are your needs considering the accuracy of the configuration results?
- How much time do you have for completing the configuration process?

The answers can range from "I have no knowledge about thermal insulation at all" to "I am a professional in the field of thermal insulation" for the first question, from "I need as accurate result as possible" to "I just want a rough estimate" for the second question and from "I have enough time for completing the configuration process" to "I have limited time for completing the configuration process" for the third question (Figure 1).

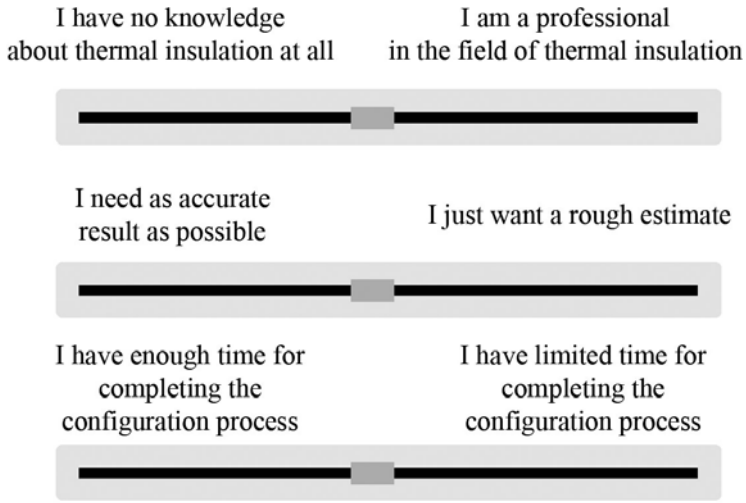

Figure 1

Initial questions for customer profile configuration

The nature of the questions and the answers refer to the use of a non-crisp logic; therefore fuzzy logic is used to determine the appropriate customer profile. The configured user (customer) profile is used in the configurator (Figure 2).

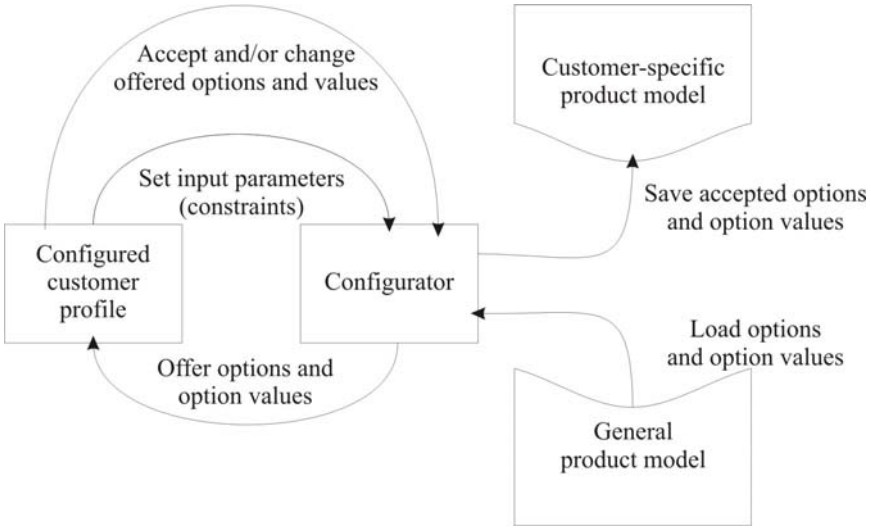

Figure 2

Modified configurator

3 Project Specific Input Parameters and Constraints

Research in the field of outer thermal insulation defines several rules that have to be considered when one wants to make the needed calculations. Those rules require knowledge about different parameters, such as the overall position of the building, the building's characteristics such as structure, measures, materials, the conditions regarding the surroundings (weather data), etc.

Different customer profiles that can be configured ask for different levels of project specific input parameters and constraints.

3.1 Project Specific Input Parameters and Constraints for "Dummy" User

Despite the impact on the final result, it is not expected that the user on this level can give an adequate answer to the questions about the overall position of the building, i.e. about the field position of the building, the lying of the building and the type of the building, thus it is not taken into consideration.

The building's structure requires the following minimal information:

- Information about the existence and position of cellar, as well as information about requirements considering the insulation of the cellar and/or floor in contact with the ground;
- 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, which cover most of the existing building types.

The building's measures require the following information:

- The estimated area of the ground-plan of the building and an information about whether a building is with high or low ceilings;
- The estimated total number of rooms (including the bathrooms, kitchen, etc.) for the estimation of the number of the windows and doors of the building.

The building's materials require the following information:

- The estimated type of the building regarding the prevailing materials used (four different basic materials) and an information regarding any previous insulation;
- Information about window and door estimated quality (three levels of quality; poor, average, high).

One of the project goals is that proposed solution should offer an accurate enough result. Therefore the only required data considering the surroundings are:

- Outer average air temperature;
- The building's inner average air temperature;

All other parameters that influence the final results are considered as constant and fixed values.

3.2 Project Specific Input Parameters and Constraints for Intermediate User

Detailed analysis of the specific input parameters and constraints for intermediate user can be found in following papers [9, 10].

3.3 Project Specific Input Parameters and Constraints for Professional User

The research field of outer thermal insulation defines several rules that have to be considered when one wants to make the needed calculations on a professional level, i.e. if one wants to have highly accurate results. These calculations include all required information in detail and will not be discussed in this paper, because several professional software packages exist on the market that deal with the problem, such as *Bausoft Winwatt, Resfen, Casa Nova,* etc.

4 Proposed Algorithm

Different structural parts of the building are taken into consideration separately by the proposed algorithm depending on the profile of the customer. 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 and far from the ground, the floors in contact with external atmosphere, loft's floor, roof, windows and doors. Based on input parameters and constraints, several input calculations are made [9, 10].

In the case of "dummy" user, the calculations include the determination of:

- Estimated total area of outer floors in contact with the ground;
- Estimated total area of outer walls in contact with the ground;
- Estimated total area of outer walls in contact with external atmosphere near the ground;
- Estimated total area of outer walls in contact with external atmosphere far from the ground;
- Estimated total area of the loft's floor;
- Estimated total area of the roof;
- Estimated number and total area of windows and doors;
- Approximate circumference of windows and doors.

In the case of intermediate user, the calculations can be found in following papers [9, 10]. The case of professional user will not be discussed here.

Based on the input 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 takes into consideration the manufacturer's advice and defines three levels of priority for initial offer of options and values for insulating material separately for every structural part of the building. After the needed insulating materials are offered, total energy loss of the building without proposed thermal insulation as well as with thermal insulation is calculated. Additionally the energy costs for different energy sources are calculated too. The offered 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 handpicked materials is calculated.

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

Different customer profiles determine the level of complexity of the configurator, and thus the complexity of the configuration process, but irrespective of the determined customer profile the configuration process should be easy to use and understandable for the user. Therefore the interaction with end users is defined in six levels [9, 10].

5 Architecture

The architecture is a three tier client server application (Figure 3).

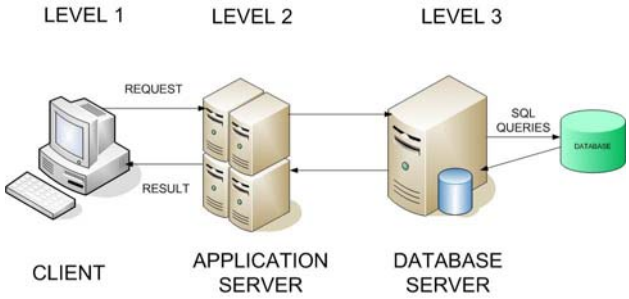

Figure 3

Client server architecture

At 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.

6 Case study

The developed configurator is tested configuring an existing building. The insulation is configured and the results are calculated for each customer profile. Heat loss is calculated, for input temperatures that are shown on Figure 4.

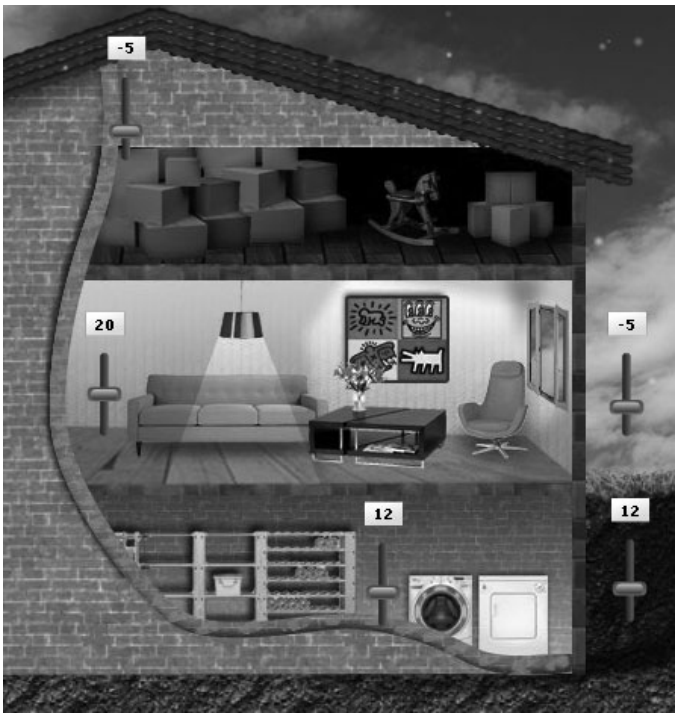

Figure 4

Input temperatures

Deviations of calculated heat losses without insulation and with proposed insulation, for different customer profiles compared to detailed calculations are shown on Figure 5.

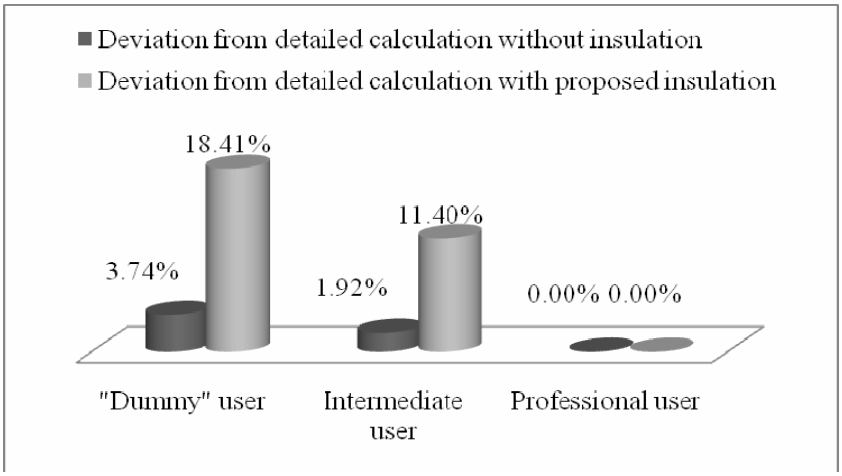

Figure 5

Deviations of calculated heat losses from detailed calculation

Deviations of calculated amounts of needed materials for “dummy” user compared to detailed calculations range from 2.2% to 7.8% for insulating materials, and from 6.7% to 53.1% for additional materials. Deviations of calculated amounts of needed materials for intermediate user compared to detailed calculations range from 0.8% to 4% for insulating materials, and from 0.7% to 23.6% for additional materials.

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, results in inadequate solutions, that can range from high installation costs and high usage cost to short lifetime and insufficiency of the built insulation. Therefore, there is a need to have automated solutions for it. On the other hand, if users are overwhelmed by the configuration task, or there is a lack of a desired option value for a specific attribute, or the users simply don't understand the configuration process, they may abort the configuration process and do not come up to the sales phase. Therefore, the developed configurator has to offer web based on-line accessibility for wide range of users, and should give instant results to be as attractive as possible to the public. The solution should be customized for each individual building, but the user interface has to maintain as general as possible to minimize the risk of abortion by the user.

The proposed configurator has to be used both by non-professional users as well as by professional users. The proposed solution should offer an accurate enough result.

The case study shows that deviations from exact calculations of heat losses for "dummy" user range from approximately 3.74% for calculations without thermal insulation to 18.41% for calculations with thermal insulation. Deviations for intermediate user range from approximately 1.92% for calculations without thermal insulation to 11.4% for calculations with thermal insulation. Based on these results one can conclude that different customer profiles give different results, but that the differences could be accepted if the nature of the research field is taken into consideration. The results for needed insulating materials and types show that for some materials, the differences are significant, but in the case of "dummy" user the overall result can be used as a good starting point for more detailed calculations, while in the case of intermediate user the results don't differ too much from the results obtained by detailed calculations if the nature of the research field is taken into consideration. The configuration process in the case of the "dummy" user lasts about 2-3 minutes, for intermediate user the required time is about 5-10 minutes, and for professional user it takes more than 10 minutes. The final solution is given in understandable form, which can be directly used for ordering. These results show that different customer profiles could be necessary for successful completion of the configuration process.

Experiences from retailers suggest that the idea of insulating a building is becoming more interesting and acceptable for the customers, when presented using the configurator, while end users suggest that there is further need to make the configurator more interesting.

The results and the gained experiences point towards several future research directions:

- Making the user interface more interesting by using as many visual and interactive elements as possible with real time multimedia help;
- Testing the new version of the configurator against the previous version on a significant statistical sample to get relevant information about the abortion level and the need for using different customer profiles;
- Testing the new version of the configurator against the previous version on a significant statistical sample to get relevant information about deviations in calculated results;
- Definition of rules for taking into account the accepted solutions by previous customers 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 customer 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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