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SCIENTIFIC PAPER

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ADVISORY-BASED PRODUCT CONFIGURATOR USED IN CHILLER CONFIGURATION AND EVALUATION

Highlights

- The product configurator is designed on a combination of inference rules and similar scenarios.
- The product configurator is designed to be a user-oriented system.
- Knowledge about the chillers is captured in a matrix form.
- The selection and evaluation of chillers is carried out using the so-called CCM methodology.

Abstract

This article presents the architecture and functional principle of an advisory-based product configurator. The program is used to create new and modify similar product configurations and is intended for users without in-depth expertise in technical fields. Due to its architecture, the configurator is designed to utilise the knowledge stored in the knowledge database. The selection is based on a combination of fuzzy inference rules and mapping techniques. Knowledge regarding the product is captured by using component-based matrices. The possibility of adding new knowledge and new rules is also provided. All this enables the configurator to link customer requirements and offers the possibility of selecting one or more products. In addition, it evaluates possible product variants based on the parameters specified by the user. The graphical representation of the results obtained includes the product technical documentation as well as a matrix representation of all the selected components and modules. The functional principle and evaluation of the product selection are demonstrated using a case study of a chiller for installation in an industrial plant. During the selection and evaluation of the chiller, better system performance is achieved with a chiller that has a water-based condenser.

Keywords: product configurator architecture, fuzzy inference rule, matrix representation, CCM methodology, product selection.

INTRODUCTION

Considering the development of products in a certain area, such as the development of chillers, there are many competing companies on the market nowadays that offer similar products in regarding of cooling power, electricity consumption, energy efficiency class, and device dimensions and mass [1]. The conditions for obtaining cooling energy are becoming increasingly complex. In addition, deviations in selecting the desired device should be minimised. For this reason, many variants of similar devices have been developed. In addition to quality, which is undeniable, special attention is paid to the impact on the environment [2]. Therefore, the construction of these devices must be carried out flexibly. As new materials are developed every day, the aim is also to reduce the mass of the device [3], both for transport and its subsequent placement. Devices are ordered per piece and are therefore of great importance to configure them according to the wishes of individual users. Given the large fluctuations in product families, caused by frequent changes in standards related to the use of working fluids, many products are withdrawn from production after just a few years. The user expects the manufacturer to be able to supply spare parts throughout the entire life cycle of these products [4].

In this regard, companies try to offer their users the possibility of choosing the desired device and configuring it in a way that someone who does not possess a high level of technical knowledge can do. Computer programs of individual manufacturers have been developed, which offer

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users with non-technical knowledge the possibility of offering and choosing several device variants, according to some input parameters, with a description of the individual product, as well as a display of parameters and their price [5]. Additionally, its appearance is offered graphically and interactively with a picture, as well as a diagram of the device with a display of possible installations. It is also possible to graphically represent potential changes in the configuration, after harmonizing customer requirements with possible engineering characteristics. These programs are called product configurators and integrate the principle of an expert system with a knowledge base and a built-in set of rules for product selection. Furthermore, there is also the possibility of checking consistency, supplementing the knowledge base with new data, and maintaining knowledge, etc. Another option offered is the knowledge to recognize the problem based on similar previous cases and offer the most favourable one when choosing. For this reason, two co-approaches to expert systems, rule-based and case-based, are combined [6]. According to studies conducted, many engineering-oriented companies have benefited greatly from this type of expert system in recent years. This is primarily reflected in improved product offer quality, faster offer preparation, and fewer errors in product technical specifications [7].

This work aims to present a product configurator. The configurator is designed as an advisory system, which is adapted to users without much technical knowledge of water coolers. In addition to the knowledge base, and by selecting products using a base of built-in rules based on fuzzy logic, a base of possible similar scenarios is presented. All the knowledge bases in the program can be updated with new data and rules. The significant advantage of its program is the ability to display graphics in matrix form, where you can see the connections of all components, subsystems, and modules. Additionally, it is possible to change customer requirements and evaluate several possible product variants according to the selected requirements. All this is shown in the case study of choosing a chiller.

LITERATURE REVIEW

The available literature includes numerous works that address the topics discussed in this article. Based on the author's selection, only the most important ones are listed below.

Blecker and coworkers [8,9] provide an overview of the area by analysing product configurators. In addition, suggestions are made for possible extensions that focus on product configuration through counselling. A framework is developed with the most important requirements for such a system and the technical infrastructure required for its implementation. Antonelli *et al.* [10] demonstrate the application of concepts taken from object programming paradigms in the creation of product configurators. Class attribute inheritance is used, and a hierarchical approach to product customization is implemented. Haug *et al.* [11] present a study on the use of product configurators and how their use reduces the time required to create quotations with technical product data. For this purpose, the study was conducted in 14 engineering-oriented companies. Haug *et al.* [12] define and compare seven different strategies in the context of product configurator development. Each of the strategies was defined through a search of existing literature, examples already presented in the industry, and based on the author's experience. Haug *et al.* [13] analyse cost estimation and the benefits of using product configurators in different scenarios. A framework has been developed with which this can be assessed. The framework includes models for the relationship between the costs and benefits of configurators. It is analysed by using case studies from five projects. Shafiee *et al.* [14] analyze product configurators in terms of understanding the difference between the problem space and the solution achieved with the Design Thinking method. As an example, 4 projects were analysed, 2 of which were developed using the Design Thinking method and 2 of which were not. The study was conducted in the form of workshops and interviews. The environment was created with integrated Design Thinking techniques, involving a structured manner to support industrial companies. Poot [15] showed the development of a framework with a design automation model for mass customisation of lightweight structures. This model uses high-level templates from CAD programmes in combination with auxiliary techniques for design optimisation and tools for production preparation. Workalemahu *et al.* [16] presented an investigation on the application of product configurators in generating customer technical specifications for complex body geometries intended for production via additive manufacturing.

Nummela [17] presents configuration matrices, the idea of which is to establish the connection between the components in the modular structure of the product in matrix notation. In this way, new knowledge sets can be added during the subsequent development of new product platforms or the analysis of existing ones. Johansson and Krus [18] present an approach based on matrix representation that utilizes configurable matrices in system engineering. The approach is suitable for use in large and complex systems. It is demonstrated using the example of a model construction for a small business aeroplane. Helo [19] explores the structure of the system for the configuration of academic and non-academic works. For this purpose, the DSM method was used for configuration modelling. The DSM method enables the representation of the structure of components and subsystems in the observed system using graph theory. It provides a matrix representation in which components with the fewest interactions are positioned along the main diagonal of the matrix. This arrangement allows the distribution of individual subsystems, or modules, to be visually identified. The idea is to obtain an easily configurable product model that is flexible in terms of further customisation and changes. Germani *et al.* [20] implemented a multi-level DSM method for formalising the product structure in the product configurator. Their idea was to develop a method that is simple and robust enough to represent the product structure. The validity of the approach was tested using the example of domestic boilers. Gopsil *et al.* [21] propose a model for the automatic generation and updating of

DSM matrices. The generation and updating are linked to the development process by monitoring changes in the available digital product models. In this way, the reduction of time required for knowledge collection was aimed at, and its updating in matrix DSM structures.

Osman *et al.* [22] present the beginning of their research in the field of product configurators. The paper introduces the principle of configuration matrices for storing product data and proposes a product configurator architecture based on this principle with a description of its components. Osman *et al.* [23] showed an iterative approach for the configuration and evaluation of chillers, which is referred to as Configuration and Change Management (CCM). The above approach is methodological, enabling product configuration through steps. This allows the selection of individual product modules depending on their purpose. In addition, it allows changes in the product configuration. The idea of the approach is to obtain the so-called optimal chiller system architecture according to predefined criteria. Osman *et al.* [24] represent a behaviour framework and mapping data between the structural and behavioural domains in studying the behaviour of the system of air handling unit variants during different modes of operation. In doing so, some of the fuzzy rules for the behaviour of the system were created by combining the automatic control method and stability check with the direct Lyapunov method. Finally, Osman *et al.* [25] show the continuation of research in the field of product configurators. The performance of a customer-oriented product configurator is presented. The dataset is based on configuration matrices to represent the modules of a single product. A case study on the configuration, evaluation, and selection of chillers is presented.

The contributions of this work are as follows:

- The system is designed so that it can be used by users without in-depth knowledge of a particular technical field.
- Through simplified dialogue boxes, it guides the user to the desired product configuration.
- The collection and modification of product data is enabled by the so-called matrix data set using the component-based DSM method, i.e., configuration matrices.
- The knowledge data set contains similar cooler configuration scenarios for a specific application, which can be supplemented and modified.
- The matrix set enables a graphical representation of the connection of all components and subsystems in the chillers.
- The system has a base of inference rules based on fuzzy logic that can be added to.
- The inference rules can also be changed or new ones added in the case of new chiller variants.
- The system can assist in generating technical documentation using a database of CAD models, schemas, and technical specifications for each product.
- The selection can be saved for possible later changes and for future use when selecting products with similar technical characteristics.

DESCRIPTION OF ADVISORY-BASED PRODUCT CONFIGURATOR ARCHITECTURE AND REASONING PROCESS

The configurator (Fig. 1) works in such a way that it is customised to the user, i.e., it is a customer-oriented or advice-based system. This means that product selection can also be made by a person who does not have in-depth technical knowledge in this area. The user is addressed through questions in the so-called dialogue windows, through the consultation process. Simple, easy-to-understand questions are asked to guide the user to the type of product and some basic parameters that are important for product selection. It was created in an interactive way that guides the user in a simplified way to the selection of the desired and optimal product type. The so-called modelling of customer interests to improve the customer's wishes. Customer preferences are processed using the so-called mapping technique, i.e., filtering processes that are translated into technical requirements. An adequate transformation is ensured to later validate the product. The customer requirements must be recognised. The reverse is also possible. In addition to searching for existing data in the knowledge base, there is also the possibility of web mining to discover existing and new structures, patterns, and knowledge about similar products. This technique is based on the principle of a web application that helps the user search for data on the web. The mapping technique is an automatic process that selects product attributes based on implemented inference rules or according to the principle of data grouping. It also ensures that no inadvertent error has been made in the interpretation of customer queries during the validation process. It is possible to update the product by adding new components or subsystems to enhance technical specifications. During the entire interaction time, a web metric runs in the background to measure the performance of the web services used.

An in-built module automatically generates the web graphical user interface (GUI) for system communication with the user. A data repository (Fig. 1) is a knowledge base that contains implemented data on the following topics: product knowledge (including its characteristics and properties), user data, and derivation rules for retrieving product knowledge. Throughout the entire consultation process and communication between the configurator and user, the integrated CRM system (Fig. 1) is utilized to support and manage the user's wishes and any technical requirements.

It is also used to store the data obtained through the web mining process. As already mentioned, the advisory system communicates with the user via the so-called non-technical language to translate their requirements into technical features.

The system also includes a so-called decoupling interface (Fig. 2), which can be interpreted as an abstract layer that serves to separate the advisory system from the actual computer configurator. It also allows direct access to the configurator and offers the possibility of changing the proposed variants by adding new components or subsystems to the configuration.

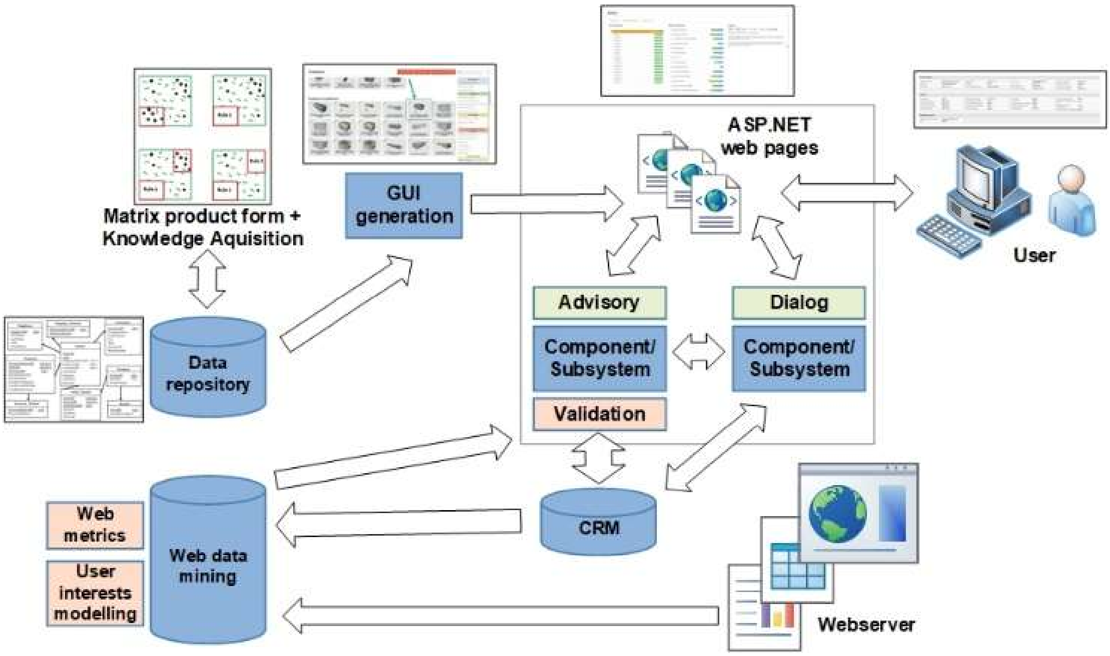

Figure 1. Simplified architecture schema of advisory-based product configurator.

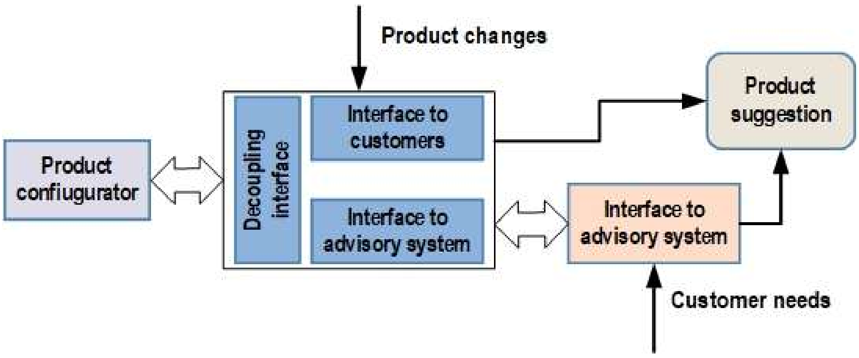

Figure 2. Block diagram for the connection between the customer advisory system and product model [9].

The user communicates with the advisory system via the following steps (Fig. 2) [26]:

1. The attributes contained in the product model are imported into the system's data repository.

2. The data collected during the consultation process is used as input data for the initial selection of the product configuration and the proposal of its possible variants, the so-called product suggestion phase.

3. The results obtained during the product configuration in the previous step are re-imported into the consulting system to provide the user with a proposal for the product variants created. Improvements can also be made to the proposed variants, known as the product change phase.

The component matrix or configuration matrix [17,18] based on the DSM method makes it possible to record components, processes, and other activities related to product development in the form of a diagram. The graph is visualised in the form of a matrix, with clusters around the main diagonal representing the components with the least interaction in the observed system. The graph illustrates very clearly: for some of the observed products, i.e., their variant, it is possible to observe several variants of the same product, which allows for new data sets or changes to data sets. It is also possible to display an advert only for a specific customer or group of customers, and it is possible to display the status of the desired product in stock and the number of pieces available. It can be seen from the illustration that changes in the matrix record are influenced by changes in sales and marketing as well as changes in the design and production process. Changes of this kind are irreversible, i.e., a reverse effect is possible, and is graphically visible in the matrix record. All changes during the sales and marketing processes are visible in the configuration matrix. In addition, changes in product design and production are also visible. Changes in the product structure, i.e., between its modules and individual components, are particularly clear.

A reasoning system based on created inference rules that contain fuzzy logic according to the Mamdani principle was shown in Fig. 4. The knowledge base contains inference rules that can be added to or changed at any time, depending on the changes the manufacturer makes to a particular product type. The reasoning steps are as follows [27,28]:

1. Softening or Fuzzyfication,
2. Inference or fuzzy decision process,
3. Sharpening or defuzzification,
4. Local and global reasoning - possible step.

All of the above processes interact and can exchange information with each other. These parts of the reasoning system are dynamically linked so that a change in one of them is automatically registered in the others.

1. *Softening or Fuzzyfication* - the input variables and the output variables are selected based on the defined influencing variables. For each variable, the number of linguistic values and the definition range of the above-mentioned variables are determined. The definition range is determined for each variable. In addition, the number and form of the membership functions that cover the definition range of the individual linguistic variables are determined. A membership function (MF) is a curve that defines the degree of membership of each point in the input space (universe of discourse). It assigns an associated value between 0 and 1 to a point in the input space. This is essentially the only condition that a membership function must fulfil in reality. The membership functions of fuzzy sets μ_A are always normalised, which means that the maximum value of the membership function is equal to 1. The form choice of the membership functions in individual fuzzy sets is subjective and depends on the problem under consideration. There are several softening functions in the Mamdani logic, of which the centre of area or centre of gravity method is the most commonly used. A linguistic variable is a variable that takes words or sentences as values.

2. *Inference or fuzzy decision process* - fuzzy inference rules are created depending on certain input and output variables. By creating behavioural rules, a rule base is created in the form of fuzzy IF-THEN rules. For each fuzzy rule, a logical operator and a weight of the fuzzy rule are selected. Known logical operators are AND, OR, and NOT. The output membership function μ_{agg} is obtained as an aggregation (combination) of the above rules.

3. *Sharpening or defuzzification* - the fuzzy output sets are converted into unique output values. There is no single method of defuzzification, but there are many methods, the most commonly used of which is the centre of area method. The results of sharpening could be presented in tabular form as rules or by graphically using the surfaces.

4. *Local and global reasoning* - possible step - the possible graphical representation of all the defined fuzzy rules, with the visualisation of their membership functions, was local reasoning. The graphical three-dimensional (3D) representation of two influential input variables and an output variable is called global reasoning.

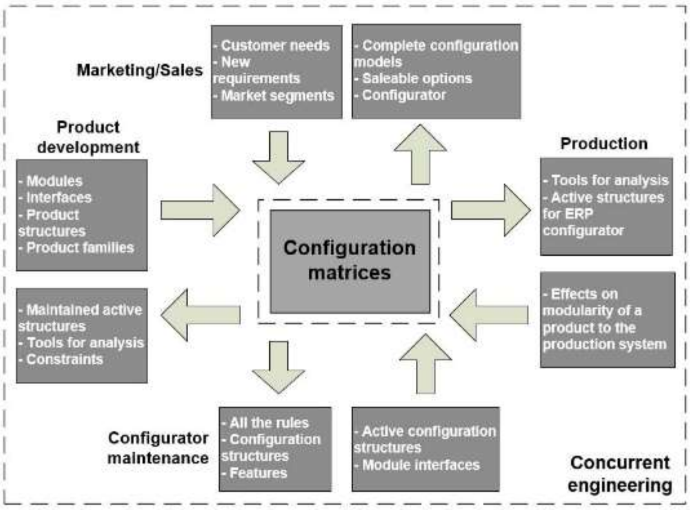

Figure 3. Influence on configuration matrix [17,22].

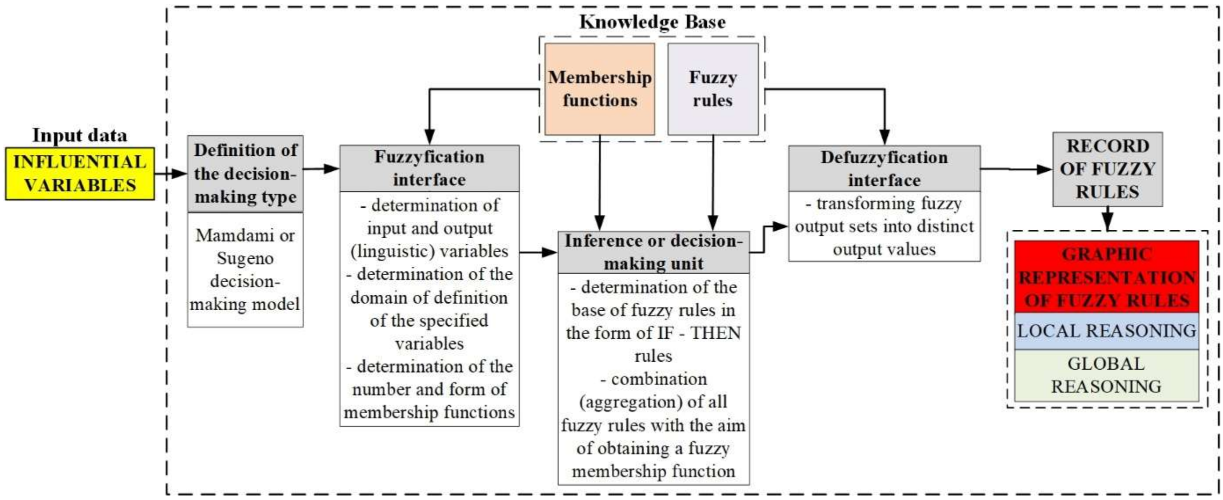

Figure 4. Reasoning system with inference fuzzy rules [24].

The Configuration and Change Management (CCM) approach (Fig. 5), which is implemented in the product configurator and used here for the selection and evaluation of cooler product variants, is described in more detail in [23]. Only the most important phases of the approach are briefly described below. The main phases are:

1. *Configuration* - an attempt is made to select and propose the most acceptable variant according to customer requirements. It is possible to propose several product variants in the first step, which differ in some characteristics.

2. *Changes* - by changing some parameters and adding or removing elements or subsystems, changes can be made. The result is systems with better values for some parameters, e.g., *EER*, operating mass, or *SPL*. To improve the desired parameters, it is sometimes necessary to change the customer requirements.

3. *Evaluation* - comparisons and evaluations are made based on the selected parameters. The chiller solution with the highest sum of all ratings for a given observed parameter is selected as the acceptable and optimal solution.

CASE STUDY - CHILLER SELECTION

The validation of the previously described approach is demonstrated on the case study of a chiller selection for an industrial plant.

The following customer requirements were drawn up with the help of the investor:

- The water cooler should operate at full thermal capacity for 16 hours a day without interruption; the rest of the day, it should operate at reduced capacity (about 60% of capacity). It must function independently of changing external conditions in all operating modes (winter, transitional, and summer operation).
- There is the option of external installation (on the roof of the building) or internal installation of the chiller (in the cooling station). In the case of external installation, it must be protected from external influences.
- The noise level must be taken into account to ensure quiet operation of the device.
- Try to select the highest possible energy class for the device.
- The technical requirements were drawn up based on customer requirements:
  - Guaranteeing the operation of the device at low winter temperatures (down to -21 °C) and at high summer temperatures (up to 50 °C);
  - An uninterrupted power supply must be ensured during operation of the device (3x400 V, 50 Hz).
  - When selecting the appliance, aim for the highest possible energy class according to Eurovent.
  - The appliance should not have a hydraulic modular subsystem.
  - The appliance must be insensitive to vibrations during operation.
  - During the selection of a chiller, make sure that you choose the device with the lowest possible power consumption.
  - Also, during selection, make sure that the dimensions (and thus the mass) of the device are as small as possible.
  - Assume a value of 870 kW as the input requirement for the heat output, with the option of increasing it by up to 15%.
  - Assume a value of 70 dB(A) as the input requirement for the upper value of the permissible noise level.

The input parameters used during the first selection of variants are: cooling capacity *Q*, permissible noise level *SPL,* and permissible dimensions of the space ($L \times W \times H$), where the chiller would be installed.

During the first step of chiller selection, both installation options were considered. Chillers for outdoor installation (with an air-cooled condenser) and one for indoor installation (with a water-cooled condenser) were selected. Table 1 shows the parameters for both chiller variants that were determined during the selection in the first step.

Table 1. Initial step during chiller selection.

Parameters	Type of chiller	
	Air-cooled	*Water-cooled*
Q [kW]	862.2	867.6
EER [kW/ kW]	3.3	5.07
ESEER	4.4	6.22
N_{el} [kW]	284.8	176
SPL [dB(A)]	66	66
Dimensions [$L\times W\times H$] [m]	8.3×2.2×2.5	3.6×1.6×1.9
m [kg]	7040	5650
Energy class	B	B

A three-dimensional view of a chiller with an air-cooled condenser is shown in Fig. 6 (on the left side), while Fig. 6 on the right side shows a three-dimensional view of a chiller with a water-based condenser.

Already during the first selection step, it became clear that the water-based chiller has much smaller dimensions, as well as the weight of the device, and lower electricity consumption. As the customer wanted the chiller to be in energy class A, some changes were made to the product configuration, and a further validation step was carried out.

Two further validation steps were then carried out, in which a slightly larger cooling capacity was required. Variants were also obtained whose dimensions correspond to the original installation requirements, and are all designed in energy class A. Also, during the next steps of device selection, the aim was to select the one with a higher *EER* coefficient, as well as smaller device dimensions and lower weight. However, selecting a device that would be in energy class A entails an increase in the thermal capacity of the device and its dimensions. All the chiller variants selected in these 3 validation steps are listed in Table 2. As can be seen in the table, the increase in dimensions of a water-based chiller is insignificant compared to a chiller with an air-cooled condenser.

Based on the many values of the observed parameters obtained through several selection steps, it is not possible to simply make a selection, but it is necessary to carry out

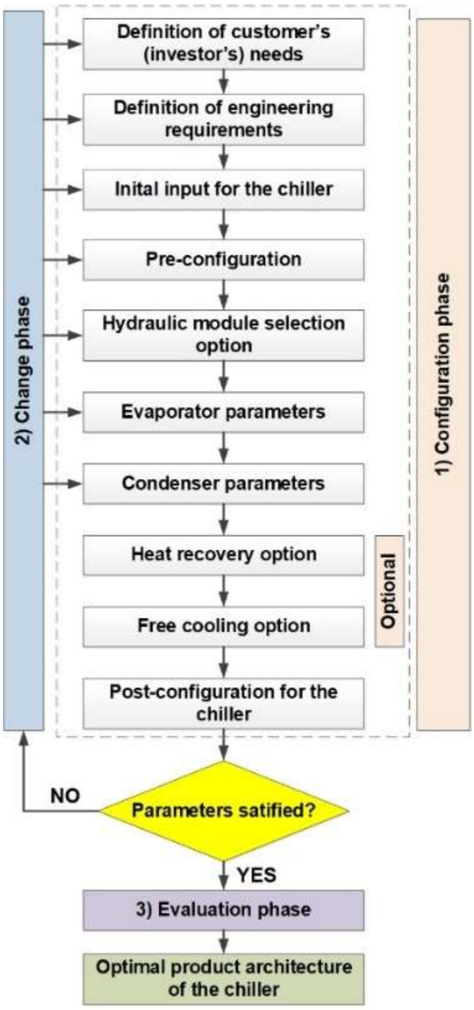

Figure 5. CCM approach [23].

Figure 6. 3D view of chillers: air-cooled chiller (left), water-cooled chiller (right).

Table 2. Several steps during the changes phase in the chiller selection process.

Parameters	Type of chiller					
	Air-cooled	*Air-cooled*	*Air-cooled*	*Water-cooled*	*Water-cooled*	*Water-cooled*
Number of iteration steps	2	3	4	2	3	4
Q [kW]	862.2	965.3	946.9	877.9	925.5	925.5
EER [kW/ kW]	3.03	3.1	3.14	5.36	6.02	5.85
ESEER	4.4	4.54	4.62	6.4	6.85	8.55
N_{el} [kW]	284.8	311.1	307.5	176	160	165
SPL [dB(A)]	63	64	61	66	66	66
Dimensions [$L \times W \times H$] [m]	8.3 × 2.2 × 2.6	10.1 × 2.2 × 2.8	10.1 × 2.2 × 2.8	3.6 × 1.6 × 1.9	4.1 × 1.6 × 1.9	4.1 × 1.8 × 2.0
m [kg]	7200	7298	5650	5790	6550	6750
Energy class	B	A	A	A	A	A

an evaluation step. The selection of the optimum type of chiller is shown in the evaluation step (Table 3). This was done by comparing the two most acceptable cooler variants for both installation methods. Depending on the values for the comparison parameters, scores of 1-10 were given. A score of 10 is the best possible score for the observed parameter. The scores in the columns were then totalled and displayed in the SUM (Σ) row.

Table 3. Evaluation step during the chiller selection process.

Parameters	Type of chiller			
	Air-cooled		*Water-cooled*	
Q [kW]	10	9	9	9
EER [kW/ kW]	9	10	10	9
ESEER	9	10	9	10
N_{el} [kW]	8	10	10	9
SPL [dB(A)]	8	10	7	7
Dimensions [$L \times W \times H$] [m]	5	5	9	9
m [kg]	6	6	10	8
Energy class	10	10	10	10
SUM (Σ)	65	70	74	71

In the evaluation process, 2 variants of air-based chillers and 2 variants of water-based chillers were considered. Two chiller variants with a water-based condenser were proposed as the final solution. Regardless of the price of the device, a water-based chiller was chosen due to its smaller dimensions, lower weight, and better *EER* coefficient. In addition, maintenance of the device should be taken into account, which is cheaper due to its internal installation.

The product configurator can also be adapted and extended for configuring other products (e.g., air conditioning units). This would require minor adjustments to dialog boxes, due to different input data and descriptions. In addition, it would be necessary to expand the knowledge base and include information about new products, such as CAD models and device schematics.

VALIDATION OF USER TESTING

To validate the configurator's performance, a survey was conducted by non-technical users. Fifteen users participated, each completing a questionnaire with ten questions about the use of the product configurator. The survey used a Likert scale with ratings from 1 to 5: 1 - Not Satisfied, 2 - Satisfied, 3 - Good, 4 - Very Good, and 5 - Excellent. The results of the survey are presented in Table 4, showing, by question, the percentage of users who selected each rating.

As shown in the attached Table 4, most non-technical users answered Excellent or Very Good. There are no unsatisfied responses in the survey. This confirms that the configurator is suitable for users without technical knowledge of the product. Additionally, only a relatively short time is needed to complete the desired selection, including any additions or corrections in configuration.

Table 4. The percentage of user responses in the survey conducted.

Questions in the survey	Percentage and number of user responses in survey [%]				
	Excellent	*Very good*	*Good*	*Satisfied*	*Not satisfied*
Q1: How do you rate the dialogue windows in the programme that guide you to the final solution?	40 (6)	33.3 (5)	13.3 (2)	13.3 (2)	0
Q2: How do you rate the accompanying graphics that assist you during product selection?	46.7 (7)	33.3 (5)	20 (3)	0	0
Q3: How do you rate the clarity and description of each step, enabling you to proceed to the next step?	46.7 (7)	40 (6)	13.3 (2)	0	0
Q4: How do you assess whether a sufficient number of steps have been provided to allow you to easily reach the final solution?	53.3 (8)	33.3 (5)	13.3 (2)	0	0
Q5: How do you rate the ability to select accessories during product selection?	60 (9)	33.3 (5)	6.7 (1)	0	0
Q6: How do you rate the quality of the files generated after product selection?	60 (9)	26.7 (4)	6.7 (1)	6.7 (1)	0
Q7: How do you rate the ability to make configuration changes during and after product selection?	53.3 (8)	33.3 (5)	13.3 (2)	0	0
Q8: How do you assess the duration of the selection process to reach the desired solution?	46.7 (7)	33.3 (5)	13.3 (2)	6.7 (1)	0
Q9: How do you rate the ability to save the selections made and the files created?	46.7 (7)	40 (6)	6.7 (1)	6.7 (1)	0
Q10: How do you rate the performance of the entire computer programme for configuring chillers?	60 (9)	33.3 (5)	6.7 (1)	0	0

CONCLUSION AND FUTURE RESEARCH

The article presents the architecture of the product configurator, which is structured as an advisory system. The functionality, data recording, and selection and evaluation of the chiller using the integrated CCM methodology were demonstrated. The research presented in the paper brings the following:

- Data retrieval is performed by a combination of mapping techniques and fuzzy rules.
- The product configurator enables the addition of the knowledge base.
- It also has the option of selecting based on a similar scenario.
- The configurator is designed in such a way that it can also be used by users who do not have in-depth specialised knowledge.
- Dialogue windows guide the user step by step to the final solution.
- The knowledge about chillers is recorded in a matrix record using the component-based DSM method.
- The CCM methodology enables the configuration and evaluation of the chiller and possible changes at the same time.
- The preparation of technical documentation.
- Matrix display of all connected components, subsystems, and modules.
- Better system performance is achieved with a chiller with a water-based condenser instead of a chiller with an air-cooled condenser.
- The option to save the completed selection as a file, to accommodate potential changes or additions to the configuration, and for possible future selections of similar products.
- Possible directions for future research are:
- A more detailed development of the knowledge base.
- Expansion of the configurator for use when selecting other products in the field of equipment for HVAC systems (e.g., air conditioning units).

NOMENCLATURE

Acronyms

CCM - Configuration and Change Management
CRM - Customer Relationship Management
DSM - Design Structure Matrix
GUI - Graphical User Interface
MF - Membership Function

VARIABLES

EER - Energy Efficiency Ratio [kW/kW]
$ESEER$ - European seasonal energy efficiency ratio
$L \times W \times H$ - chiller dimensions (length×width×height) [mm]
m - operating chiller mass [kg]
N_{el} - total electrical power input [kW]
SPL - sound pressure level at 10 m [dB(A)]
Q - cooling capacity of chiller [kW]
μ_A - membership function of fuzzy sets
μ_{agg} - output membership function

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NAUČNI RAD

KONFIGURATOR PROIZVODA ZASNOVAN NA SAVETOVANJU, KORIŠĆEN U KONFIGURISANJU I EVALUACIJI RASHLADNIH SISTEM

Ovaj članak predstavlja arhitekturu i funkcionalni princip konfiguratora proizvoda zasnovanog na na savetovanju. Program se koristi za kreiranje novih i modifikovanje sličnih konfiguracija proizvoda i namenjen je korisnicima bez većeg stručnog znanja u tehničkim oblastima. Zbog svoje arhitekture, konfigurator je dizajniran da koristi znanje uskladišteno u bazi znanja. Izbor se zasniva na kombinaciji fazizih pravila zaključivanja i tehnika mapiranja. Znanje o proizvodu se sakuplja korišćenjem matrica zasnovanih na komponentama. Takođe je obezbeđena mogućnost dodavanja novog znanja i novih pravila. Sve ovo omogućava konfiguratoru da poveže zahteve kupaca i nudi mogućnost izbora jednog ili više proizvoda. Pored toga, procenjuje moguće varijante proizvoda na osnovu parametara koje je korisnik naveo. Grafički prikaz dobijenih rezultata uključuje tehničku dokumentaciju proizvoda, kao i matrični prikaz svih izabranih komponenti i modula. Funkcionalni princip i evaluacija izbora proizvoda demonstrirani su korišćenjem studije slučaja rashladnih sistema za industrijska postrojenja. Tokom izbora i evaluacije rashladnog sistem, bolje performanse postrojenja se postižu rashladnim sistemom koji ima kondenzator na bazi vode..

Ključne reči: arhitektura konfiguratora proizvoda, pravilo fazi inferencije, matrična reprezentacija, CCM metodologija, izbor proizvoda.