July-August 2020
ISSN: 0193-4120 Page No. 4451 - 4464

Approach of Knowledge-intensive Support and Fuzzy FMEA for System Development: Application for Product Design

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Abstract
In the trend of variant global market, to promote the product competitiveness, researchers and companies have persistently seeking out the optimal ways regarding product development. This study investigates the suitability of knowledge system methodology to current competitive product development with high-quality demand in the design phase. Also an assisted architecture with knowledge-intensive method for new product development is presented. According to the above mentioned methodology and approach, a prototype platform is generated and implemented. Meanwhile, the results are validated by using a fuzzy DFMEA evaluation approach. Because this proposed system can support novice designers to execute quality improvement, evaluate design alteration and select appropriate materials, it enhances the robustness of products in early design phase. Finally, an instance is depicted and discussed by applying the prototype system.

Keywords:*Knowledge-intensive support, Product development, DFMEA, Modular design.*

I. INTRODUCTION

Product design is extremely important for satisfying customers' demands and enhance the product quality and processing. Enterprises, particularly desire to keep the competitive advantage, expect to reduce the lead times of design and manufacturing through the automation of design procedure. Thus, the generation of computer support design system is turning into an important issue in academia and enterprise. In this study, the goal is to explore the methodology and technology of knowledge support in an integrated modular design process for New Product Design (NPD). There are several portions involved in this process: generation of customer demands, development of product architecture, construction of product platform, and product evaluation. A knowledge-intensive support product design framework is proposed to assist novice designers to execute the analysis and decision of product in the early design phase. This study is organized as follows: the background and related researches of product development are surveyed in Section 2. The architecture of product design with knowledge-based support is outlined in Section 3. The related topics and technologies to implement the method of knowledge-intensive support is addressed in Section 4. The last section makes a summary and depicts future issues.

July-August 2020
ISSN: 0193-4120 Page No. 4451 - 4464

II. LITERATURE REVIEW

Design with Knowledge-Driven Mode

Regarding development of a knowledge-based system, its methodologies are created on the basis of multiple models that connect the gap between a notional pattern and an execution. The transformation process between the patterns is structure-preserving, i.e. the structure and content of knowledge in the notional pattern are maintained all over the intervening patterns to the eventual execution. The main advantage is that the transformation between them becomes simpler and semi-automatic transitions are possible when two models possess a corresponding structure. This is very helpful for validating and verifying the models except modifications easily. The structure and character of the various models have been addressed in previous study in knowledge engineering, e.g. MOKA [1], UDeKAM [2], CommonKADS [3], and involve the succeeding: a notional pattern is devoted to catch the knowledge in an unofficial but structured manner. It depicts the various categories and characters of knowledge in inferring activities. Also it assists original KBS description and person's comprehension. A formal pattern compiles knowledge in a representative form with a proclaimed semantics and a mathematical basis. It accepts to remove paradoxes and inconsistency from the notional model and enables regular validation and verification. A design model is regarded as an effective representation of the notional model or/and formal model on a computer. It indicates the approaches, the data structure and the framework of the objective application. In addition, it also takes down the criteria for the selections made [4].

Meanwhile, researchers started to utilize KBS method to deal with the problems of engineering design [5]. A general review of KBSs was proposed for engineering design. But, they just considered definite portions of the entire design. For instance, a KBS on pneumatic diagnostic system that enables engineers to achieve the goal of optimal design [6]. A domain knowledge based methodology was developed to assist the problem-solving in product design phase [7]. In the phase of conceptual design, designers generally confront many situations in product features and demands, such as attributes, materials, dimensions and functions. The eventual resolutions made in this phase have significant effect on entire cost [8].

Evaluation-Aided Module for Design

An approach of risk assessment, FMEA (failure mode and effect analysis), offers a structure for analyzing the possible causes and effects about product failures. It is necessary to combine a cross-functional group from various disciplines, such as design, manufacturing and quality, to entirely check and quantify the relationships among different features, e.g. causes, results, failure modes, etc. Generally, there are three variables of failure mode evaluated: frequency of happening (h), severity (s) and detectability (d). A common evaluation module offers a value between two positive integers for each of the three variables. By applying the formula of RPN (risk priority number), i.e. RPN = $h\times s\times d$, the group can recognize the components or procedures that require the priority activities for product development.

It may be not easy to exactly decide the probability of failure events while implementing FMEA [9]. A lot of information of FMEA is represented in linguistically. Besides, an evaluation on multiple states is qualitatively depicted by natural language, e.g. *Feasibility*, *Harmlessness* and *Reliability*. It is often difficult to assess the linguistic parameters objectively. In conventional FMEA methodology, the difference and specialty of group are the chief deliberations, traced through learning for the group actors. The effects on a high expenses. Meanwhile, it is difficult to share knowledge and experience among group members of various domains for

July-August 2020
ISSN: 0193-4120 Page No. 4451 - 4464

industrial practitioners. This certainly obstructs the employment of FMEA in many fields.

Many activities of decision-making are too complicated to be comprehended easily. The researchers, however, succeed through applying knowledge which is ambiguous rather than accuracy. For example, A decision assist platform for product design was addressed in concurrent engineering. It was used to analyze the properties of multiphase assessment, fuzzy and decision making in the procedure of product development [10]. The usability of KBS technologies and fuzzy-logic based framework was investigated to competitive product development in the early design phase [11]. The product modeling and decision assist module toward product design was mentioned within which product retreated topics.

To solve the above problems suffered in present frameworks and improve present approaches for product design and the traps and challenges that presently prevent an extensive utilization of KBE[73], this study addresses a modeling of knowledge-intensive design and assist system and generates a web-based support framework to aid users for making quick and smarter decisions in design procedure. Meanwhile, an architecture of fuzzy assessment for product design is presented. According to the presented methods, a subsystem prototype for supporting design decisions is developed, which could assist to promote product firmness in the earlier design phase.

III. THE FRAMEWORK OF KNOWLEDGE-INTENSTIVE SUPPORT PRODUCT DEVELOPMENT

The Structure of Knowledge Support and Vital Items

Fig. 1 illustrates the process of product concept development, there are three stages included: generation of concept, development and assessment, and filtering of concept. Knowledge-oriented support schemes are presented for assisting decision-making all over the entire process of notion generation. In the stage of product concept generation, a list of client demands is reviewed and conducted according to the client inputs. While the requirements are confirmed, the design elements and corresponding specifications are normalized as the inputs to the following stage. Referring to a product development strategy [12], there are two tiers included in the process of design demand review. The first tier is utilized to transform the client demands into coincident engineering properties, when the second tier shifts farther into the design procedure of part through transforming the engineering properties into crucial components properties.

Fig. 2 shows the two portion of the method that transforms the checklist of design demands into two main portions: part and product. The ability to track design and component elements requires back client demands is created through getting the properties from the head of the original frame and utilizing them as the left hand of the next frame. This procedure keeps till the result of specification of component and product.

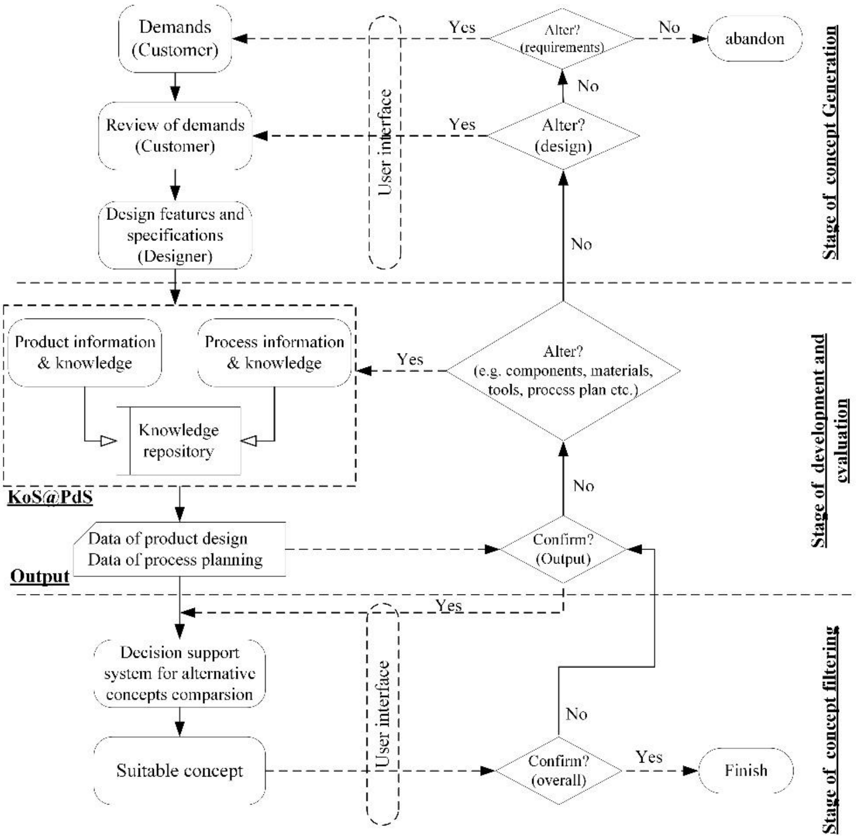

Fig. 1: Framework of proposed knowledge-orientedsupport product development system

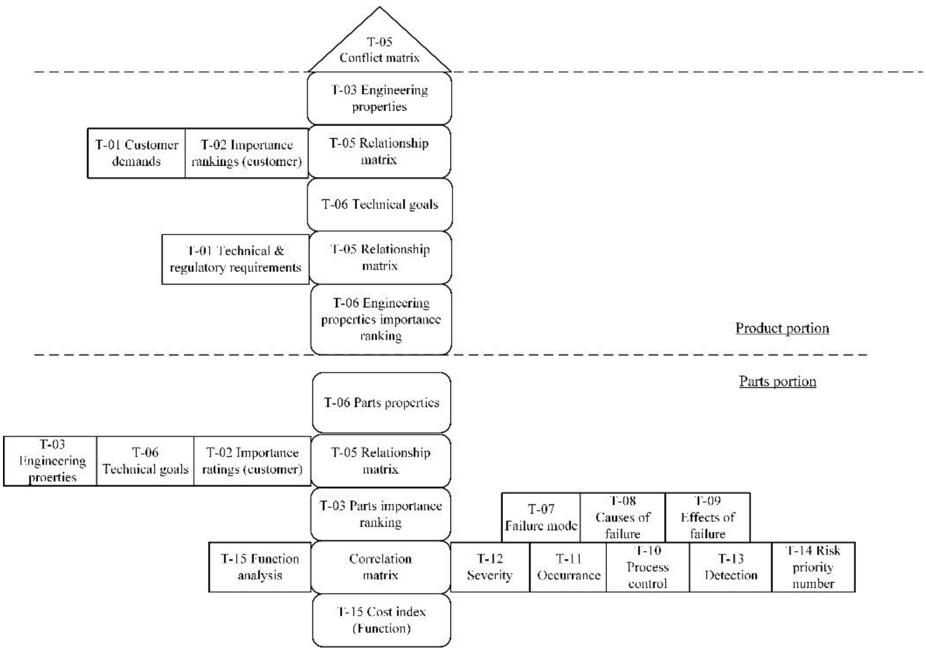

Fig. 2: Check list of product and its parts design review

July-August 2020
ISSN: 0193-4120 Page No. 4451 - 4464

As the above mentioned, the first tier of the checklist is employed to transform the client requirement into coincident engineering properties. Hence, it offers a manner of changing qualitative client demands, extracted from market assessment into quantitative engineering properties. The second tier shift farther return in the design process of part through transforming the engineering properties into crucial component properties. It is achieved by getting picked design demands from the first tier and carries them into the second tier. The design disposition are component properties. The second tier is utilized to farther assess the properties of respective component by disposition of reliability and cost. For each component properties, coincident fundamental capabilities and aiding capabilities are depicted as revealed on left hand of the list. By spreading the function depiction column for right hand, possible failure manners of each function are shown. According to the recognition of failure manners, the group discussion, i.e. brainstorm, is needed to determine what are the influences to user while the failure manner happens. Eventually, an initiatory risk evaluation on each function is acquired by the formula of RPN (as depicted in section 2.2).

In the stage of development and assessment, there are two subsystems presented. One is KBS for knowledge information decides the most proper features, such as parts, tools and materials, on the basis of concept and demands. Another is KBS for process planning determines the fabrication plan. Based on these results, the alternative notions can be contrasted with the help of a decision assist framework to verify the most appropriate case. As shown in Figure 1, a knowledge-oriented support framework (KoS@PdS) is proposed for estimating alternative design of product notions in the fields of part and material selection toward sound product design and process planning. Based on the present models of decision-making utilized, the KoS@PdS possesses a modular architecture to promote the accessibility of knowledge and to assure its expandability. A prototype fuzzy DFMEA module, named DdAS (design decision assisted sub-system), has been generated for selection of part and material.

Furthermore, there are two portions involved in design knowledge: product knowledge and design process knowledge. They are used to assist the planning and design of product. How knowledge is constructed and assist the product design will be depicted below. The knowledge assistance for product planning supports the designers to obtain the clients' idea and market tendencies, and putted them into the design goal for developing PDS (product design specification) and customizing products for clients' contentment. The knowledge assistance for product design supports designers to understand plentiful product variation to meet a group of customer requirements.

Modelling and Assistance of Product Design Knowledge

In accordance with the above mentioned knowledge assist plot, the execution of knowledge-oriented support product design can be reached by two stages: knowledge generation and process of knowledge assistance.

Represenation and modelling of design knowledge

The client's demands is the beginning of product design. The demands are fulfilled through a group of modules represented in the light of design parameters. The parameters of a module are send to the functional demands which are located on lower-layer entities of the module, till all the modules and entities are designated. Several knowledge issues are required in the product design procedure [13]: (1) dispose lower-layer modules with product functions; (2) choose the resolutions from the client or formal modules; (3) deploy all resolutions to be a final product. Next, the effect of them is evaluated to support the client and the designer for decision-making. The design knowledge has to be un-concreted and categorized into various classifications by applying design process analysis. Because design knowledge involves all data required all over the entire design procedure, a new model of product data has to be utilized. Its contents involve client demands, specifications, structures, assemblies, functions, etc.

The product storage may generally consist of types, structures, functions, constraints, assessment criteria, etc. Actually, an effectual approach to construct a model of product information representation is to combine two models, i.e. design process and database representation. According to the demands for designing product with highly commonality around reusable parts, two primary kinds of the architecture are included: libraries of reusable solution and specifications of universal product. Part architectures are treated as product architectures in the same manner, i.e. a hierarchical structure of structures is applied. Hence, parts can be combined into the framework after they are picked from the solution library. Fig. 3 illustrates the procedure (from Step 1 to Step 4) for creating product platform and the reuse about applications of definite field (Step 5). Thus, based on an integration of features of semantic relations with the OO information model, a multi-layer blended expression schema, such as notion layer, geometry layer, meta layer and instance layer, is used for representing the knowledge of design process in various design phases. To conduct and apply design knowledge effectively, a universalized matrix is addressed. In this matrix, all design activities are shown in columns and all design information are classified in rows. The contents for each activity and its design knowledge, they are listed in the related grid of the matrix with proper expressions. Furthermore, the representation of OO knowledge is on the basis of a merged representation approach and the techniques of OO programming, and permits engineers to examine the issue as an accumulation of sub-issues or objects connected together by norms. In case of the problem can be split into the type of enough designated, plainly operative pieces with self-involving messages, which is correlated by a bunch of constraints and norms, the problem will be readily settled. Through the module structure, the class and its instances of an object are described.

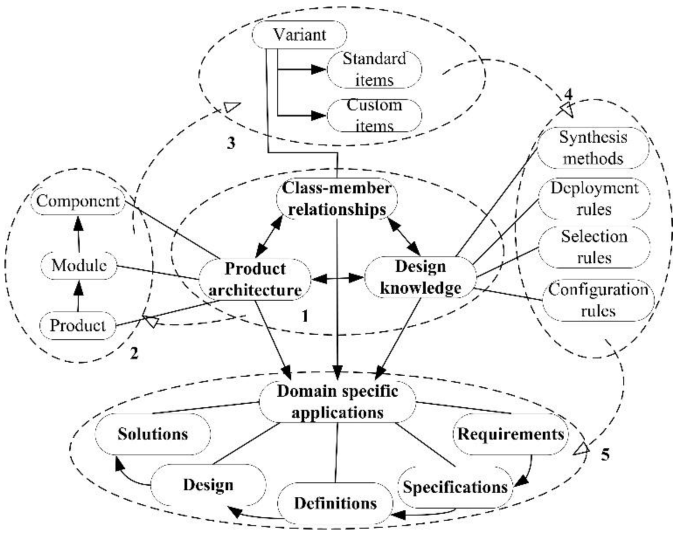

Fig. 3: Diagram for product platform construction process, representation and reuse

July-August 2020
ISSN: 0193-4120 Page No. 4451 - 4464

Evaluation of Product Design

The presented fuzzy evaluation pattern with design failure mode and effective analysis (DFMEA). Three main phases, fuzzification, defuzzification, and rule assessment [14], are included in this model to fulfil the evaluation. The pattern firstly applies linguistic parameters to describe the failure detectability, severity, and frequency of happening. Next, the partner grade in each import set is decided by fuzzing these imports. The resulting ‘fuzzy imports’ are estimated utilizing the fuzzy-logic operations and linguistic criterion repository to construct a categorization of the riskiness about failure mode and a related partner grade in the risk set. As for the ‘fuzzy export’, it is defuzzified to offer the priority of failure mode. To transform these imports, i.e. happening, severity, risk and detectability, into the fuzzy representations in the fuzzification phase, a crisp rankings is used. Next they can be met with the premise of the criteria in the criterion repository [14]. Applying linguistic parameters and the corresponding definitions, grading of happening, severity, detectability and risktowards the failure manner can be created in a rank principle. The ranks and the partner functions discern the extent of import parameters relevant to each fuzzy linguistic term.

The riskiness of each conjunction of import parameters is depicted in the criterion repository. It consists of the expertise with regard to the correlations between different failure types and consequences which are expressed with rule ‘IF-THEN’. Such sort of criterions are more easily defined in linguistic term than in numeral labels, and frequently represented as ‘IF-THEN’ statements that are conveniently executed through fuzzy conditional descriptions. The fuzzy rule includes two portions: a preceding term and a consequent term. For instance, ‘IF *w* is *T* THEN *r* is *V*’ where *T* and *V* are linguistic parameters described through fuzzy sets on the extents *w* and *r*, individually. The rule ‘*w* is *T*’ in the segment IF is named the premise or the preceding term, while the rule ‘*r* is *V*’ in the segment THEN is named the conclusion or the consequent term. The preceding term is a translation that responses a single value between 1 and 0, while the consequent term is an allocation that appoints the whole fuzzy set *V* to export parameter *r*.

In real employments, the fuzziness of the preceding terms removes the demand for an accurate meet the imports. The entirerules that have any fact in their hypotheses will dedicate to the fuzzy conclusiongroup. When the preceding term is real to several grade of partner, the consequent term is also real to be a function of the grade to which its preceding term meets the import. This results in a normal manner to join multi-qualitative evaluations. As regards DFMES, therefore, the fuzzy rules depicting the connections between failure manners and conclusions can be integrated in this aspect. The inexact correspondence offers a principle towards addition between probable import situations and furnish to minify the amount of rules demand to depict the I/O relation. An example of the rule base as revealed in the following is employed for the cruciality analysis.

If happening is *Moderate* and detectability is *Fair* and severity is *High* then the risk is *very-essential*. The significance of fuzzy rules derives from the truth that expert knowledge and experience can always be expressed with ‘IF-THEN’ format. Regarding the analysis of fuzzy criticality, the system represents the failure probability by frequency of happening, the failure criticality by severity and how a fault can be easily discovered by detectability. Rules that are based on these kinds of linguistic parameters are more real and representative than the other methods, e.g. the calculations of cruciality number and the ranking of numerical RPN. Meanwhile, the rules also accept quantitative data (e.g. probability of failure) and qualitative

July-August 2020
ISSN: 0193-4120 Page No. 4451 - 4464

data (detectability and severity) to be integrated in a regular way.

In the process of fuzzy inference, a Max-Min inferencing is applied to evaluate the rule consequences on the basis of the system import parameters [15]. The result is named the fuzzy consequence. The utility of a rule, called fact value, is decided as a result of the combination of the premises. With combination designated as *minimum*, then rule assessment makes up of deciding the minimized premise that gotten to be the fact values. Then this utility is used to whole results of the rule. In case of any fuzzy export is a result of over one rule, which export is assigned to the maximum fact values of the whole rules that involve it as a result. The consequence of the rule assessment is a group of fuzzy conclusions that respond the results of all the rules whose fact values are not zero.

A crisp ranking is constructed in the process of defuzzification from the fuzzy result set for representing the design riskiness in order to prioritize the design corrections and remedial tasks. It is necessary to indicate the denotation of the fuzzy results and their partner values and settle contradictions among various conclusions that may have been actuated while the rule estimation. As for defuzzification, it decidesthe cruciality grading of a failure mode, the approach of defuzzificationshould lead to a continuous extent of crucialitygrading, and deliberate the whole rules activated while the rule estimation in accordance with the factuality, i.e. fact grade.

Despite many defuzzification methods had been proposed, the best approach is not found for all domains [14]. One of the popularly utilized defuzzification approaches, barycenter, is adopted as it offers the arithmetic mean, weighted through their factuality, of the assist values on which entire the functions of membership which utilize achieve their maximum value.

$$G_c = \frac{\sum_{i=1}^{n} f_i . z_i}{\sum_{i=1}^{n} f_i} \quad (1)$$

Where G_c means barycenter of conclusions; f_i shows the factuality of the ith membership function; z_i reveals the support value at which the ith membership function achieves its maximum value (if functions of trapezoidal membership, it is got the center of maximal extent); n indicates the number of numerical risk conclusions.

Implemenation of DdAS

Referring to the proposed architecture (as shown in Fig.1),product specifications and its preparatory design elements can be acquired by the survey after the conceptual demands of product are imported by the users or company policy. For decisions, the requirement knowledge of reciprocal effects among several portions involving the demands of component design, selection of component/material, material cost, possible failure modes and RPN, which interact with each other. Meanwhile, there are five primary portions involved in the DdAS: GUI (graphical user interaction), properties import, exploring and ranking, and criticality evaluation. These portions are assisted through a database of knowledge and material. Fig.4 shows the implementation procedure and the associated depictions are listed below.

The preliminary list established in a hierarchical structure of product analysis from the review of design demand is import into the DdAS, as shown in Fig.2 Next, DdAS will deal with the evaluation of fuzzy cruciality on the presented parts. In this subsystem, the linguistic parameters are used to depictthe detectability, frequency of happening and severityfor the breakdown. The entire information in DFMEA can be expressed through the usually utilized triangular membership function. Regarding the happening, severity, risk and detectability, the assessment norms and fuzzy set definitions are listed from Tab.1 to Tab.4, individually. Eventually, the DdAS creates the priority numbers of risk to reveal the risk order of each part. The results will be shown for selection of part or material.

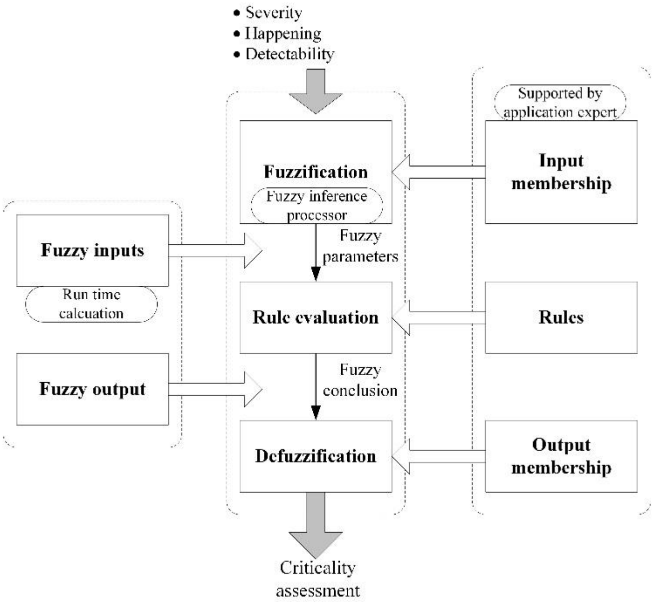

Fig. 4: The architecture of design support decision

Tab. 1: Evaluation criteria of 3D polarized glasses suit – frequency of happening

Grade	Happening	Description	Probability (%)	Process capability
1	seldom	Unlikely	≃ 0	≧2.00
2	low	Few	10	≧1.58
3	moderate	Occasional	25	≧1.00
4	high	Repeated	30	≧0.75
5	very high	Inevitable	≧50	≧0.51

Tab. 2: Evaluation criteria of 3D polarized glasses suit - severity

Grade	Severity effect	Description
1	none	No effect.
2	low	Fit / tighten item does not conform. Defect noticed by most customers. Item operable, but comfort/convenience item(s) operable at reduced level of performance. Customer experiences some dissatisfaction.
3	moderate	Item operable, but comfort/convenience item(s) inoperable. Customer experiences discomfort.
4	high	Item operable, but at reduced level of performance. Customer dissatisfied.
5	very high	Item operable, with loss of primary function.

July-August 2020
ISSN: 0193-4120 Page No. 4451 - 4464

Tab. 3: Evaluation criteria of 3D polarized glasses suit - risk

Grade	Risk	Description (to take the subsequent actions)
1	less significant	It's not important
2	low	It's low priority
3	moderate	Moderate priority
4	significant	It's important
5	most significant	It's very important

Tab. 4: Evaluation criteria of 3D polarized glasses suit - detectability

Grade	Detectability	Description
1	definite	A potential cause is definitely detected.
2	high	A potential cause is detected in high chance.
3	moderate	A potential cause is detected in moderate chance.
4	low	A potential cause is detected in low chance.
5	none	A potential cause cannot be detected, or There is no design control.

Next, DdAS will seek out proper materials (parts) on the basis of the import messages. Applying the seeking approach, the suitable materials (parts) are shown with ranking through scores. The purpose of the ranking is to assign the priority of alternative parts (materials), related to the state of weightiness of their properties to the engineers. For the ranking process, a quantitative scoring unit is used.

$$R_{st}= C_{rs}+C_{cs}+C_{re}$$

where C_{rs} indicates the material (part) risk that is ranked from 5 to 0 with 5 stands for 'most significant' and 0 represents 'less significant' that is decided in the evaluation phase of fuzzy criticality; C_{cs} shows the score of material (part) cost, in which the score of cost is ranked from 5 to 0 with 5 reveals 'less expensive' and 0 represents 'most expensive'; C_{re}indicates the score of the material (part) reliability that the score of reliability is ranked from 1 to 0 with 1 reveals 'the highest reliability' and 0 stands for 'the lowest reliability'; and R_{st}means the risk totality, reliability and cost of part (material).

Next, the proper part (material) can be chosen through the designer on the basis of these messages. Eventually, a recommended BOM can be produced when all the parts (materials) are picked and checked.

IV. THE PROTOTYPE FRAMEWORK OF KNOWLEDGE-ORIENTED SUPPORT PRODUCT DESIGN

Structure of Client-Server Design

The scheme with modules, knowledge server, and network is utilized in the design architecture. Thus, the knowledge-intensive assist method can use the modularity of KBSs, in that the knowledge repositories and inference unit are situated on server and the GUI is displayed to user devices by the Internet. The distributed object technology is applied to turn the module structure into a C/S architecture. The server end of knowledge systems use the connectivity offered through the Internet. To support the product design interactions, a three-layered C/S architecture and web-based GUI are used. The knowledge core and the basic framework are created in Java, combined with Jess [16]. Furthermore, it also combines with current application suits, such as database and CAD. The common object request broker architecture (CORBA) is applied to take on the exchange infrastructure of information service over the Internet tier and offers the capability to

communicate with current DBMS and CAD applications by other ORBs [17]. The architecture supplies the interfaces and approaches required to interact with other units under the network settings.
According to the architecture of knowledge assisted system, the several subsystems must be implemented to reach its functionality for product design: GUI, decision engine and knowledge database. The GUI on web offers users with the several functions below: (1) check tradeoffs and alterations through revising design variables within modules; (2) confirm the client's demands and the deployment of models of design problems; (3) construct a platform of product (i.e. several universal modules); and (4) select the eventual solutions. By using browser-based GUI, the client application is implemented as an integration of Java applets, VRML, and XML documents. The decision engine involves mechanism of decision-making, design suggestion and reasoning. The knowledge database can obtain, retrieve and store knowledge, e.g. client demands, design intentions, norms, assessment criteria, design modules and product alterations. The reasoning module of knowledge-oriented support product design is created to infer about sets of product structure, to contrast architecture modules through various aspects, to interpret design demands into constraints and to list all available modules applying the method of 'create-and-test'.
In the back-end side of the proposed system, there are several features involved: product creation server, modular design server, product assessment server, knowledge base, knowledge helper and inter-server communications' interpretation tools. To communicate remotely between the system features of back end and the Java applet, the ORB execution of Java applets with commercial version is utilized [17-18].

Example

To describe the implementation of the proposed system, an example of a stereo glasses suit is adopted through applying KoS@PdS. A screen snapshot of the proposed system is illustrated in Fig.5. The usage of a stereo glasses is for viewing 3D photos, films and playing 3D games. The preliminary sheet is created (as shown Fig.6) in design demand review after the qualitative client demands and product elements are imported to the stage of concept creation.

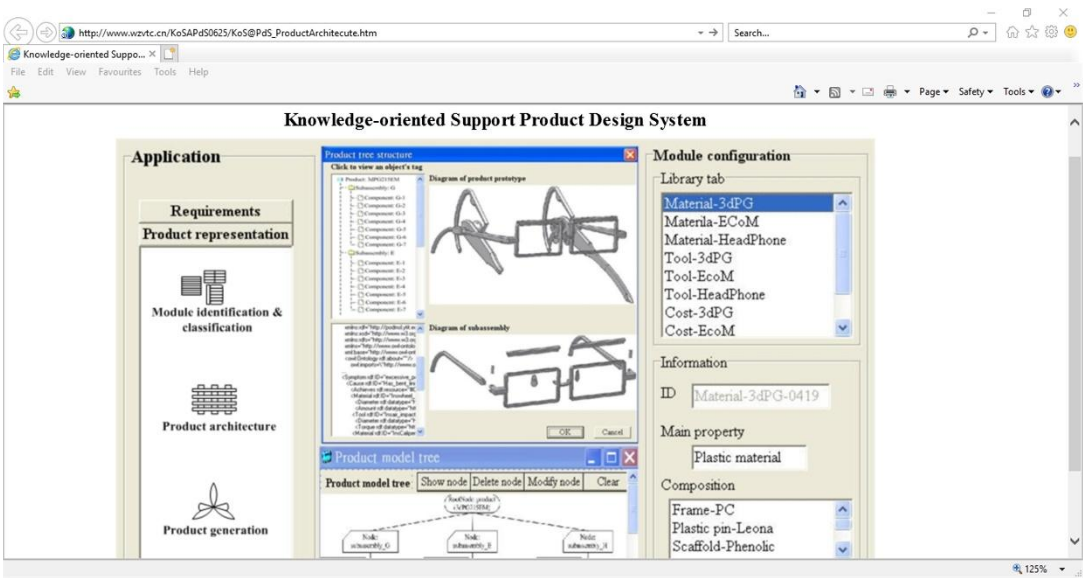

Fig. 5: Screen snapshot of knowledge-orientedsupport product design system

July-August 2020
ISSN: 0193-4120 Page No. 4451 - 4464

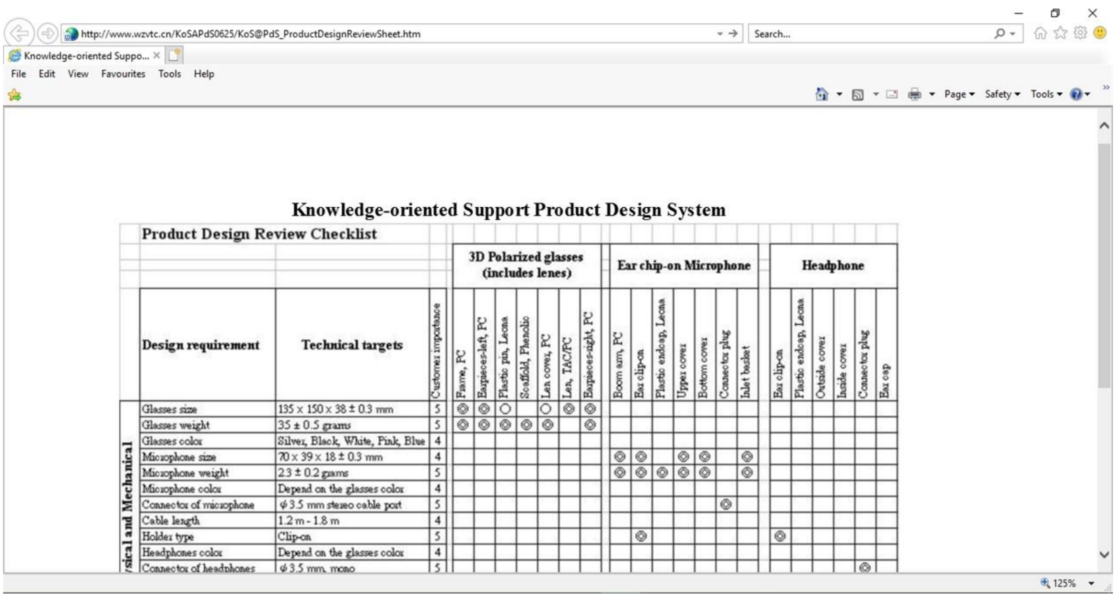

Fig. 6: Output table of design requirement review sheet

As shown in Fig. 7(*a*), the related values, including happening, severity and detectability of each part, are displayed on the DFMEA inferencing interface after clicking the button 'Load'. Next, the designer modifies the three values of a specific part to obtain a more exact import. Afterwards, the risk of each part is prioritized by DFMEA inference with fuzzy-logic ranking method. To support the assessment of fuzzy DFMEA in the proposed system, there are 725 rules created by rule matrix of riskiness. This system could support the users to cull out the parts' risk in the classifications of 'significant' and 'most significant'. The GUI of DdAS is shown in Fig. 9(*a*).

As the process of DFMEA inference, in accordance with the potential failure and ranking of happening, severity and detectability of each part, the risk is sorted through fuzzy-logic ranking approach. Eventually, the parts' sheet regarding the robustness of product design is created after the selection of alternative part is completed by DdAS by clicking the button 'Finish' (as illustrated in Fig.7(*b*)).

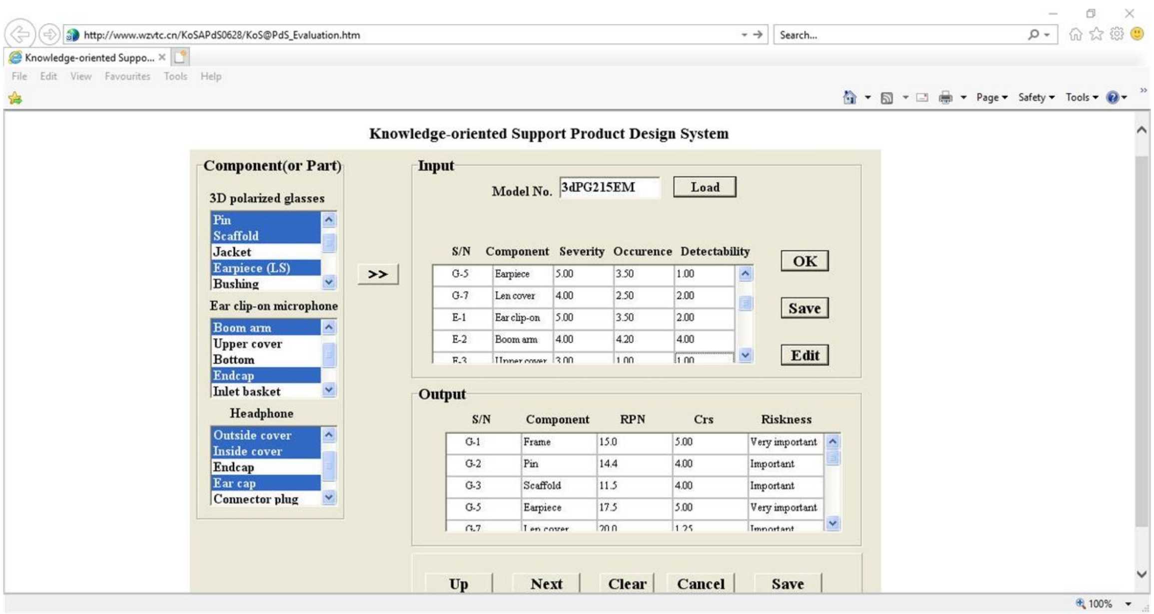

Fig. 7(*a*): Fuzzy DFMEA evaluation of 3D polarized glasses suit

July-August 2020
ISSN: 0193-4120 Page No. 4451 - 4464

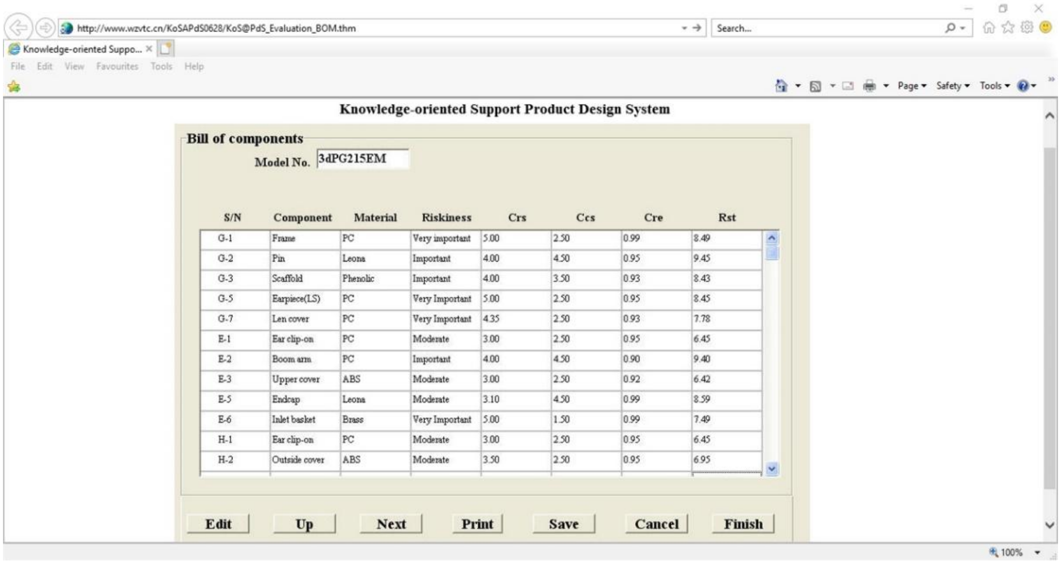

Fig. 7(*b*): Recommended bill of parts for proposed 3D polarized glasses suit

V. SUMMARY AND FUTURE WORK

A knowledge-oriented assist product design framework has been presented in this study. Meanwhile, a product design scheme with integrated modular platform is proposed for modeling client demands and product architecture, creating product platform, evaluating product variant as well as generating product. This proposed framework and approach can also be employed in the support of design process, representation and management of product design knowledge. Eventually, the topics correlated with the execution of knowledge assist framework are mentioned. Furthermore, the task undertakes the planning and assessment intelligently, through combining various domains. The functions of proposed system, named the KoS@PdS, can be encapsulated as estimating concepts of alterative product design in the fields of part and material selection. This system is developed to support the optimization of quality, reliability and cost of product, to reduce the lead time of product design. Based on the present models of decision-making applied, the KoS@PdS possesses a modular mechanism to easily access the repositories and to assure the prospective expandability. Yet, the present scheme only concentrates on the creation of simple product. Regarding complicated product design, the assembly could be catered in this framework.

Besides, a prototype of DdAS is developed to support product designers in the selection of parts and materials based on product demands and design robustness. The DFMEA approach is employed to estimate the reliability of product. Having thinking difficulties confronted in conducting the interrelationships among different failure modes with inexact and uncertain messages. A fuzzy-based method with knowledge-intensive feature is employed for generating this subsystem in DFMEA. To promote the DFMEA evaluation effectively, the knowledge with human heuristic property and experience can be included. To clarify the practicability of the presented system, an example of stereo glasses suit is managed by application of KoS@PdS. The result indicates this system with knowledge-oriented technology and fuzzy set principle are profitable methods toward the design applications. Therefore, it is appropriate for enterprises to focus on the development of customized products.

As for the future work, a design support system and knowledge base has to be further enhanced for modular product design, interchangeability development for heterogeneous systems and cooperative product generation through the Internet. In addition, the generation task of knowledge repositories of product procedure planning, product and tooling cost evaluates of sketched knowledge-oriented product generation system is also be developed.

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