Proceedings of the ASME 2011 International Manufacturing Science and Engineering Conference
MSEC2011
June 13-17, 2011, Corvallis, Oregon, USA

MSEC2011-50157

The Use of Hybrid System of Classification for the retrieval and modification of Mechanical Products

A.O.M. Adeoye
Afe Babalola University,
Dept. of Mechanical & Mechatronics Engineering
Afe Babalola Way, Ado-Ekiti, Ekiti State, Nigeria
Phone: +234(0)7061904836, E-mail:
yinkael_roi@yahoo.com

T. Szécsi
Dublin City University,
School of Mechanical & Manuf. Engineering
Glasnevin, Dublin 9, Ireland
Phone: +353(0)17008300, E-mail:
tamas.szecsi@dcu.ie

ABSTRACT

With people becoming more individualistic in their choices they make in personalizing the goods and services they use, as resulted in major development that has been recorded in the customisation world. This individualism has resulted in the increase in demand of customized products in many industries especially in the footwear, kitchen and computer industries. However, little has been done when it comes to mechanically oriented products and little flexibility has been given to the consumers in the co-creation of customized products. The Hybrid system of classification is one way to satisfy the customers' need for the products that are mechanically oriented in nature thereby meeting their desire needs.

This paper presents a framework in which an Hybrid system of classification is used to integrates Customers into the design process by defining, configuring, matching, or modifying personal product that is mechanically oriented in nature and grouping the products into classes and sub-classes using a wide range of product parameters, products configuration which make it possible to add and/or change functionalities of a core product, a coding system for mechanical designs which is applicable to each product in the hierarchy, the use of a database for the products information. And the retrieval system to retrieve a similar product code from the database if the initial customer configuration data does not yield a feasible product code through the application of Analytic Hierarchy Process and finally modifying the existing similar product to suit the customers desire.

INTRODUCTION

The fact from research point of view is that customer demand and technology innovations are increasingly stretching manufacturing capability to the limit [1, 2]. For a firm to be able to compete and survive in this dynamic environment, it must have the ability to rapidly adjust in order to reduce the Lead time needed to design, model, test, manufacture and deliver quality customised product to the customer. In a Mass Customisation environment, the level of customer involvement, and latitude afforded to the customer is necessarily limited, even the products family on offer is limited as well. This is largely driven by the manufacturers' desire to maintain mass production-type economies and the desire to maintain control [3] and as a result, the flexibility that ought to come along in a co-design setting and customer designing their own products with varieties of products from different family of products has been greatly affected. Consumers are becoming increasingly insistent on having a say in the design of products and looking for an avenue to bring their ideas to reality and coupled with the needed rapid adjustment in the area of manufacturing/product lead time in getting the customised product to them, this has led to this new concept- Customer-Led Design (CLD). And when this concept is applied, the manufacturer tends to save time, cost and labour in re-designing as identical product could be search for from the database and modifies to suit the customer request.

While engineers have made successful use of Group Technology (GT) techniques in the area of part design classification, coding and retrieval which has led to reduction in design time, part proliferation, production lead-time and reduced product cost in the market, the same could be adopted in the customisation of products that are mechanically oriented whereby, customers will be actively involved in the designing of their products. Customer-Led Design (CLD) is one way to satisfy this individualisation of the mechanically oriented products. CLD is a customer co-design process of products which meet the needs of each individual customer/user with regard to certain product features and all operations are performed within a fixed solution space, characterized by stable but still flexible and responsive processes [4]. Customers are integrated into design creation by defining, configuring, matching, or modifying an individual product – mainly mechanical related products. This is done by the applications of a hybrid (combination of hierarchical and chain-type) classification system to group the products into classes and subclasses using attribute parameters; the Configuration of products which make it possible to add and/or change functionalities of a core product by suggesting similar products if requested product is not found; a coding system for mechanical designs and applying it to each product according to their position in the hierarchy; and the use of a database to store and retrieve information about the products [5].

The development of Customer-Led Design System (CLD) arises from the need to develop effective and efficient system that will enable the customer/user with little or no technical know-how the flexibility, creativity and influence they desire in bringing their ideal product into reality which were not part of similar systems and also to allow them to select from different family of products in order to build their own product. Established Group Technology (GT) concepts in the area of classification, coding, search and retrieval of similar designs [6] were modified to suit the purpose of the CLD system used. The GT structure has been employed to classify the mechanically oriented products into different applications and each of the products were coded using a code system for mechanical design. Having selected a product from various applications in combination with other attributes, the customers build their own individual product and if the initial configuration does not yield any product code from the product database, a method has been developed [7] to suggest a similar product codes from the product database.

The remainder of this paper is organised as follows. In the second section, an overview of some existing concepts is given that were used to develop this new concept. Section three explains the details of the CLD system using GT (hierarchical classification and coding system) and the test runs for identical product codes. Section four describes the modification process involved. In Section five, we conclude and give insight on further work to be done which is based on the present study.

OVERVIEW

CUSTOMISATION OF PRODUCTS

The demand for individualisation of products are on the increase and Mass Customisation (MC) has strives to produce customised products and services on a mass scale with the same levels of responsiveness, quality, efficiency, and costs that are typical of mass production [8] but with little flexibility or constraint that has restricted the involvement of the customer as a co-designer. R. Duray and G.W. Milligan [9] categorised MC based on external involvement of the customer in design, fabrication, assembly or delivery stages of the manufacturing process of the product, all with constraint on the part of customer involvement. In an attempt to satisfy the individualistic taste of the customer based on the product order, a method was adopted to separate products into categories such as Made-to-Stock, Assemble-to-Order, Made-to-Order, and Engineer-to-Order [10] and all of these are example of Customer-Driven "Manipulation", which is define as the customer/user's ability to directly influence or manipulate a product's aesthetic, functional or dimensional characteristics [1].

Although many manufacturing firms, have put MC into practice such as Dell (in computer industry), Adidas Salomon (in footwear industry) [11] and virtual kitchens (in kitchen and cabinet industry) [12], not all the products are mechanically oriented and the degree of customer involvement is limited to pre-defined. In order to fully incorporate the customer into the design process, Z. Siddique and J.A. Ninan [13] designed a web based framework to provide customisable products by integrating the customer into the design process. This would have been a perfect model but due to constraint in the configuration the customer involvement is still restricted and the system does not entail products varieties.

GROUP TECHNOLOGY (GT)

Group technology was introduced by Frederick Taylor in 1919 as a way to improve productivity and in 1958 Mitrofanov (a Russian engineer) formalized this concept in his book, "The Science Principle of Group Technology". Ever since, GT has become a very important tool in manufacturing and production systems. This is a manufacturing philosophy that seeks to improve productivity by grouping parts and products with similar characteristics into families and forming production cells with group of dissimilar machines and processes [14].

The impact of group technology on the production process among other things is: quicker design changes, improved customer service and building customer relationship through classification. Group technology can be implemented through the following techniques namely: classification system, coding system and retrieval system. All of these were used for classifying and coding of product parts which work hand in hand, and retrieving of engineering design parts. Because of its high effectiveness, the Group Technology technique was adapted for use in the development of the classification, product coding and retrieval system for this research work in which some modifications were carried out, in order to be used in the Customer-Led Design system for the consumer products family that are mechanically oriented.

PRODUCT DESIGN RETRIEVAL SYSTEM

In the 1950s, a number of systems were developed to facilitate design retrieval. These were systems that allowed the designer to describe a part in numeric or alphanumeric values. When a new part entered into the design process, the designer could code it and, with the code designation, retrieve the same or similar drawing from a file cabinet [15]. Although this system worked in conjunction with classification and coding systems, research has shown that they are not part of GT applications as was earlier believed [16]. This is because the design retrieval process is focused on finding the most suitable individual component, not a family of parts as the case may be with GT.

The retrieval system has come of age and as a result, it has found acceptance in the photo-image industry which is used in retrieving similar product images [17], in manufacturing for retrieving similar engineering drawings from the database. The wide usage of this system is accounted to the fact that it prevents proliferation of parts or products, thereby saving cost in designing a new one and also time for creating new parts.

The relevance of similarity retrieval systems to CLD systems is that the author applies the knowledge of the retrieval system of similar parts from the database, since one of the process of realising the aim of the CLD is by suggesting a similar product code in the database to the customer/user if the product he/she requested could not be found through the first interaction.

THE CLD SYSTEM APPROACH

The approach adopted for this work is based on the overview conducted as presented above. It can be pointed out that most, if not all of the research that has been carried out on Customisation is only able to address one issue which is allowing the customers/users to customized their desired product from a pre-defined template or catalogue, in which case they are unable to express their idea about their ideal product and thereby constraining their choice. Though customisation has been implemented in some consumer products, it has not been extended to mechanically oriented products and services. Secondly, from all indications, Group Technology has been merely based on classifications and coding of engineering parts and drawings without considering the products in its classification and coding. The hierarchy used in classification can only work for a particular item thereby limited in its options for variety of product of family. And finally, the retrieval system as popular as it is, has not been tried or used outside data, drawings and part retrieval.

HYBRID SYSTEM OF CLASSIFICATION

The Product Chain System (PCS) is the platform from which the whole concept of CLD emerges. It consist of product attributes that are developed to form the hybrid (chain-hierarchical) type of classification system which gives the customer/user the opportunity of a wide-range of product options to select from, and this is based on nine chain-hierarchy attributes. The GT coding structure consist of Hierarchical, Chain type, and Hybrid codes. The code type adopted for this system is the hybrid type structure. With the hybrid selected, the authors were able to combine the mixture of hierarchy and chain type to develop the PCS of the CLD system which makes it comprehensive to permit for the variety of products which will help the customers in defining exactly what they wanted by systematically following the defined steps through interacting with the system. The hybrid (chain-hierarchy) system that is used to classified the products is a detailed hierarchical system that make use of such attributes as; Applications (a function base attribute), Motions-external and internal, Energy Source, Power Rate, Maximum Dimension, Weight of the Product, Product Shape, and Material from which the product is made, to draw information about the product from customer. Each of these attributes has classes and subclasses in hierarchical order which help to figure and narrow down the customer's product just like a Decision Tree Classification. The hybrid also allow both vertical and horizontal cross reference of features or attributes of the products irrespective of other characteristics, that is, relating one attribute feature to another position of such attribute or sub-attribute in the hierarchy notwithstanding [18]. The schematic diagram for Product Chain System attributes is shown in figure 1.

Product Application Attribute

This is a function base attribute that defines the products and classify them in hierarchical order according to their uses and is the main attribute of the PCS. The product classes are: Appliance, Sports, Tools and Transportation, However, the application attribute can be enlarged to hold as many sub-attributes as possible. There is no limitation to this functional base attribute. Figure 2 below illustrates the combine weight factor, codes and application attribute.

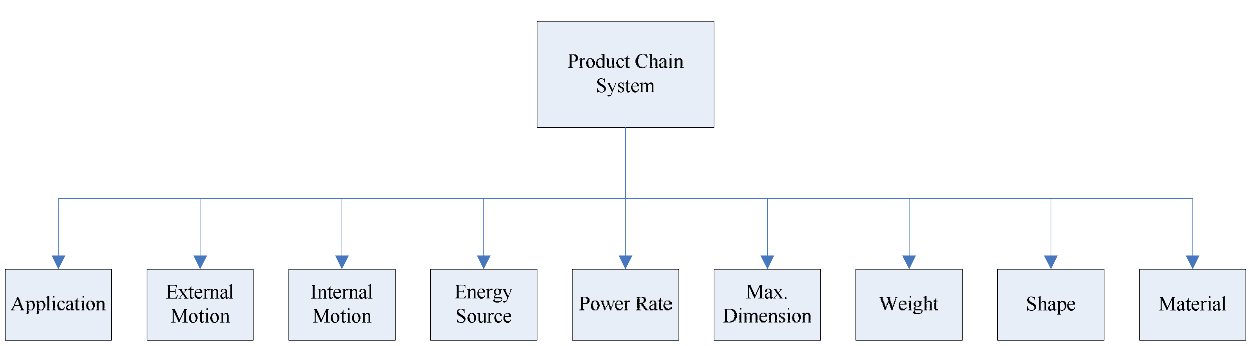


Figure 1: Product Chain System Schematic Diagram

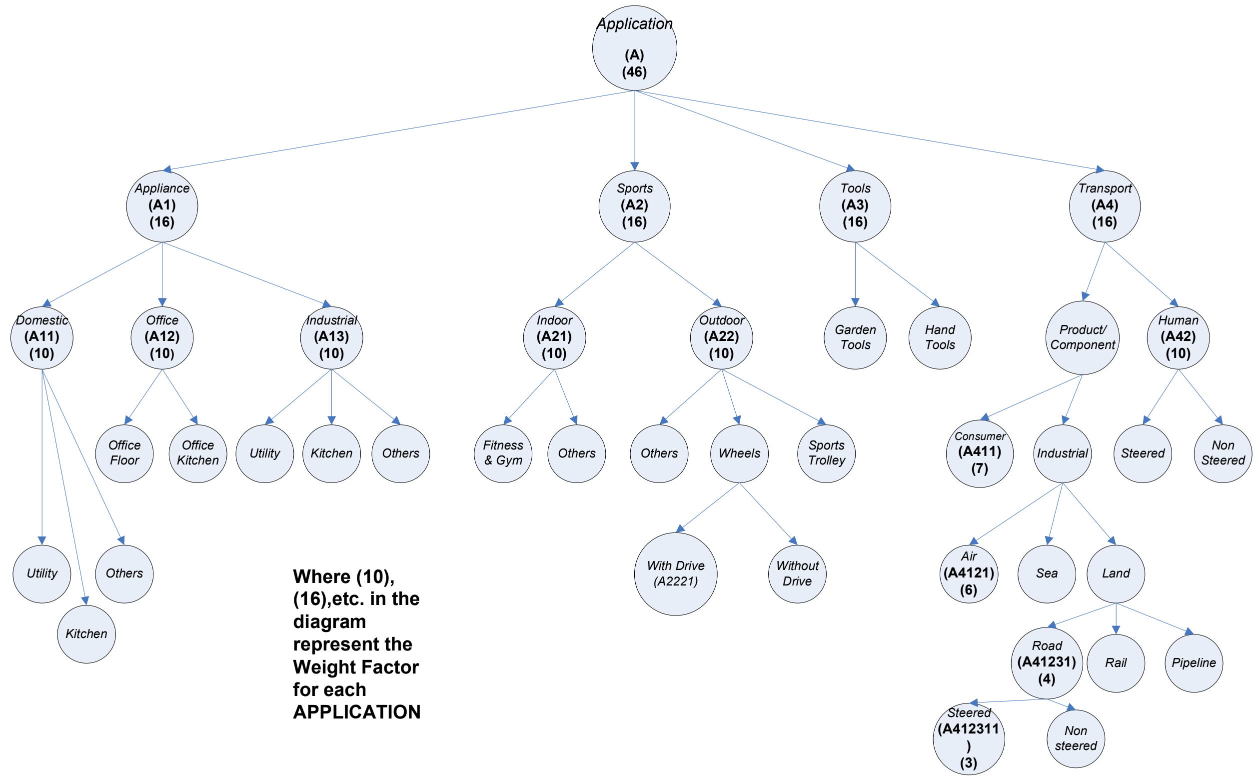


Figure 2: Combination of Weight Factor, Codes and Application Attribute

Mechanical Design Coding System

Another feature of the CLD is the coding system for mechanical design which assigns a symbolic description (code) to the Products in the hybrid (combined hierarchical and chain type) classification system as can be seen in the combine application attribute figure 2. The main characteristic that is implored in designing the Products Coding System is the flexibility, because customers want to be able to select products from different options and also to build their own products that will suit them and since no two customers have exactly the same needs and that various customers' needs may have conflicting requirements [19].

In installing the coding system for mechanical design, there are three methods of going about this:

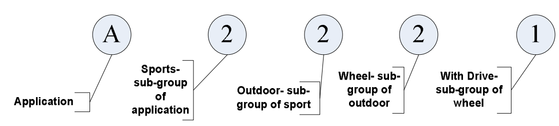
i. By purchasing a commercial package from a vendor;

ii. By modifying a publicly available system to fit the required purposes; and

iii. By developing an original system based on the analysis of samples parts [21].

The second method was adapted for the purpose of this work. The Opitz coding system [22] was modified to suit mechanical design Coding System used for the work. This is because Opitz coding system is a mixed coding system of Monocode and Polycode in that the monocodes allows a vertical search while the polycodes enables a horizontal across the board irrespective of other characteristics [23]. This cross references as was earlier mentioned above under the hybrid system of classification makes the Opitz coding system the suitable choice for the purpose of this work.

Each item on the Application is given a unique code with a letter A at the front representing the attribute and every other sub-group in application hierarchy will be represented by a digit according to their position in the hierarchy which might result in a very large number of codes and this will be arranged into a framework such as groups, classes and subclass, and as a result, customers will be able to select products from various applications to build their own individual product(s). The coding structure for the application attribute is illustrated in figure 2 above. For example, from figure 2, the letter and digits of code A2221 is interpreted below.



Also, the same modality is applicable to other attributes in the Hybrid Classification System with each attribute starting with a letter and then the sub-groups with digits.

To arrive at the Coding Structure used, the following factors were considered; the population of Attributes (application, motion, materials, shape, etc.), the detail the code should represent, the code structure: chain-hierarchy type, and the letter representation (A, M, E, etc.) [23].

METHODOLOGY FOR RETRIEVAL OF SIMILAR PRODUCT FROM THE DATABASE

The objective of the problem at hand is to suggest a similar product codes from the product database of the design system, which are similar to the customer request code due to the fact that the initial customer configuration input into the design system is unable to bring out a product code.

Weight Factor Method

In this method, Weight Factor (WF) is assigned to the attributes based on their importance in the PCS. The WF used is summed up to 100% which is distributed to the attributes as shown in table 2 below. This is done using a structural technique called Analytic Hierarchy Process (AHP) [23] [24] [25], this is used to structure and determine the WF value assigned for the ranking of the attributes. Also, each of these values is share among the sub-groups of each attributes. For instance, Application with 46% shared it among its sub-groups base on hierarchy levels as shown in figure 2 above (the WF value is shown in the bracket in the attribute). Same thing is applicable to other attributes based on the number of hierarchy level they have. With this method, the weighted factor (WF) of the attributes for each product is sum up and the database displace the product codes in the user graphic interface according to their higher value of WF with the one with higher WF value at the top. The higher the WF value, the similar the product code is to the customer requested product. And one good thing about this is that the customer/user can indicate the level of similarity he/she wants based on the similarity index.

Table 1: Weight Factor for PCS Attributes Attribute

Attribute	Weight Factor (WF)	Distribution Of WF In Hierarchy Sub-Group/Level					
		1	2	3	4	5	6
Application	46	16	10	7	6	4	3
Ext. Motion	12	8	4	-	-	-	-
Int. Motion	8	8	-	-	-	-	-
Energy Source	7	7	-	-	-	-	-
Power Rate	5	5	-	-	-	-	-
Max. Dimension	4	3	1	-	-	-	-
Weight	5	3	2	-	-	-	-
Shape	6	6	-	-	-	-	-
Materials	7	7	-	-	-	-	-

RETRIEVAL OF SIMILAR PRODUCT FROM THE PRODUCT DATABASE

Here, we present the steps followed in order to generate product code from the customer/user based on the Weight Factor method. This is because of its ability to generate product codes that closely similar to the candidate product code.

In generating the product code for a customer/user request and to determine if the code generated is actually what the customer want, a two steps process is used to optimize the model of the product chain system template.

Step 1: Gather code from user's specification/ configuration.

In order to gather product request code from the customer/user, the Product Chain System template in table 2 could be utilized. If a feasible solution is achieved in this step, then step 2 is of no importance.

Table 2: Product Chain System Template Use in S election of Appropriate Product.

PF = {App, Ext M, Int M, Ene S, PoR, Max D, Wei, Sha P, Mat P}
App={Apl, Spo, Tol, Tra},
Ext M={Fi, Mo, Hh},
Int M={Li, Ro, Re, Os},
Ene S={Ma, Ba, Em, Fu},
PoR={_100 - >2000},
Max D= {L(min.),L(max.)},
Wei= {Lo, Me, Hy},
Sha P= {1D, 2D, 3D, Rd, Ir},
Mat P= {Mt, Ce, El, Pl, Co, Wo}
Pi={(App, Ext M, Int M, Ene S, PoR, Max D, Wei, Sha P, Mat P)_App=(Apl,
Spo, Tol, Tra)}
Spo= {In D, Out D},
Out D = {Whl, Spo T, Oth}
Whl Op= {x, y}
SP={(x={WD},Ext M={Fi, Mo, Hh},Int M={Li, Ro, Re, Os},Ene S={Ma, Ba, Em, Fu},
PoR={_100 - >2000}, Max D={L(min.),L(max.)},Wei={Lo, Me, Hy},Sha
P={1D, 2D,3D Rd, Ir},Mat P={Mt, Ce, El, Pl ,Co})}
SP={x={WD}, Ext M={Mo}, Int M={Li}, Ene S={Ma}, PoR={0}, Max D={L(min.)},
Wei={Lo}, Sha P={2D}, Mat P={Co})}
Where: *Ext M= external motion; Int M= internal motion; Ene S=energy source; PoR= power rates; Max D=maximum dimension; Wei=weight; Sha P=shape of product; Mat P=product materials;*
Mo=moving; Li=linear; Ma=manual; L(min.)=minimum length; Lo=Light;
2D=two dimensional; Co=composite.

Step 2: Find closet product code in Hierarchical database.

If the first step does not yield a feasible solution, the design system will try to find a similar product codes to that generated initially. This is done through the Product Similarity Retrieval System from the product database by using the parameters inputted by the customer/user when configuring the initial product request.

In order to examine the practicability of the system step, the following test was conducted.

TEST:

Assuming customer/user initial (requested) product code is:

A222200 E22 I2 S1 P0 D12 W11 F2 M5

Which represent a Scooter, and from the database, there is no feasible product that matches the code, then, by finding the closest product code, we apply step 2 to generate a similar product code to the candidate code. By applying the WF method of the retrieval system, we have the weighted factor as shown in table 4 below. The product code gathered from the customer configuration data has 100% WF value, i.e.

A222200 (46) **E22** (12) **I2** (8) **S1** (7) **P0** (5) **D12** (4) **W11** (5) **F2** (6) **M5** (7)

Weight Factor value is then generated for the product codes in the database. This is done by ascribing WF values to each attribute of the product codes and the value for each attribute is

Table 3: Calculation of the weight factor for each attributes

Application	External Motion	Internal Motion	Energy Source	Power Rate	Maximum Dimension	Weight	Shape	Material	Product Database
A211000 (16)	E10 (-)	I2 (8)	S1 (7)	P0 (5)	D21 (-)	W11 (5)	F5 (-)	M5 (7)	Exercise Bike (48)
A310000 (-)	E22 (12)	I2 (8)	S1 (7)	P0 (5)	D21 (-)	W11 (5)	F5 (-)	M1 (-)	Wheel Barrow (37)
A412311 (-)	E22 (12)	I2 (8)	S1 (7)	P0 (5)	D21 (-)	W21 (-)	F2 (6)	M1 (-)	Pallet Truck (38)
A310000 (-)	E22 (12)	I2 (8)	S3 (-)	P5 (-)	D12 (4)	W11 (5)	F5 (-)	M1 (-)	Lawn Mower (29)
A211000 (16)	E10 (-)	I1 (-)	S3 (-)	P2 (-)	D22 (-)	W12 (3)	F5 (-)	M5 (7)	Tread Mill (26)
A222200 (33)	E22 (12)	I2 (8)	S1 (7)	P0 (5)	D11 (3)	W11 (5)	F2 (6)	M6 (-)	Skate Board (79)
A223000 (26)	E22 (12)	I2 (8)	S1 (7)	P0 (5)	D22 (-)	W12 (3)	F2 (6)	M1 (-)	Trolley (67)
A222200 (33)	E22 (12)	I2 (8)	S1 (7)	P0 (5)	D12 (4)	W11 (5)	F2 (6)	M5 (7)	Scooter (83)
A222200(33)	E22 (12)	I2 (8)	S1 (7)	P0 (5)	D21 (-)	W11 (5)	F2 (6)	M5 (7)	Unicycle (81)
A412311 (-)	E22 (12)	I2 (8)	S1 (7)	P0 (5)	D21 (-)	W11 (5)	F2 (6)	M1 (-)	Hand Truck (43)

Table 4: Ranking of the database product codes based on the weight factor calculation

Application	External Motion	Internal Motion	Energy Source	Power Rate	Maximum Dimension	Weight	Shape	Material	Product Database
A2222	E22	I2	S1	P0	D21	W11	F2	M5	Unicycle (81)
A2222	E22	I2	S1	P0	D12	W11	F2	M5	Scooter (83)
A2222	E22	I2	S1	P0	D11	W11	F2	M6	Skate Board (79)
A223	E22	I2	S1	P0	D22	W12	F2	M1	Trolley (69)
A211	E1	12	S1	P0	D21	W11	F5	M5	Exercise Bike (48)
A412311	E22	I2	S1	P0	D21	W11	F2	M1	Hand Truck (43)
A412311	E22	I2	S1	P0	D21	W21	F2	M1	Pallet Truck (38)
A31	E22	I2	S1	P0	D21	W11	F5	M1	Wheel Barrow (37)
A211	E1	I1	S3	P2	D22	W12	F5	M5	Tread Mill (26)
A31	E22	I2	S3	P5	D12	W11	F5	M1	Lawn Mower (29)

dependent on their hierarchy level/sub-group as contain in table 1 above. This automatically ranks the product codes according to their WF values with the highest value on top. The higher the WF value, the closer/similar the product code to the candidate code gathered from the customer. Table 3 shows the calculation of WF value for each attributes and the total WF value for the product in the database, while table 4 illustrates the ranking of the product codes from the highest to the lowest. From table 3 it can be deduce that the closer product codes to the candidate one are the codes with WF between 52%- 87% similarity indexes. And these could be suggested as a similar product codes to the customer based on his/her configured data.

MODIFICATION PROCESS FOR THE RETRIEVED PRODUCT CODE

After retrieving the product that is similar or closely matched to the intended product from the database, the next step for the user/customer is to modify the selected product in order to match more accurately the customer configured product.

The modification process is a complex procedure because it analyses the internal structure of the product parts for modification. This involves the product assembly and sub-assembly structures which includes the hierarchical relationships between the product parts or sub-assemblies and mating conditions, the product module library, and product link structure. The process for modification is divided into two sections. The first section is called customer/user interaction and the second section is referred to as the internal system execution. The two sections will run concurrently during the modification process.

There are three stages for the product modification for the customer retrieved product.

Stage 1: Selection of the Product for Modification

This is the first step in the stages involved in the product modification and it is divided into two tasks:

TASK A: Here, the similar retrieved products are displayed with products code name, SI values and the pictorial view of each of the products in the user graphic interface according to their closeness to the candidate product. The products are arranged with the highest Similarity Index (SI) value on top while the product with least SI value will be at the bottom of the ranking. The user selects the product that is more closely matched or similar to his/her configured product from the list of products displayed on the screen based on the SI value by ticking the appropriate box beside the product chosen. Task A of stage 1 on the GUI screen will resemble the model shown in Figure 3.

TASK B: this task consists of three steps. After the customer/user has selected a product to be modified from Figure 3, the system automatically carries out Step 1 as soon as Task B is completed without any interference from the customer/user. This involves checking the selected product to find out in terms of motion if the selected product has the same motion orientation or specification with the candidate product. If it does, the “Compatible” box will be highlighted and the modification process will proceed to the next stage. But if it does not have the same motion specification, the “Not compatible” box will be highlighted and an error text will be shown in a text box (in light blue, as shown in figure 4); “one of the product chain system attributes of the candidate product code is not motion compatible with the selected product”.

This is followed by Step 2 which has two options buttons - “AMEND” or “IGNORE”. The customer has to select one of the options. If the “IGNORE” button is selected, then the system proceeds to the next stage of modification. But if the “AMEND” button is selected, the system activates the next step.

In Step 3, the system will prompt the customer/user to select from the drop-down menu the type of motion to be given to the selected product. The customer, placing the cursor on any of the parameters of the drop-down menu will find the description of each parameter (motion type). After the selection has been made, the system proceeds to the next modification stage.

Task B of stage 1 on the GUI screen will resemble the model shown in Figure 4.

STAGE 1: Product for modification is selected.

Task A: Check the result produced by the retrieval system and the Artificial Neural Network to choose the product that is very similar to the desired one based on the Similarity index value (SI).

Product Code Name	SI Value (%)	Pictorial View
☐ A	87	Picture of A
☐ B	83	Picture of B
☐ C	71	Picture of C
☐ D	68	Picture of D
☐ E	64	Picture of E
☐ F	61	Picture of F
☐ G	59	Picture of G
☐ H	35	Picture of H
☐ I	23	Picture of I
☐ K	9	Picture of K

Figure 3: Model of the Selection of Product for Modification Process.

Task B: Product Compatibility Check.

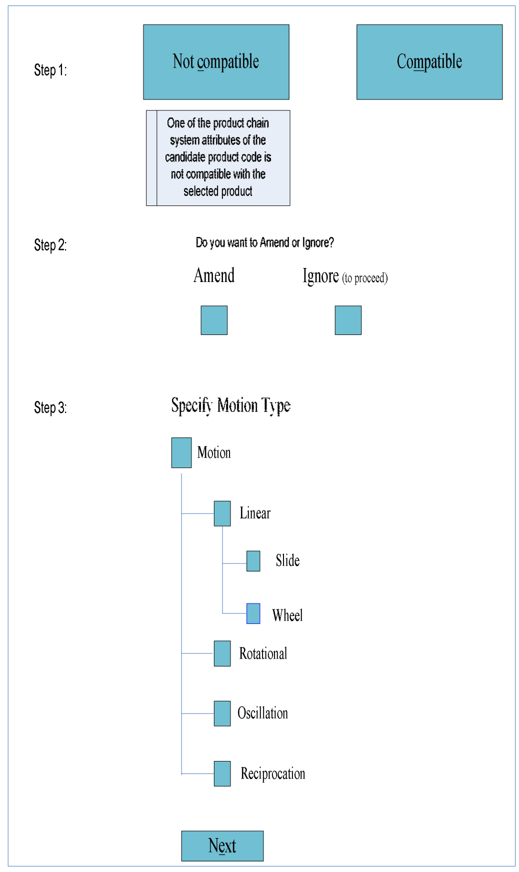


Figure 4: Model of Product Compatibility Check

Stage 2: Displaying of the Parameters that Define the Product

There are parameters that define each of the products. Only one product can be analysed per time and that is the selected product. These parameters are used to analyse the selected product so that the customer/user will have the understanding of the product to be modified. On seeing the picture and composition of the product the user will know what he/she needs on the product in order to get his/her intended product. The parameters used in analysing the product are as follows -

(I). The Product Assembly and Model Structure: this shows the picture and the module assembly and sub-assemblies of the product. The module assembly involves the placement and fastening of a sub-assembly or more sub-assemblies into or upon another [24]. It is of importance to understand the nature and the structure of dependencies that exist between parts in a product module assembly to be able to carry out a proper modification on it. One of the designs for assembly guidelines [25] that were used here is the use of module sub-assemblies instead of parts which greatly simplifies the final product assembly.

While looking at the displayed product picture, the customer/user will have an idea of what part of the product will need to be modified and what module will need to be changed in order to conform to his/her required product. Each of the labelled sub-assemblies of the product when clicked on or the cursor is placed on it gives its component(s) part details. The essence of this is to make the system as simple as possible for the user/customer to understand.

(II). Hierarchical Module Sub-Assembly structure: the best way to represent the hierarchical relationship between the various modules of an assembly is by using an assembly tree [26]. The product itself represents an assembly while the modules that are combined together to form the assembly are the module sub-assemblies. The hierarchical module sub-assembly structure shows the parts that form the module sub-assemblies. The module sub-assemblies are considered as single parts when inserting them into the main assembly. Figure 4 shows a product module assembly structure with the assembly consisting of four sub-assemblies, and these sub-assemblies are further broken down into sub-assemblies. The structure represents a product assembly sequence by which the product assembly can be produced.

(III). Mating Conditions, Attachment Type and Constraint in the Product: Mating conditions define how the modules are attached to one other [27]. Mating features information can be provided interactively with ease because mating features are simple graphics entities such as faces and centrelines. The reason why mating condition is incorporated into the system is because it automatically computes and stores for each module sub-assembly the transformation matrices that merge [26] sub-assembly modules into their product assembly since the modification process will involve disassembly and then re- assembly of the product. It also helps to determine the appropriate position where the customer/user can place the module sub-assemblies in an assembly for the product to be assembled. The mating condition will be represented by its type and the two faces that mate.

In order for the mating condition to work effectively in the modification process, the mating feature between a pair of module sub-assemblies has to satisfy the conditions of constraints such as "against", "fit", "tight fit", "contact", "co-planar", "semi-fit", etc.

(IV). Link Structure: The Link structure is a complete set of information required to describe the type of attachment and mating conditions between the mating pair. Each constraint links one surface of a module sub-assembly/part to a surface of another one and the surface definitions [20] are taken from the module library. The Link structure showed which part is attached to other parts and through which surfaces. The type of link and the mating conditions can also be shown. The link structure can be derived from constraints, or need to be added to the model if the spatial position of parts is defined with transformation matrices.

When any changes are made on the product assembly during the modification process, the system will automatically effect/modify the changes in the link structure of the product.

(V). Product Module Library: Of a note with the product module library is that its sub-assemblies/parts are arranged in hierarchical order of the link assembly.

Stage 3: User Input Parameters for Modification

This is the main stage where the modification of the product actually occurs. Whatever changes that need to be carried out on the product module or part are done here. The system will prompt the user/customer through the task for what is to be done. The following procedure is carried out in changing the product module sub-assembly features.

Task: Start modification for changes required on the selected product.

The user is asked to begin to effect the changes he/she wanted on the selected product.

NOTE

For the modification initiated to be effected, the following criteria must be satisfied -

i. *The product part/module sub-assembly must be properly constrained*
ii. *Modification can only take place where mating conditions are met (that is, where mating pairs or attachment occur)*

The user/customer changes or modifies the product sub-assembly/part by selecting and modifying its parameters. This is carried out as follows:

Modification Procedure:

Sub-task 1: select the part/module sub-assembly from the main module library

Sub-task 2: drag the part/module from the library where it is unconstrained; place the product ready to reach intermediate position where the constraint position will change

Sub-task 3: bring the part/module sub-assembly to the assembly position to complete the part mating process. As the changes to the product are effected, the product link structure is automatically updated since it is programmed to interlink with the product module library. Figure 5 illustrates the process of modification that was explained above.

The result is displayed on the product user's interface. If the modification is accepted then the user saves the new product and if not, the user is prompted to repeat stage 3 again. If no feasible modification is achieved (that is, the user is not satisfied with the modified product), the system prompts him/her to exit and re-start the process again.

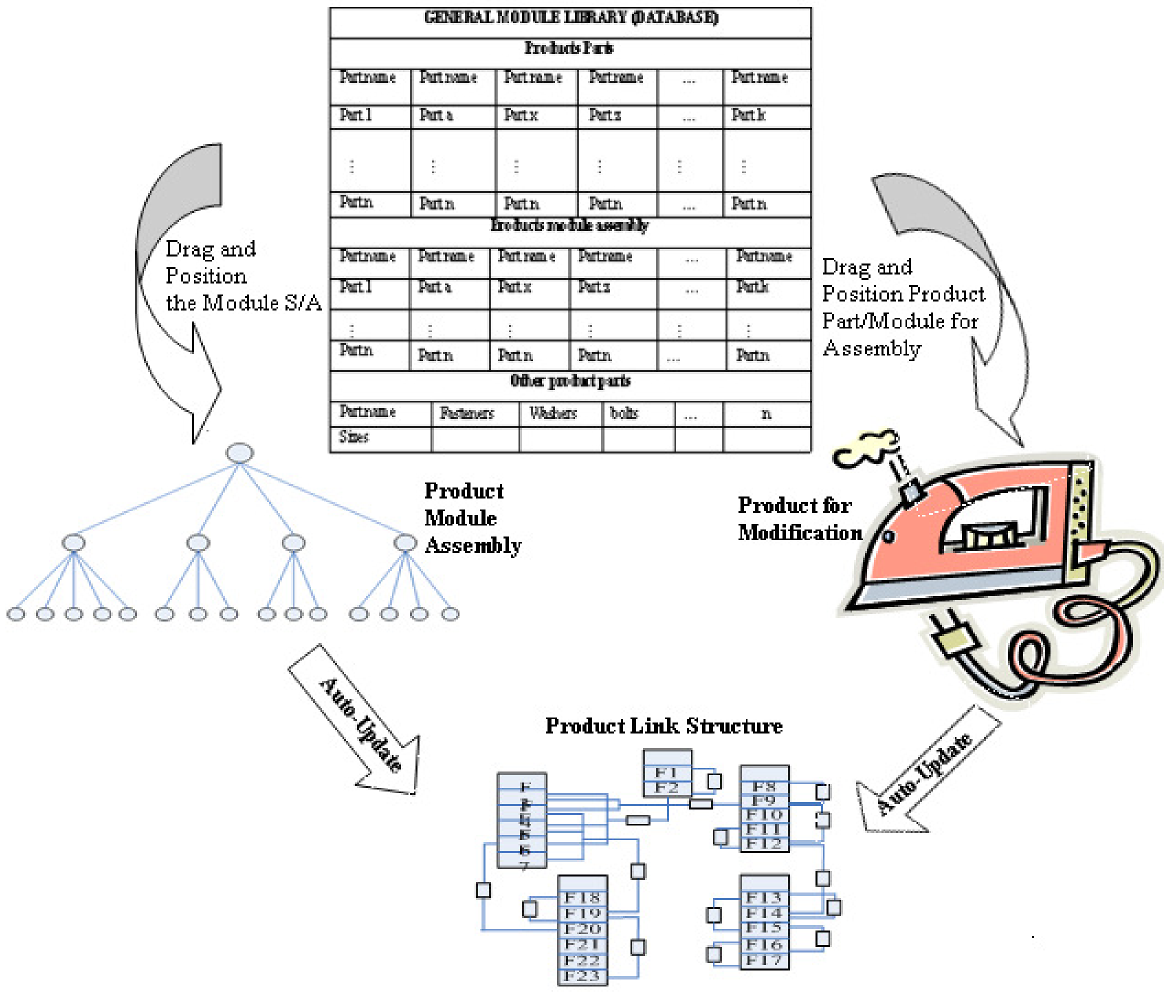


Figure 5: Process of Modification

CONCLUSION

The Use of Hybrid System of Classification for the retrieval and modification of Mechanically Oriented Products to classify, code and retrieve of products offers a great market prospective to manufacturers in a competitive world/environment. When manufacturers use this kind of design, it will give them an edge in the saturated market of mass and products customisation and also attracts more customers who are more individualistic in their taste because of the flexibility and opportunity to create/design to their satisfaction that are inherent in the design network. It will also save them time, cost and labour in redesigning as identical products could be searched for from the database and modified to suit the customer request.

This paper focused on the implementation of hierarchical coding/retrieval system in classifying, coding and retrieving of mechanically oriented products that are similar from the database. This is carried out by the application of GT concepts using a hybrid (combined hierarchical and chain-type) classification system in which the structure is based on coding an application (area of product use) that are functionality base with variety of families and then define the selected application through other products parameters that are inherent in the chain-hierarchy which will eventually lead to the exact or similar group of products that may match the desired product of the customer which are stored in the database and if this is not achieved, the customer then proceed to modify the closest to the desired product in order to build to suit his/her desire.

The project objective has been achieved in that the test carried out in the retrieval of similar product codes and modification to the exact product using the CLD system was successfully done and customer/user can get as many suggested products codes as he/she wants base on the level of similarity index indicated and then modifies to suit the need.

The following areas could be considered as the main areas for future work.

Enhancing the Modification Step

Further improvement could be undertaken on the modification step. For instance, the use of CAD with parametric, variational modelling is recommended to allow for detailed design.

Development for Commercial Purpose

The developed system can be made into a commercial software package either as a stand-alone system or as an additional module to an already existing CAD system.

Improving the Product Chain Structure

Further work can be done to enhance the product chain structure of the CLD system as follows:

More attributes can be added to the hybrid system to give more options in defining the product features.

The function-based application attribute can be expanded to accommodate more sub-groups which would allow the specification of more products.

REFERENCES

[1]http://articles.directorym.net/Article.aspx?ArticleId=915196

[2] I. Shekhar and N. Rakesh: "Identification of Similar Parts in Agile Manufacturing", American Society of Mechanical Engineers, Design Engineering Division (Publication) DE, Vol.74, Concurrent Product Design, pp.87-96, 1994.

[3] B. MacCarthy and P. Brabazon: "In The Business of Mass Customisation", IEE Manufacturing Engineer, pp.30-33, August 2003.

[4] D. Janitza, M. Lacher, M. Maurer, U. Pulm. and H. Rudolf: "A Product Model for Mass-Customisation Products", *KES 2003,LNAI 2774,* pp. 1023-1029, 2003.

[5] A. Adeoye and T. Szécsi: "An Introduction to Customer-Led Design for Mechanically Oriented Products", *Proceedings of the 18th International Conference on Flexible Automation and Intelligent Manufacturing*, pp.436-442, Skövde, Sweden, 2008.

[6] I. Shekhar and N. Rakesh: "Identification and Ranking of Similar Parts in Agile Manufacturing", Proceedings of the 4th Industrial Engineering Research Conference, pp.709-717, Nashville, TN, USA, 1997.

[7] I. Shekhar, and N. Rakesh: "Automated Retrieval and Ranking of Similar Parts in Agile Manufacturing", IIE Transactions Vol. 29, pp. 859-876, 1997.

[8] B. MacCarthy, "Mass Customisation- An Emerging Strategy", IEE Manufacturing Engineer, pp. 29, August 2003.

[9] R. Duray and G.W. Milligan: "Improving Customer Satisfaction through Mass Customization", Quality Progress 32(8), pp.60-66, 1999.

[10] J.C. Wortmann, D.R. Muntslag, and P.J.M. Timmermanns: Customer Driven Manufacturing, Springer, London, 1997.

[11] C. Berger, and F. Piller: "Customers as Co-Designers", IEE Manufacturing Engineer, pp.42-45, 12 August 2003.

[12]http://2020technologies.com/products-residential/20-20_design.aspx .

[13] Z. Siddique and J.A. Ninan: Modelling of Modularity and Scaling for Integration of Customer in Design of Engineer-to- Order Products, Integrated Computer-Aided Engineering, IOS Press, 13 pp.133-148, 2006.

[14]http://www.freequality.org/sites/www_freequality_org/documents/training/GroupTechnology%5B1%5D.ppt#256,1,Group

[15] T. Eric and N.O. Joel: 1987, Computer Integrated Manufacturing Handbook, McGraw-Hill, Inc., United States of America.

[16] J.A. Barton and D.M. Love,: 2002 "Development Issues for a Practical Design Retrieval System Based On Automatic Coding", in P.J., Armstrong, ed., Proc. Int. Manufacturing Conference, Belfast, pp 607-616.

[17] K. Suzuki, X. Wang, and H. Ikeda: 2002, "An Artistic Design System for Industrial Product Image", IEE Industrial Applications Magazine, Jan/Feb 2002.

[18] A. Adeoye, A.S.M. Hoque, and T. Szécsi: 2008, "The Principle of Customer-Led Design for Mechanically Oriented Products", *Proceedings of the International Conference on Advance Manufacturing and Automation*, March26-28, Tanulnadu, India.

[19] P. Power-Hill: "Developing a Product Coding System for Industries That Cross Sectors", Voorburg Group on Service Statistics 12th Meeting Copenhagen, 15 - 19 September 1997.

[20] T. Szécsi: CAD/CAM Integration MM522, Module Notes, 2nd Edition, January 2004.

[21] P. Shilpan: Development 0f a Classification and Coding System for Computer Aided Planning, Thesis of the Faculty of the Graduate School of the New Jersey Institute of Technology, 1991

[22]http://msdn.microsoft.com/en-us/magazine/cc163785.aspx

[23]http://en.wikipedia.org/wiki/Analytic_Hierarchy_Process

[24]. James G.B. *"Design for Manufacturability Handbook",* Second Edition, McGraw-Hill, Inc., New York, 1999.

[25]. Anderson D.M. *"Design for Manufacturing",* University of Rhode Island Press, Providence, 1983.

[26]. Zeid I. *"CAD/CAM Theory and Practice"*, McGraw-Hill, Inc., New York, 1991.

Nomenclature

ACRONYM	DEFINITION
PCS	Product Chain System
CLD	Customer-Led Design
CDD	Customer Driven Design
ANN	Artificial Neural Network
MC	Mass Customisation
GT	Group Technology
AHP	Analytic Hierarchy Process
DOF	Degrees of Freedom
MDCS	Mechanical Design Code System
PF	Product Family
APP	Application
WF	Weight Factor
SI	Similarity Index
NN	Neural Network
S/A	Sub-Assembly
SIV	Similarity Index Value