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Using Product Platform Architecture for Identification of Part Commonality in Support of Design for Modularity

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ABSTRACT

Modular approach is one of the best design techniques as it promotes better and faster designing process. Due to functional independence and physical similarities, it tends to drive platform development. This paper will discuss the application of modularity approach to drive for platform design from a multi-family home appliances product. By utilising the conventional heuristics rules to identify modules, a platform is then developed so that it can be shared among those products. Three consumer products from different family are used as case study. As a result, a new design is proposed with several improvements to the products in terms of part count and part commonality.

Keywords: Modular approach, heuristic approach, platform, commonality

ABSTRAK

Kaedah modular merupakan antara teknik reka bentuk terbaik sebagaimana ia menjurus kepada proses reka bentuk yang lebih cepat dan baik. Oleh kerana bersifat kebebasan fungsian dan kesamaan fizikal, ia boleh menghasilkan platform yang lebih baik dan sistematik. Kertas kerja ini membincangkan aplikasi kaedah modular untuk memacu seni bina platform dari perspektif produk daripada keluarga yang berbeza. Dengan menggunakan tatacara heuristik sedia ada untuk mengenal pasti modul, platform seterusnya dibina untuk dikongsi oleh produk-produk tersebut. Tiga produk pengguna daripada keluarga yang berlainan digunakan sebagai kajian kes. Keputusan menunjukkan bahawa daripada reka bentuk baru yang dihasilkan beberapa penambahbaikan telah dapat dicapai dari segi bilangan komponen dan kesepunyaan komponen.

Keywords: Pendekatan bermodul, pendekatan heuristik, pelantar, kesepunyaan

INTRODUCTION

Modular and integral architectures are always the techniques that were used by designers to design a product. For most of the designers, modular architecture is the best technique as it promotes better and faster designing process. Furthermore product designed by this technique requires less effort for redesign (Huang 2000). Besides it also reduces number of parts and components compared to the product designed using integral architecture or in other words most of manufacturing industry nowadays is very interested in modular architecture. Pahl and Beitz (1988) defined modular products as machines assemblies or components that accomplish an overall function through combination of distinct building block or modules. Modules can be described as physical structures that have a one to one correspondence with functional structures (Ulrich & Tung 1991). These characteristics, i.e., similarity and interaction, can promoted for platform development. A product platform can best be understood as a part of product that can be shared among its variants to perform different functions (Gonzales-Zugasti et al. 2000). Modular architecture is capable of increasing product simplification. Modular architecture does not always mean that the number of parts in a product must be reduced, but sometimes adding simpler part also can improve product performance. For example the product tends to simplify assembly method such as snap-fit which does not require any tools, instead of using screws and nuts to the assembly. Special features of modular products attract customers as they are easy to use and sometime can be upgraded (Huang & Kusiak 1998). A very good example in explaining a modular product is personal computer. Many more success in product platform has been published and marketed recently (Brenmer 1999).

There are many techniques used to design modular product which more focusing in identification of modules (Abdullah & Ripin, 2002). In the area of product platform, there are also other techniques, which have been used. Methods such as Generational Variety Index (GVI) and Coupling Index (CI) are widely used in product platform to increase product variety (Martin & Ishii 1997). These methods are used for complex product such as electronic product that rapidly evolved with time. Similar to that Sudjianto and Otto (2001) has proved that modularity can enhance the process of platform development from multi-brand product, while Abdullah and Ripin (2003) used modularity index to identify platform that can be shared for product from similar brand and family. Product platform architecture and modularity approach are relatively similar in nature.

This paper intent to prove that modular architecture can be used to support the design of a product platform from multi-family product which generally have different product configuration. Here the method of module heuristic developed by Stone et al. (2000) will be utilised to identify modules and product platform design is suggested. Throughout this work, existing design methodology has been improved to meet the requirements of lean and agile manufacturing.

LITERATURE REVIEW

Before using the method of module heuristic, a comprehensive function structure must first be built. Function structure consists of the flow of material, energy and signal involved while using a product (Gonzales-Zugasti & Otto, 2000). To build a function structure, a standard vocabulary of functional basis must be used. Also to build a function structure, several steps must be followed. A black box model is a representation model of a product's overall function and input/output flows (Stone et al., 2000). The overall function of the product is expressed in verb-object form. An example of a Black Box model for a consumer power screwdriver is shown in Figure 1.

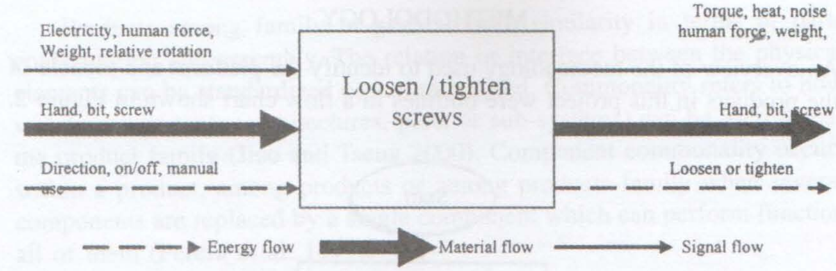


FIGURE 1. A Block Box model for a power screwdriver (Stone et al. 2000)

The method of module heuristics consists of three separate strategies to identify modules. The necessary starting point is a well refined functional model as derived in the previous section. Then three heuristics will be applied to the function structure and this will be explained as follow.

DOMINANT FLOW HEURISTIC

The dominant flow heuristic examines each non-branching flow of a function structure and groups the sub-function the flow travels through until exiting the system or transformed into another flow. The identified set of sub-functions defines a module that deals with the flow traced through the system. The identified sub-function forms the boundary, or interface, of the module. Others flow, in addition to the traced flow that crosses the boundary intersections between the module and the remaining product. To implement the module, conduits must be specified to carry the interactions across the interface.

BRANCHING FLOW HEURISTIC

The second heuristic is referred to as branching flow and requires identification of flows associated with parallel function chains. Each limb of a parallel function chain defines a potential module. The module is in the form of the sub-functions that make up the limb (technically, each limb consists of a sequential function chain). All modules (one per limb) must interface with the product at the flow's branch point. All flows that cross this interface are the interactions between the remaining product and the module (Stone et al. 2000).

CONVERSION–TRANSMISSION HEURISTIC

The third heuristic method deals with conversion sub-functions and conversion to transmission chains. Conversion sub-function accepts a flow of material or energy and converts the flow to another form of material or energy. In standard verb-object form, a conversion sub-function appears as convert flow A to flow B. In many cases, these conversion sub-functions are already components or modules themselves. For instance, electrical motors, hydraulic cylinders, and electrical heaters can be represented by a single conversion sub-function and exist in a chain with a transmit sub-function (or transport sub-function for material flow), then the chain presents an opportunity to form a module. This converts an energy or material to another form and then implements (transmits or transports) that new form of energy or material.

METHODOLOGY

An overview of the methodology used to identify the platform and module of the products in this project were outlines in a flow chart shown in Figure 2.

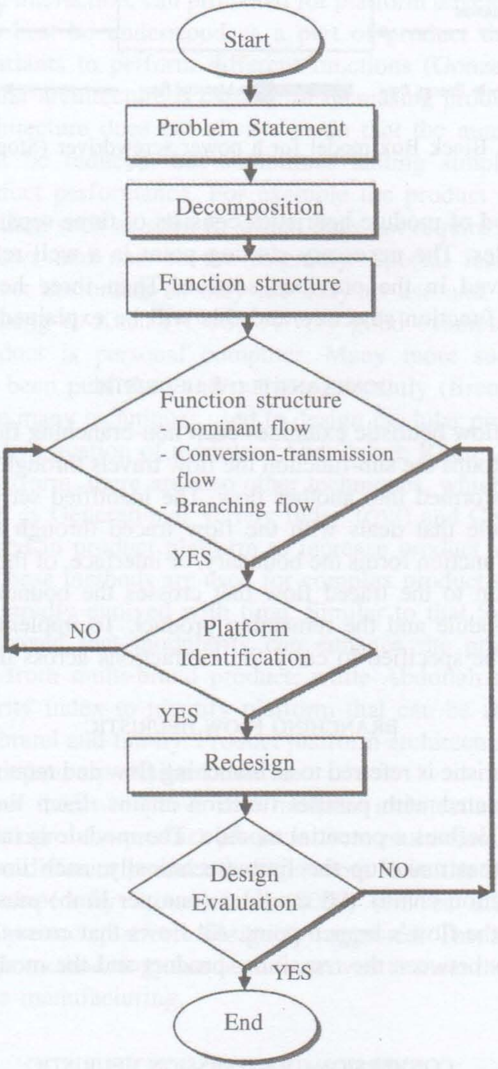


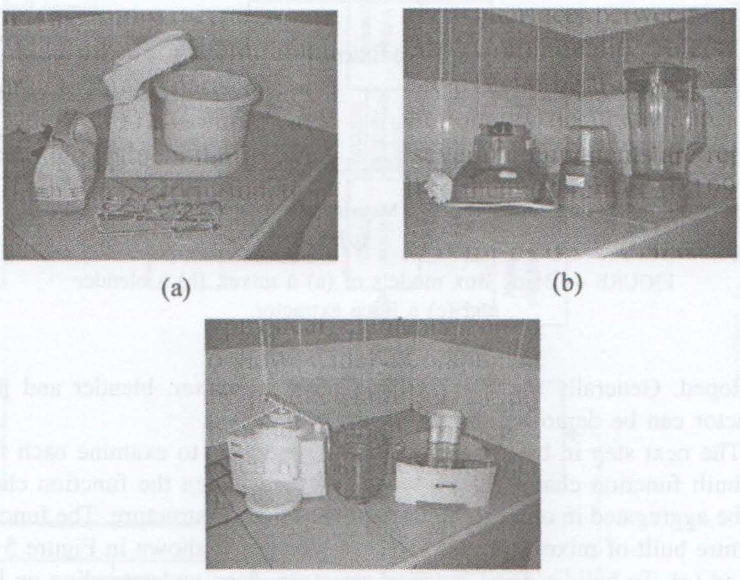
FIGURE 2. Schematic arrangement of the INSTRON tensile machine

In order to understand the product functionality, it should be broken down into smaller parts and components. Every parts and components functionality is then presented in the form of black box model and after that the function structure for each product can be developed. After a function structures for each product have been built the method of module heuristics to identify modules is then applied. Modules that have been identified will then be listed and this will help us to identify platform of those products by highlighting the similar modules identified from the products. Finally the platform is then suggested.

Products among family in general have similarity in terms of parts configuration and assembly. The relation or interface between the physical elements can be standardized or communalised. Commonality refers to how widely components (architectures, parts or sub-systems) can be used across the product family (Jiao and Tseng 2000). Component commonality occurs within a product, among products or among products family when several components are replaced by a single component which can perform function all of them (Perera et al. 1999).

IMPLEMENTATION

In this project, three types of consumer product from different families have been studied. The products are flour mixer, blender and juice extractor as shown in Figure 3. Generally all these three products have several similarities in terms of functionality but have obvious differentiation in physical appearance. Through this section, those similarities in terms of functionality of the products will be identified and new design, which also has similarity in physical appearance, will be suggested at the end of the paper.



(a) (b) (c)

FIGURE 3. Three customer products from different family are used as a case study, (a) flour mixer, (b) electric blender and (c) juice extractor

PROBLEM STATEMENT

In market, most of the consumer products have similar operation in order to accomplish their tasks, i.e., need motor to rotate blade for blender and extractor and beater for mixer, but unfortunately, are designed distinctly.

FUNCTION STRUCTURE

In order to build function structure for each product as explained in the previous section, the black box models for each product must firstly be

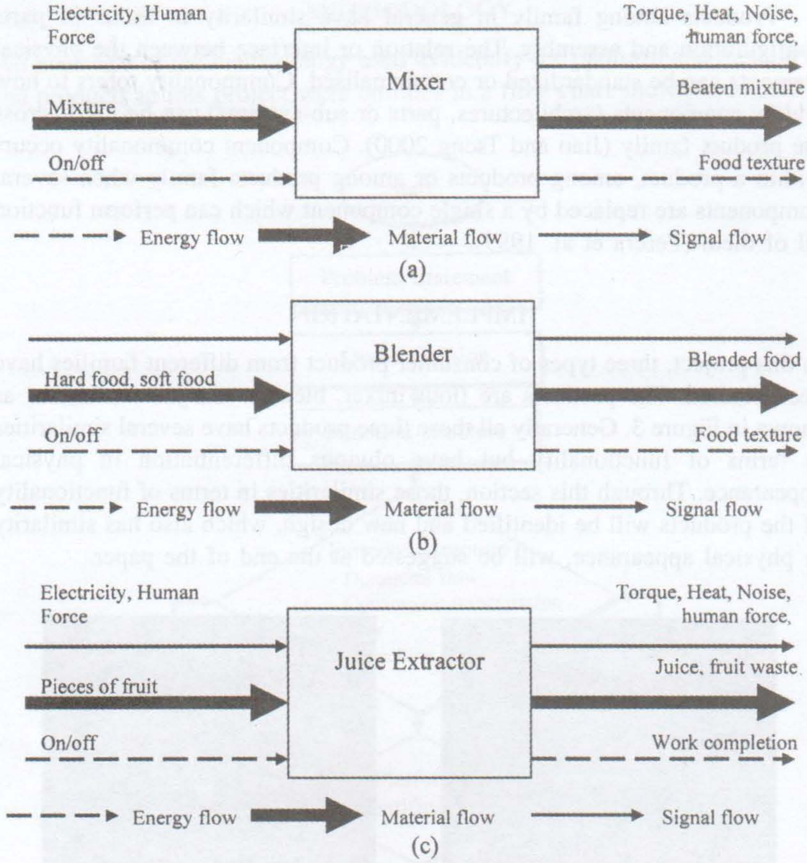


FIGURE 4. Black Box models of (a) a mixer, (b) a blender and (c) a juice extractor.

developed. Generally the Black Box models for mixer, blender and juice extractor can be demonstrated as shown in Figure 4.

The next step in building a function structure is to examine each flow and built function chains for every one of them. Then the function chains will be aggregated in order to build the final function structure. The function structure built of mixer, blender and extractor are as shown in Figure 5 (a), (b) and (c). To build a good function structure, deep understanding on how the machines work and the functionality of each component in the product is needed.

Modules contained in mixer, blender and juice extractor can only be identified after the function structure has been fully built. The result upon using the method of module heuristics will be presented in the next section.

MODULES IDENTIFICATION

In this section, based on the developed function structures of the mixer, the blender and the juice extractor, after using dominant flow, branching flow and conversion-transmission rule discussed in previous section, all modules can be identified easily. To reduce number of figures, only modules identified from blender are shown in Figure 6, while Table 1 lists down all modules identified in the products. Modules are depicted by dash rectangular lines.

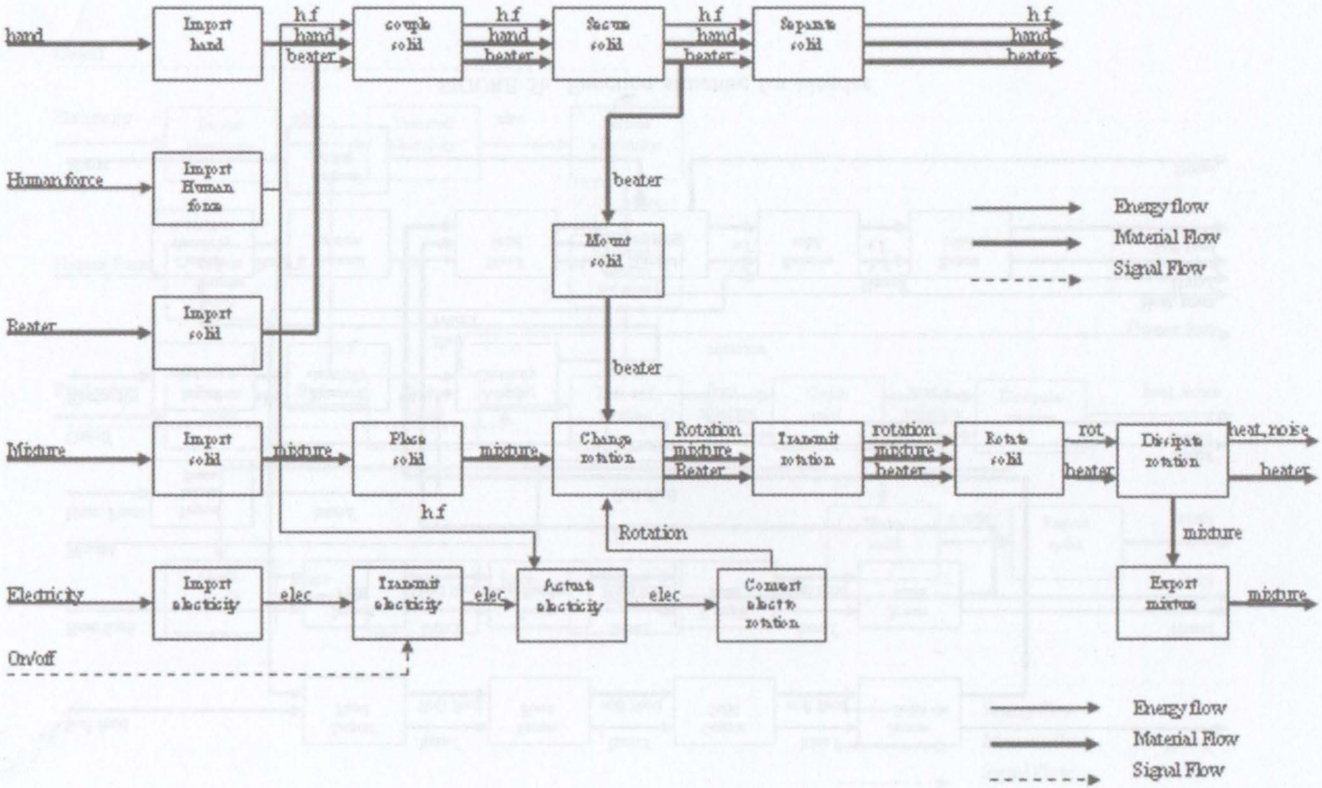


FIGURE 5a. Function structure for mixer

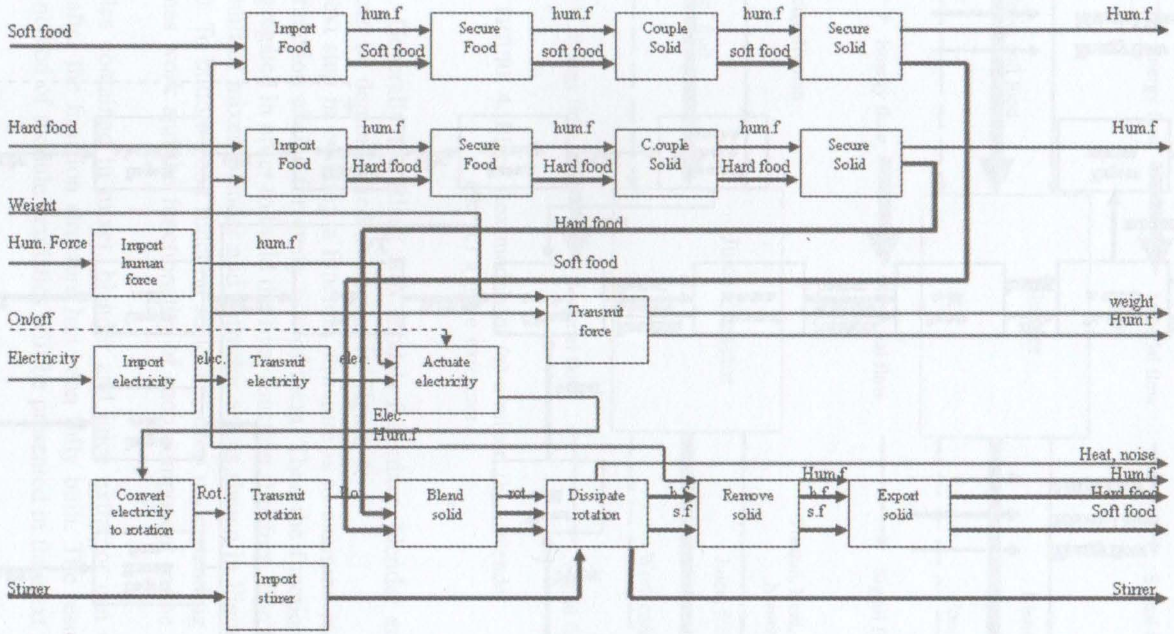


FIGURE 5b. Function structure for blender

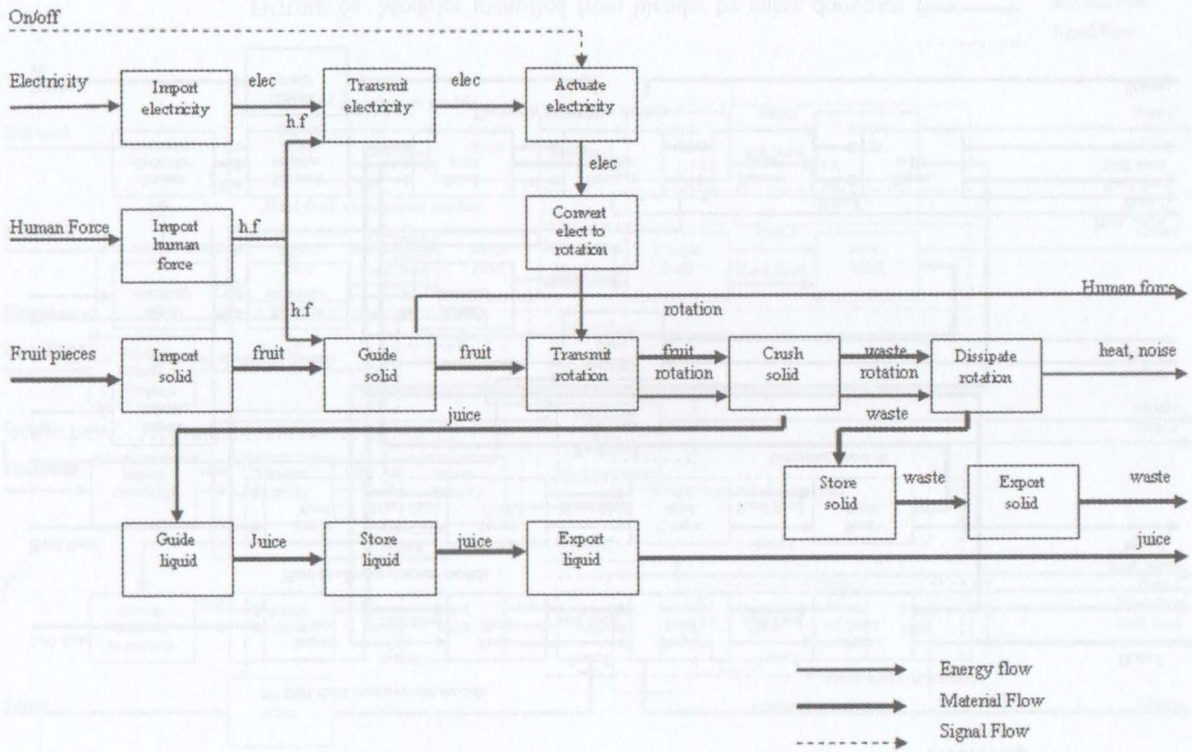


FIGURE 5c. Function Structures for juice extractor

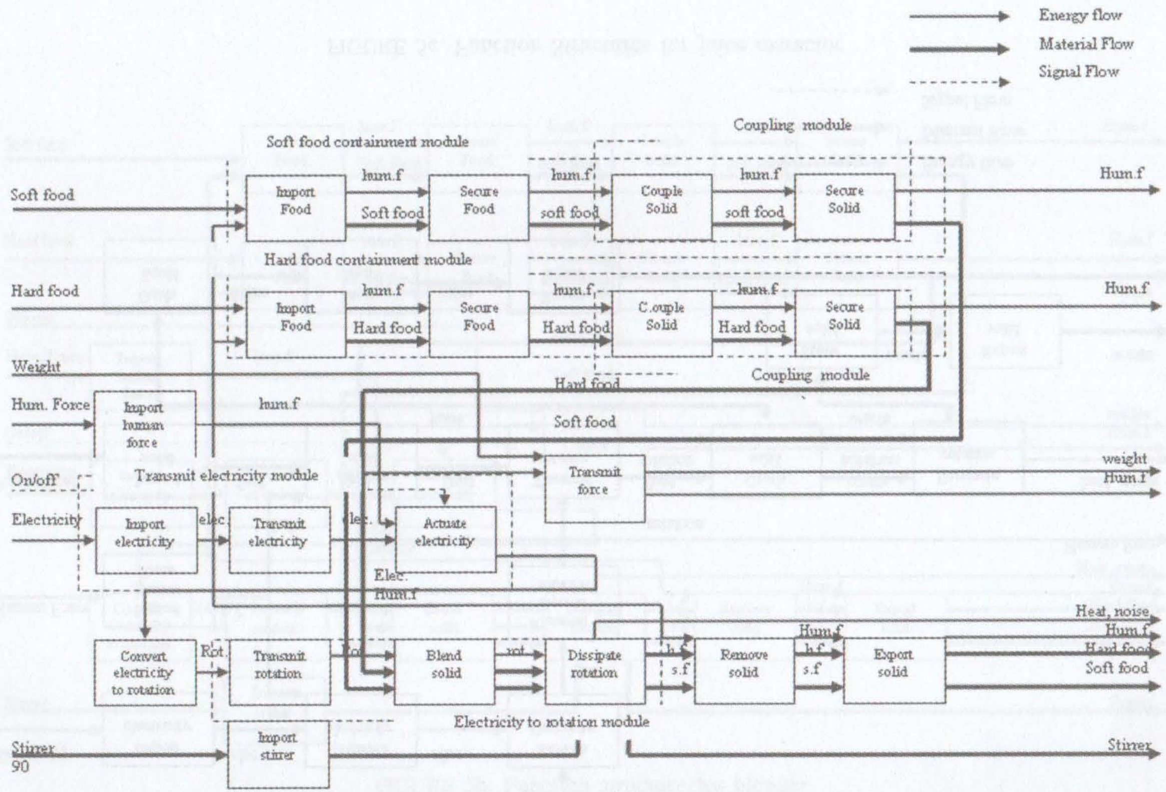


FIGURE 6a. Modules identified from blender by using dominant flow

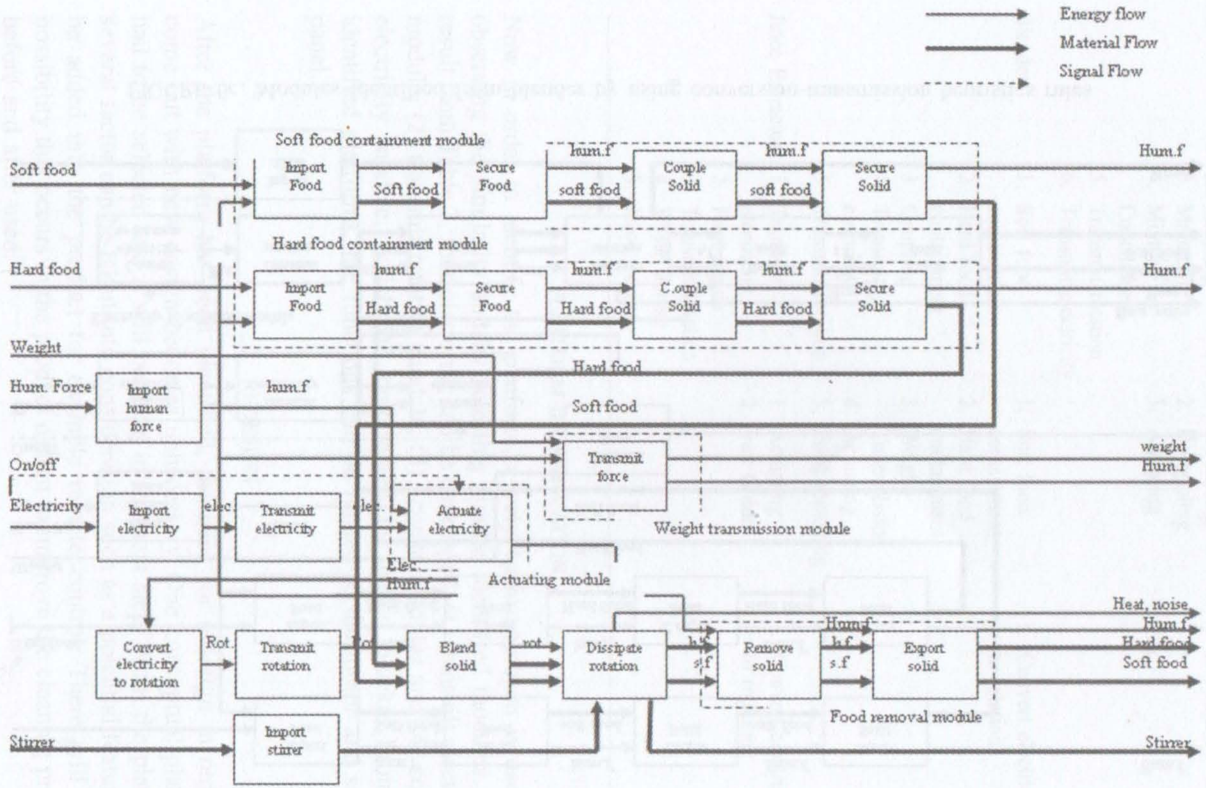


FIGURE 6b. Modules identified from blender by using branching flow

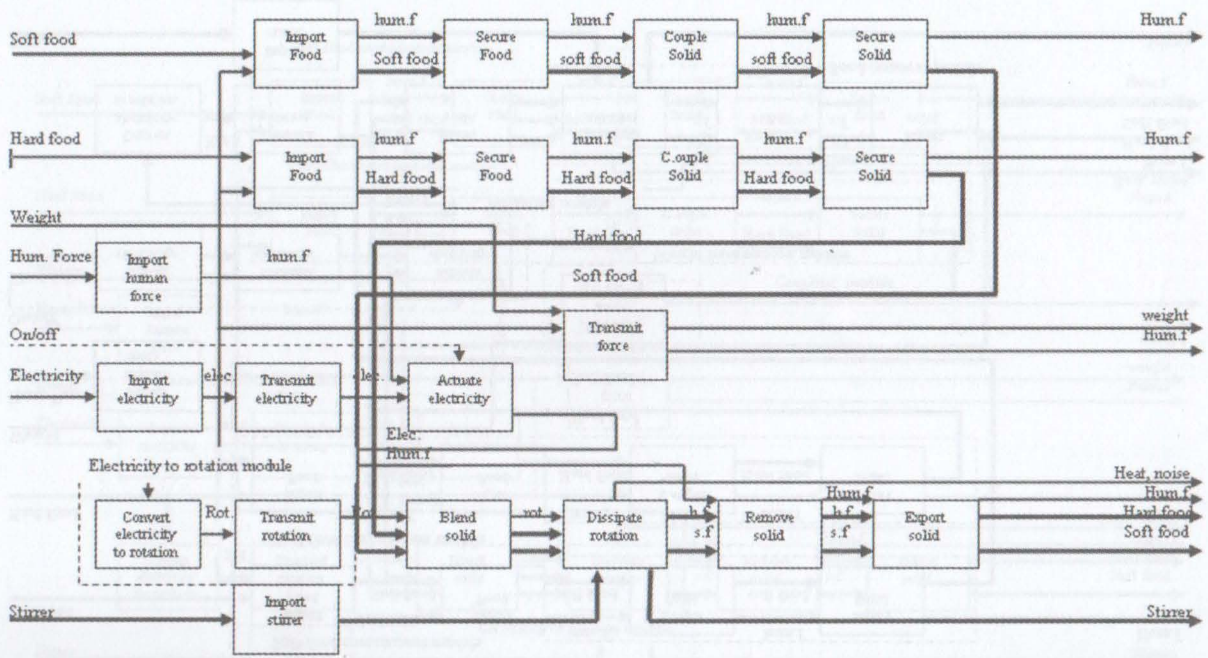


FIGURE 6c. Modules identified from blender by using conversion-transmission heuristics rules

TABLE 1. Module identified in products studied

Product Family	Module		
	Dominant flow	Branching flow	Conversion-Trans
Mixer	1. Hand Interface 2. Coupling 3. Mounting 4. Mixture Containment 5. Transmit rotation 6. Transmit electricity	1. Coupling/ decoupling 2. Decoupling 3. Actuating	1. Convert electricity to rotation
Blender	1. Soft food containment 2. Hard food containment 3. Coupling 4. Transmit electricity 5. Transmit rotation	1. Soft food containment 2. Hard food containment 3. Weight Transmission 4. Actuating 5. Food removing	1. Convert electricity to rotation
Juice Extractor	1. Transmit electricity 2. Fruit Guide 3. Transmit rotation 4. Waste storing 5. Juice storing	1. Actuating 2. Fruit Guide	1. Convert electricity to rotation

PLATFORM IDENTIFICATION

Now in order to identify the platform, a very basic approach is used by observing the similarity and by selecting similar identified modules. As a result from Table 2, four platforms can be developed; (1) transmit electricity module, (2) transmit rotation module, (3) actuate modules and (4) convert electricity module, which are represented in shaded blocks. From the identified platforms, the functions can be related to the motor and switch panel.

REDESIGN

After the platform has been identified, the need for redesign in order to come out with new design becomes unnecessary. One conceptual platform had to be selected and it will be done in the next step. From the platform several factor can be taken into consideration such as a potential features to be added into the product for example remote control. There will be a possibility that occurs in the product design to improve the cleaning process before and after used.

Waste storing/cleaning module also has potential to be developed. A new part can be added to the juice extractor's variant so that the waste can be moved without disassemble the machine. Traditionally juice extractor, which is extractor assembly that consist of blade, main housing and top cover need to be disassembled before waste can be remove.

TABLE 2. Platform identified from listed modules

Product Family	Module		
	Dominant flow	Branching flow	Conversion-Trans
Mixer	1. Hand Interface 2. Coupling 3. Mounting 4. Mixture Containment 5. Transmit rotation 6. Transmit electricity	1. Coupling/ decoupling 2. Decoupling 3. Actuating	1. Convert electricity to rotation
Blender	1. Soft food containment 2. Hard food containment 3. Coupling 4. Transmit electricity 5. Transmit rotation	1. Soft food containment 2. Hard food containment 3. Weight Transmission 4. Actuating 5. Food removing	1. Convert electricity to rotation
Juice Extractor	1. Transmit electricity 2. Fruit Guide 3. Transmit rotation 4. Waste storing 5. Juice storing	1. Actuating 2. Fruit Guide	1. Convert electricity to rotation

DESIGN EVALUATION

In the design stage, there several proposed design and only one design is selected and presented as the final design. The selection is based on several indicators as describe below, where the bolded criteria in the bracket are key indicators:

1. Platform which require the less number of parts. (Part Count)
2. Platform which perform exactly the same functionality and performance as the actual product. (Functionality)
3. Platform which can accommodate to as many variants. (Part Commonality)

Variants can added to the module of coupling and decoupling for jar, mill and juice extractor. With this module added to the new product it will be easy to couple them to the platform. Coupling/decoupling module may perform as weight transmission module for blender. There is no need to press the top of the jar, as the jar had been attached properly to the platform (blender's machine operation). The numbers of parts is less comparatively. Conceptually, platform and its variants will perform as well as the older product. Also with the added module (coupling decoupling module for jar, mill and juice extractor) the performance of the new product will be improved. Figure 7 shows the platform and its variants.

The upper arm module can be easily attached to the main body module for preparing flour and detached for blending and extracting applications.

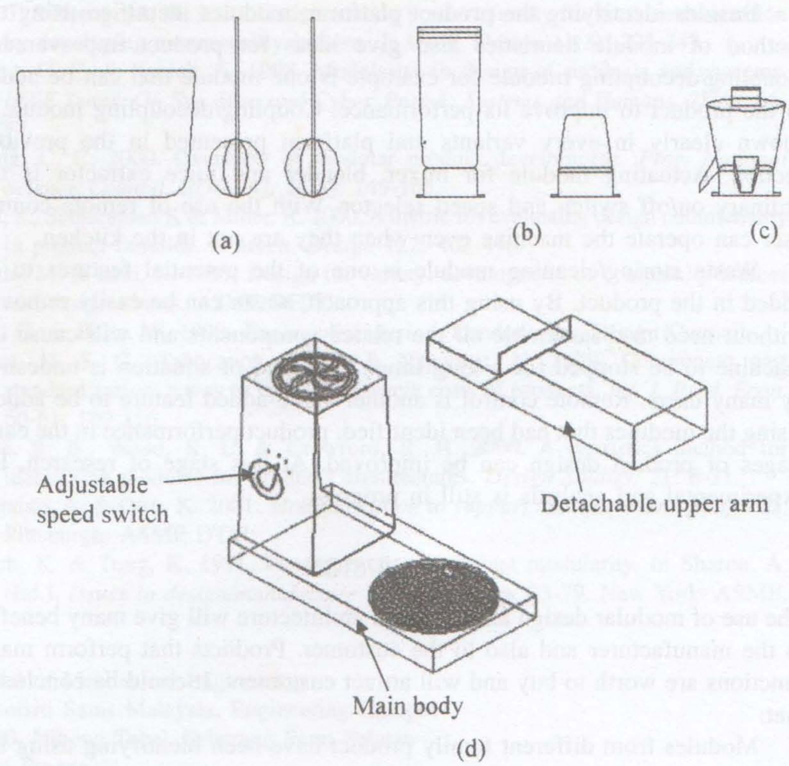


FIGURE 7. New design of platform (d) which can accommodate with several variants, (a) mixer, (b) blender and (c) juice extractor by direct attachment to the platform.

TABLE 3. Design improvements

	Current Design	New Design	Improvement (%)
Part Count	43	26	39.5
Part Commonality	8.5	30.2	255.3

The main issue is that the coupling between these modules via impeller needs to be properly mounted. Table 3 summarises the design improvements from applications of product platform using modular approach. This case study indicates that the part count is reduced by about 40% and there is a tremendous increment in part commonality where it increased by 255%. The commonality measure is based on Product Line Commonality Index (PCI) developed by Kota et al. (2000).

DISCUSSION

In this project, three types of products have been taken into consideration. As mentioned earlier, the products are mixer, blender and juice extractor. These products are home appliances product from different family and they are chosen due to simplicity of the products that use AC motor to perform their function and familiar to most of the customer.

Besides identifying the product platform, modules identified using the method of module heuristics also give ideas for product improvement. Coupling/decoupling module for example is one module that can be added to the product to improve its performance. Coupling/decoupling module is shown clearly in every variants and platform presented in the previous section. Actuating module for mixer, blender and juice extractor is the ordinary on/off switch and speed selector. With the use of remote control user can operate the machine even when they are not in the kitchen.

Waste storing/cleaning module is one of the potential features to be added in the product. By using this approach, waste can be easily removed without need to disassemble all the related components and will cause the machine to be stopped for a long time. This kind of situation is undesired by many users. Remote control is another value-added feature to be added. Using the modules that had been identified, product performance in the early stages of product design can be improved. At this stage of research, the experimental and analysis is still in progress.

CONCLUSION

The use of modular design and platform architecture will give many benefits to the manufacturer and also to the customer. Products that perform many functions are worth to buy and will attract customers. It could be concluded that:

1. Modules from different family product have been identifying using the method of heuristics rules.
2. Similarities between modules identified in products function structure can be exploited to design the product platform.
3. The method of module heuristic is a good tool for generation of ideas to improve product performance, especially for simple products.
4. Part count and part commonality were improved tremendously.

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