Development of Design Structure Matrix of Product Architecture Case Study: Multi Purpose CNC Router

Irfan Hilmy[1, a], Erry Yulian T. Adesta[1,b], Nur'atiyah Najwa Binti Samsul Bahrim[1], Aini Nurrasyidah Binti Azhar[1], Siti Fatimah Binti Mohd Shahar[1]

[1]Manufacturing and Material Engineering Department, Kulliyyah of Engineering, International Islamic University Malaysia, P.O. Box 10, 50728, Kuala Lumpur, Malaysia

[a]ihilmy@iium.edu.my, [b]eadesta@iium.edu.my,

Keywords: Design Structure Matrix, CNC Router, Product architecture

Abstract. In developing any engineering product, it is crucial to develop product architecture of the system. An engineering team who responsible in developing different module should work together in order to obtain product architecture as a blueprint of the project. It is common to breakdown system or product into smaller elements as follows: subsystems, modules and component and define the interactions between components and subsystems. In order to achieve the performance of the system as a whole, these elements must be integrated to work together. One of the method to develop product architecture is Design Structure Matrix (DSM). The use of DSM for Development of Product architecture with case study a CNC router platform is presented. Using DSM, order of product development can be optimized and any form of wastes can be eliminated in the design stage.

Introduction

Among many modeling tools, the DSM has advantage in sense that it represents not only the breakdown of the components, but also the interaction or behaviour between the components[1]. Thereby, DSM highlight the system's designed structure or architecture. In the development of engineered system with great complexity, DSM is well suited and mainly used in the area of engineering design project or management. The power of DSM also lies with its graphical nature of the matrix presentation format. Using the DSM, the system architecture can be developed in an easily scalable, a highly compact and an intuitively readable representation manner. The application of DSM is not only in Product Architecture[2], but also cover Organizational architecture[3] and Process architecture[4].

Many machines are designed or naturally shared a similar component such as CNC router platform. For example, by comparing CNC milling and 3D Printing system, CNC router platform can be found as a similar mechanism for controlling the movement of the device in a 3D space. This feature also can be applied for other devices: 3D scanner and friction welding machine.

Methodology

Development of a product architecture of a CNC Router Platform consists of five mappings activity: (1) hierarchical breakdown of the product into modules and components, (2) using a rectangular matrix diagram, assignment of functions to the modules and components is mapped and (3) development of the interactions between modules and components. (4) Create a DSM representation of the model, highlighting features of a special interest or particular importance and (5) Improve the sequence of process by optimizing the DSM of the system.

One of the major tool that works based on the Design Structure Matrix Methodology is ProjectDSM[5]. The software has a standard DSM tool such as project planning, analysis, optimization and also has advance feature such as risk management tool that allows the user to

distinguish between project risks that can be managed by the project team and risks that require organizational management attention.

Before these five steps applied, appropriate preparation in light of the purposes, goals, and constraints for the effort should be initiated. The last step, ideally, should include a feedback to the first step in order to perform a continuous improvement loop in term of model's richness and accuracy. Eventually, a systematic cycle of learning will increase the knowledge of the system.

Result and discussion

The task to design and fabricate a CNC router platform was assigned to a team with three members. Each person should develop a component or sub-system and breakdown the component into a hierarchy modules. Once the development finished, they discussed and combine/merged the component into an integrated system. The first map that they developed is the system map as shown in the Fig. 1. In this map, all the modules are presented and any missing components or modules can be introduced by adding new component.

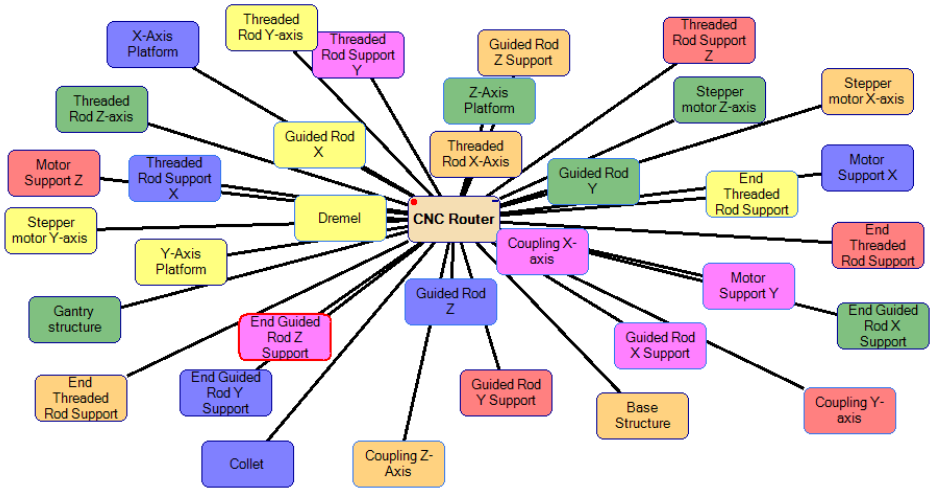


Fig. 1: System map

The next stage is the development of dependency map. This map is presenting the interaction between components. In term of product architecture, the interaction exists in four types of interaction. Those are (1) the spatial proximity or assembly how the components mating each other, (2) material flow, (3) information flow and (4) energy transfer. In this research, the first interaction become the main concern. This is related to the field of Design For Assembly (DFA), the knowledge that deal with the logic of assembly process. As shown in Fig. 2, the dependency map of CNC router platform is presented.

After completing the definition of dependency, the next stage is the representation of product architecture in the form of DSM. It can be seen from Fig. 3(a) that the size of the square matrix agreed with the number of components. DSM models can be rearranged or repartitioned using a variety of analytical methods, the most common of which are clustering and sequencing. In this case, the sequencing process was performed as shown in Fig. 3(b).

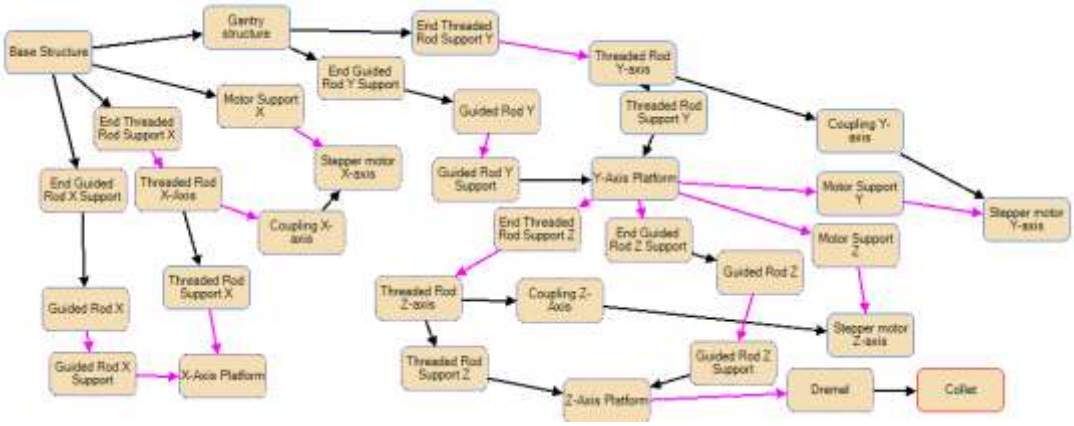
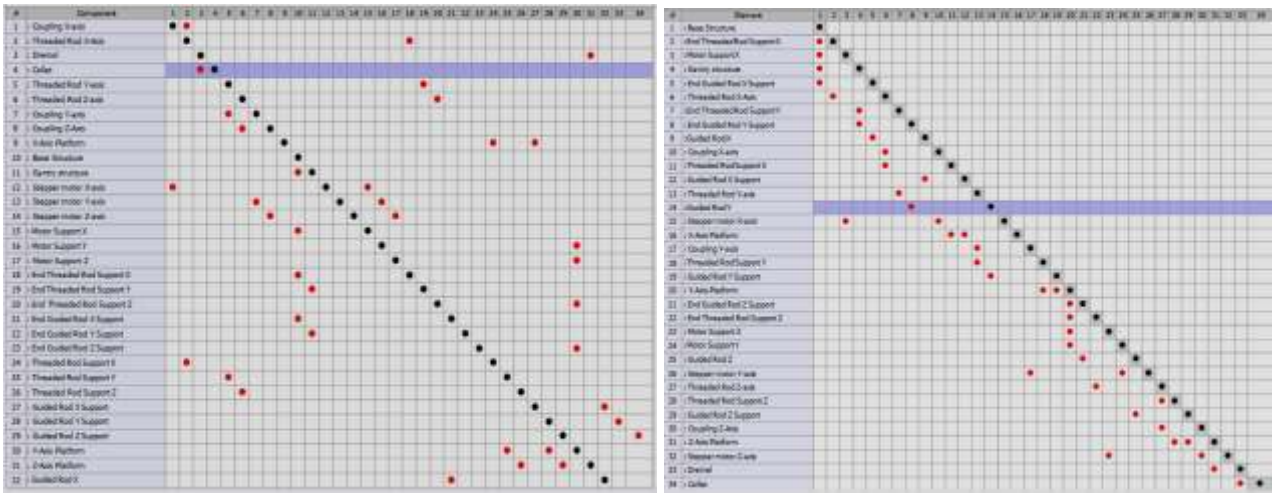


Fig. 2: Dependency map

The reason of sequencing is to reduce production delay as one form of waste (based on lean production concept). Using the sequencing method, as it can be seen in Fig. 3(b), order of production process was rearranged.



(a) (b)

Figure 3: Design Structure Matrix before (a) and after (b) Optimization

Fig. 4(a) shows the implementation of CNC router platform development. This CNC router was designed to become a multipurpose platform for Mini Milling machine, 3D Printer, 3D scanner and Friction welding machine. This is possible since the CNC platform is designed in a modular form as shown in Fib. 4(b) that can be replaced and exchanged easily.

Conclusion

It can be seen that for the development of product architecture of CNC router, DSM provides a highly effective representation for product components and their relationships. Both the product decomposition and the network of interactions can be well documented. Via clustering analysis, alternative groupings of components into modules, architectural improvement and architectural innovation can be analyzed. As products become larger and more complex systems, the value of the product architecture increases.

(a) (b)

Fig.4: Implementation; Manufacturing process (a) and Final Product (b)

It was proven that, due to the complexity of the project, it was impossible for any single individual to have a detailed, accurate and complete mental model of the entire system. Teamwork become unavoidable. Using DSM, each individual in a group able to communicate, compare, and integrate their partial models of the system. It is agreed with the statement that two of the main benefits of a DSM model are its capabilities to (1) highlight important groups of modules and patterns of interactions, such as those influencing modularity and (2) concisely represent a relatively large number of module and their relationships.

Acknowledgement

This work was supported by The Endowment B Ressearch grant, EDW B11-127-0605, RMC, IIUM Malaysia

References

1. Steven D. Eppinger and Tyson R. Browning, Design *Structure Matrix Methods and Applications*, The MIT Press Cambridge, Massachusetts London, England, 2012
2. Holtta-Otto, Katja, V. Tang, and Kevin Otto, *Analyzing Module Commonality for Platform Design using Dendrograms*, Research in Engineering Design 19 (2):127-141, 2008
3. Browning, Tyson R, *Using the Design Structure Matrix to Design Program Organizations. In Handbook of Systems Engineering and Management*, 2nd ed., eds. Andrew P. Sage and William B. Rouse. New York: Wiley, pp. 1401-1424, 2009
4. Levardy, Viktor, and Tyson R. Browning, *An Adaptive Process Model to Support Product Development Project Management*, IEEE Transactions on Engineering Management 56 (4):600-620, 2009.
5. ProjectDSM Team, ProjectDSM, http://www.projectdsm.com