Product Structuring in Reality

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Bei Yu
Department of Engineering, Glasgow Caledonian University
City Campus, Cowcaddens Road, Glasgow G4 0BA, UK
Email: B.Yu@gcal.ac.uk

Ken MacCallum
CAD Centre, University of Strathclyde
75 Montrose Street, Glasgow G1 1XJ, UK
Email: ken@cad.strath.ac.uk

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Abstract

Recently, product structuring has increased in interest both at the academic and at the industrial level. For industry particularly, appropriate product structures can support the design process from different aspects. However , developing product structures is not easy in practice.

This paper presents an experience of product structuring within an individual company. The work is part of the configuration research project which has been presented in the first WDK Workshop on Product Structuring. The hypothesis of two interrelated product structure formalisms has been tested through this case study. The industrial case has shown that there are difficulties in creating these product structures due to the lack of product information and designing knowledge at the abstract level. Nonetheless, this experience indicates the importance to the design process and especially to the configuration process. That is, once these product structures are developed, a product can then be configured rapidly and correctly, assisted by an effective reasoning engine.

1. Introduction

In order to challenge the competitive market, product development needs to be faster and better within a minimum cost. Nonetheless, the product nowadays becomes a complex technical system especially for a product which has been involved in many engineering disciplines. There is a need, therefore, to handle the complexity of a product to ensure the design process is as short as possible without losing quality of the product.

Managing existing product families with variants, is also important in practice. In most cases within industrial companies, the design process starts from the previous design solutions, and then modifies them based on the customer requirements to produce a newer design solution, i.e. customisation. When the business is growing, it is a problem to manage a product range and its variants. How to manage and reuse existing products is thus of interest recently both in the design research area and industrial practice.

This paper presents the authors' practical experience on product structuring based on the research work on the configuration project carried out in the CAD Centre, University of Strathclyde. The practice was carried out in the Elm company based in Glasgow. The objectives of the work are:

- To test and verify an hypothesis of product structure formalism;
- To gain an experience of product structuring in a real world.

2. A Formalism For the Product Structures

Two interrelated product structures, that is, *Product Breakdown Structure (PBS)* and *Product Family Classification Trees (PFCTs)*, have been developed in the configuration project. The framework of the product structure formalism is shown in Figure 1. The PBS represents a conceptual product model in a hierarchy of a parts breakdown. Links in the structure are viewed as "a part of". Each node in this structure stands for a module, a subsystem or an element. All the attributes, features and properties of selected elements are recorded in the elements list. Each node in the PBS belongs to its own family classification tree also called Product Family Classification Tree, in which a group of elements have high commonality of functions, characteristics or manufacturing process. Nodes in a PFCT have relevant parts breakdown at different levels of detail[Yu 1995b].

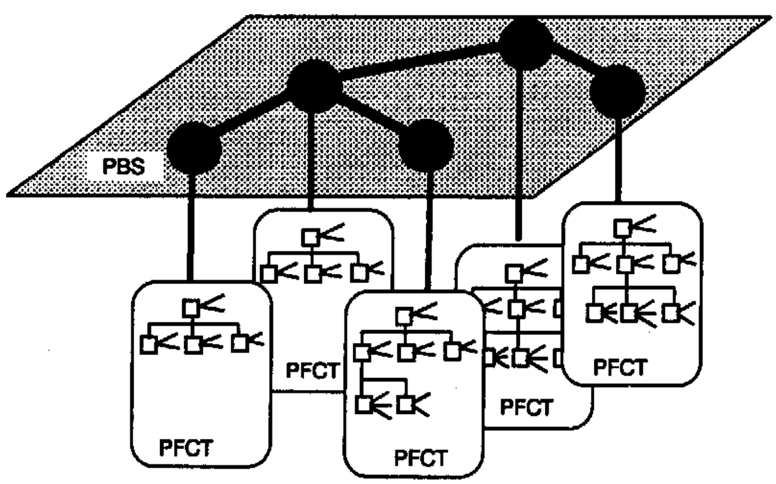

Figure 1: The Framework of the Product Structures

A product range can be classified as a set of PFCT, i.e., PFCTs, each of which is the tree structure that presents a class of product and its modules from an abstract level to product instances. Each node in the tree represents a product or a module class with its parts breakdown. The ancestor-descendant relationship between two classes is presented as "a kind of", i.e., a class of product is a kind of the super-class of product.

There will be several product family classification trees which are related to one another. In other words, all existing modules, parts and elements that might be configured can be found in the given knowledge sources in terms of their own Product Family Classification Trees. In addition, constraints about elements exist among those Product Family Classification trees.

The criteria for classifying PFCT is the key to develop such a product structure. There are number of possible criteria for developing PFCTs, such as function, user requirements, product performance, application aspect, customer group, manufacture location, etc. For a product range therefore, there can be multiple PFCTs corresponding to different classification criteria[Yu 1995a].

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3. The Elm Company

Elm Limited company [Elm 1995] designs and manufactures a variety of plant controllers for compressor packs, condensers, header stations, alarm units and timeclocks within a refrigeration system. These controllers are the microprocessor-based systems for controlling and monitoring compressors, condenser fans and defrost procedure in a networking refrigeration system. The physical architecture of the plant controller is demonstrated in Figure 2.

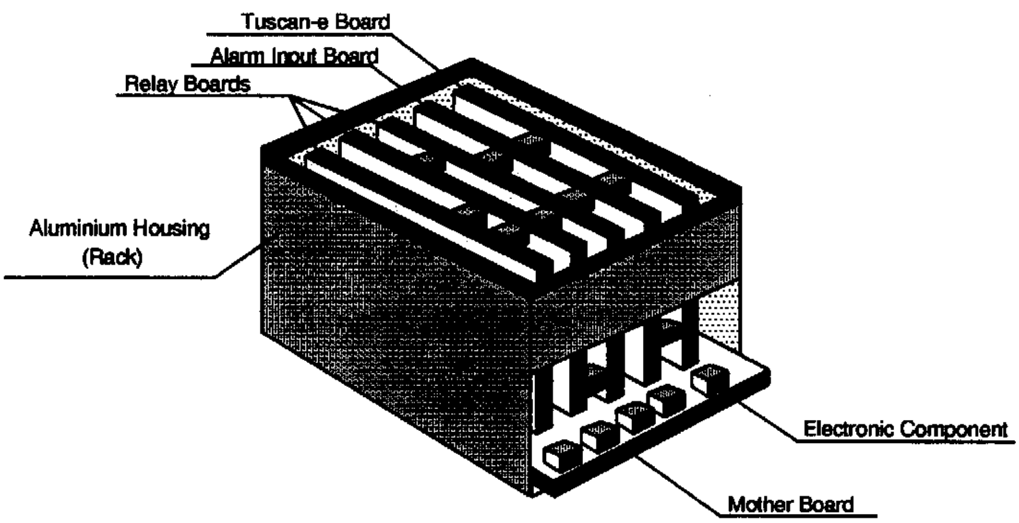


Figure 2: Architecture of the Plant Controllers

A range of plant controllers in rack configuration with stack to special order are divided into different plant controller products based on their functionality. There are individual control functions such as the *Pack Controller, Condenser Controller* etc., as well as for a combined control function for compressor, condenser and defrost procedure. The plant controller can control liquid level, air pressure, temperature and run hours through monitoring of these parameters. The control of the process is by either the switch method or relay method. These controllers also can read the thermistor temperature probes, pressure transducers and on/off input; communicate with the supervisor equipment over the network lines; and can display information on LCD or LED display mode.

The design process of a plant controller starts from the customer requirements, then forms a design specification which covers required functions, working principles, control methods, as well as the requirements and constraints for mechanical parts and hardware/software. Based on the past design experience, the designer selects an applicable controller model or a module which is close to the required functions and features in the design specifications. The designer then modifies this model by cutting or adding appropriate functions or features which may cause changes on mechanical parts or hardware/software, and then goes on to a detailed design based on these changes to create a new model or variant of plant controller that meets the design requirements.

As part of design, configuration design is taken into account when considering how to put the elements together to satisfy the design requirements. For the plant controller, the design requirements rely on the customer requirements mainly on the functions, features and behaviour of the controller. The design specifications are then derived from these requirements. The configuration process is to select controller parts and to define relationships between parts that are designed or to be designed based on the relevant configuration requirements and constraints.

There are various restrictions on designing a plant controller, which are normally called by designer as *constraints*. An example of the logical restriction could be:

5-way rack and 5-slot motherboard must exist at the same time.

Another example of feature constraint could be like this:

*5-way rack size (W*H*D): 350*280*170 mm.*

As a design solution, it is represented as a 3-D drawing for the controller geometry as well as a parts list with their ordering numbers, which is ready for the manufacture stage to produce a plant controller. All models and variants of the plant controller range are recorded in the company numbering system.

4. Information Gathering

For this case study, the plant controllers have been chosen to test the feasibility of the proposed product structures and also to gain experience on product structuring. The procedure started with product information gathering. This activity was carried out through a series of discussions with sales engineers, industrial designers, production engineers and maintenance engineers. Through the information gathering, the product information needs for individual engineers as well as the relationships among these product data, have been identified. The information gathering formed a base for the creation of the appropriate structures for the Elm controllers.

However, this practice has shown that there are the difficulties on producing such product structures due to the following factors:

1. Lack of information;
   The required information about products for the hypothesis of product structure is not all available in practice.

2. Poor documentation;
   Documentation for product information in product development has not been organised to suit product structuring. Rather, it has evolved and is related to tasks and procedures. In Elm, the documentation is merely a description of the product functions and its operation procedures, i.e. more or less a user manual.

3. Product complexity;
   The products of Elm controllers are relatively complex since they are the electronic control systems for refrigeration plant which consists of control principles, hardware/software and mechanical parts.

4. Limited product knowledge at the conceptual/abstract level.
   To construct the proposed product structures, knowledge about the product at the conceptual/abstract level is required. In general, explicit knowledge about a product at the conceptual level is very limited.

The above aspects shows that, to produce product structures, requires close collaboration with a company to extract information which is often implicit.

6. Approaches

In response to the difficulties, an approach for the product structuring has been set up. Firstly, several viewpoints in terms of the control objects e.g. pack compressors, are considered. Secondly, the potential "user" of the product structures are defined, i.e. who is going to use these product structures. Construct the product structures, a set of criteria are then considered:

- Functional;
- Customer oriented;
- Production/assembly based;
- Multiple functions with same configuration;
- Multiple configurations with same functionality.

7. Solutions

7.1. The Controller PBS

As one of the PBS structures, the functional PBS plant controller is shown in Figure 3. In Figure 3, the plant controller is broken down into four parts levels based on individual functions. Each part has its PFCT which consists of all the alternatives of this part. For instance, the *Mother Board* which is a part of *Control Board,* has a *Mother Board* PFCT that includes all kind of mother board classes and instance models.

Plant Controller PBS

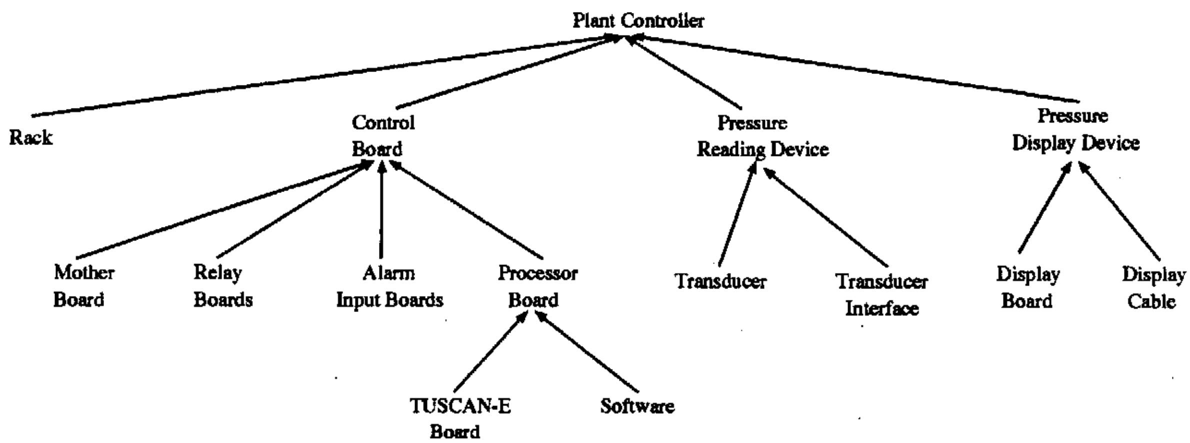


Figure 3: The Product Breakdown Structure of Plant Controller

7.2. Controller PFCTs

A set of PFCTs of plant controller are shown in Figures 4 (see the next page) and Figure 5. They are the classifications of the plant controller and its parts families. Each node in the trees has its one level parts breakdown in individual detail. For example, the *Condenser Controller* has *Condenser Control* as its control board, whereas the condenser controller instance model *YZ0002* has *Proportional Control* as its specific control board.

The one level parts breakdown in the PFCTs is in fact a linkage between the plant controller PBS and PFCTs. In other words, it presents relationships between these two structures. More importantly, it is a key aspect to carry out the configuration process in a computer supported configuration system which is developed based on the hypothesis of the product structures.

7.3. Decision Network

To support sales configuration particularly, a customer-oriented decision network has been created for the company daily business. Figure 6 shows a part of such a decision network. This decision network has been implemented in an expert system shell, so that the sales engineers are able to access the decision network to obtain a quotation or a customised controller configuration.

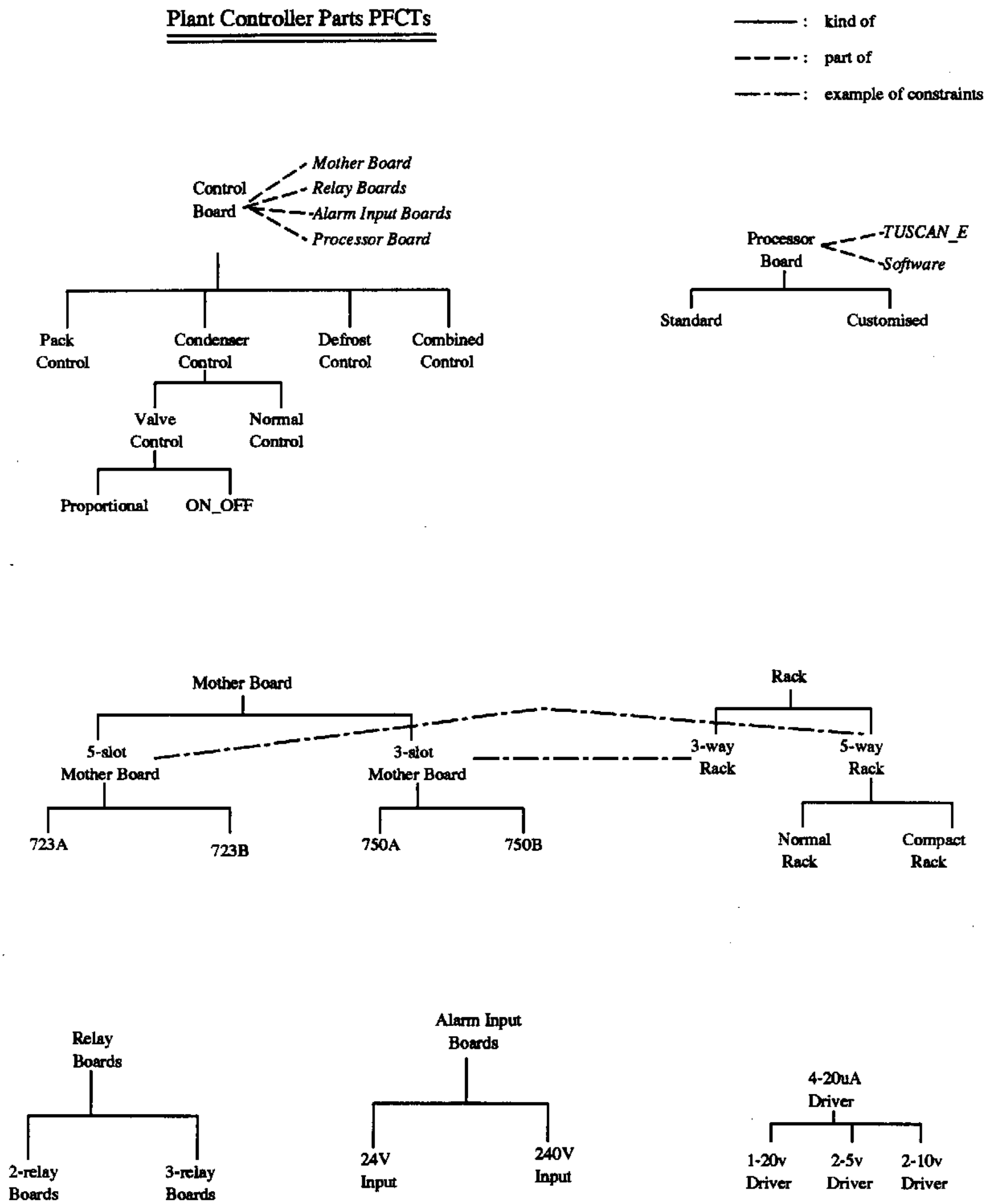
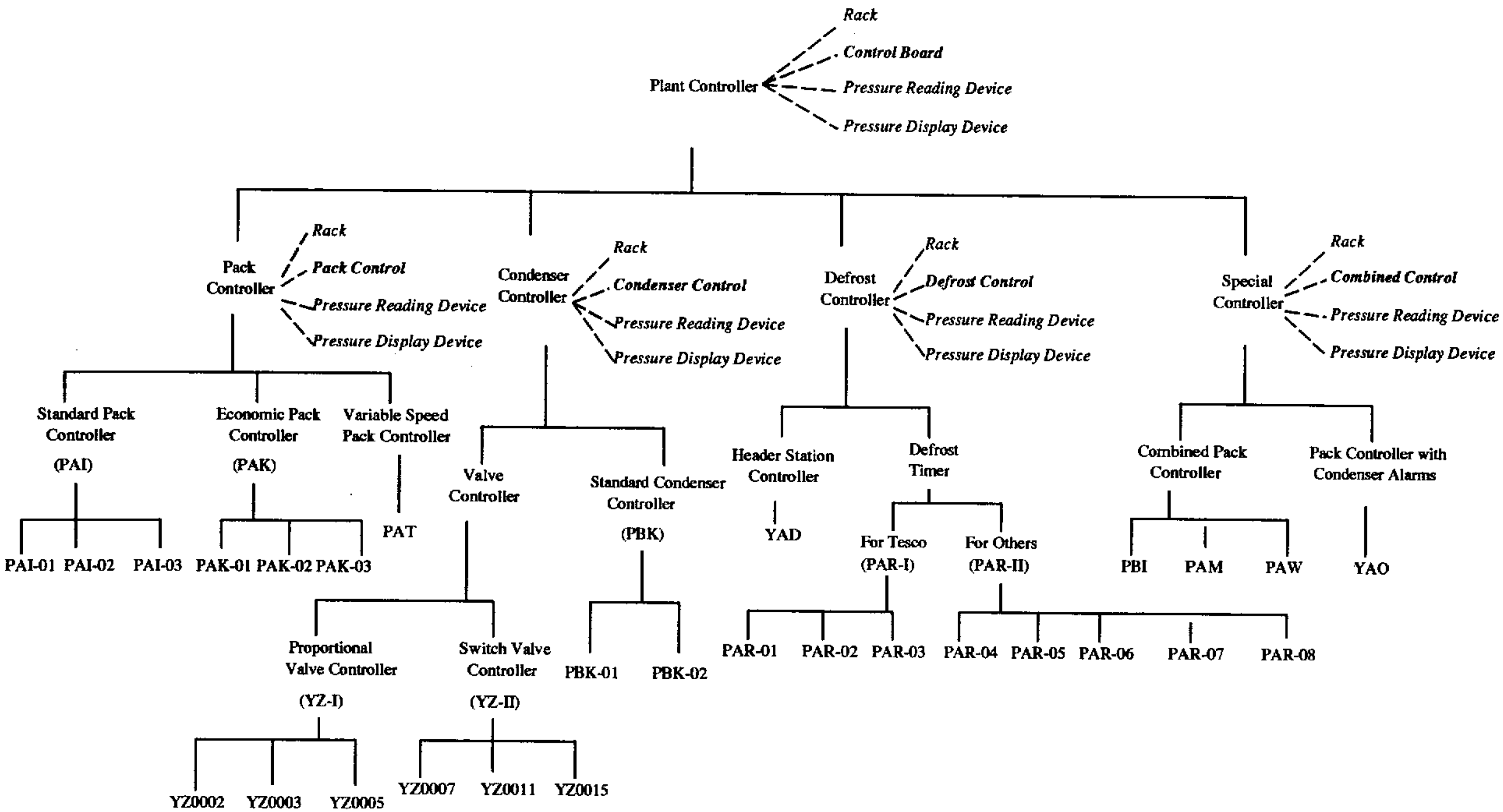


Figure 5: The Product Family Classification Trees of Plant Controller Parts

Plant Controller PFCT



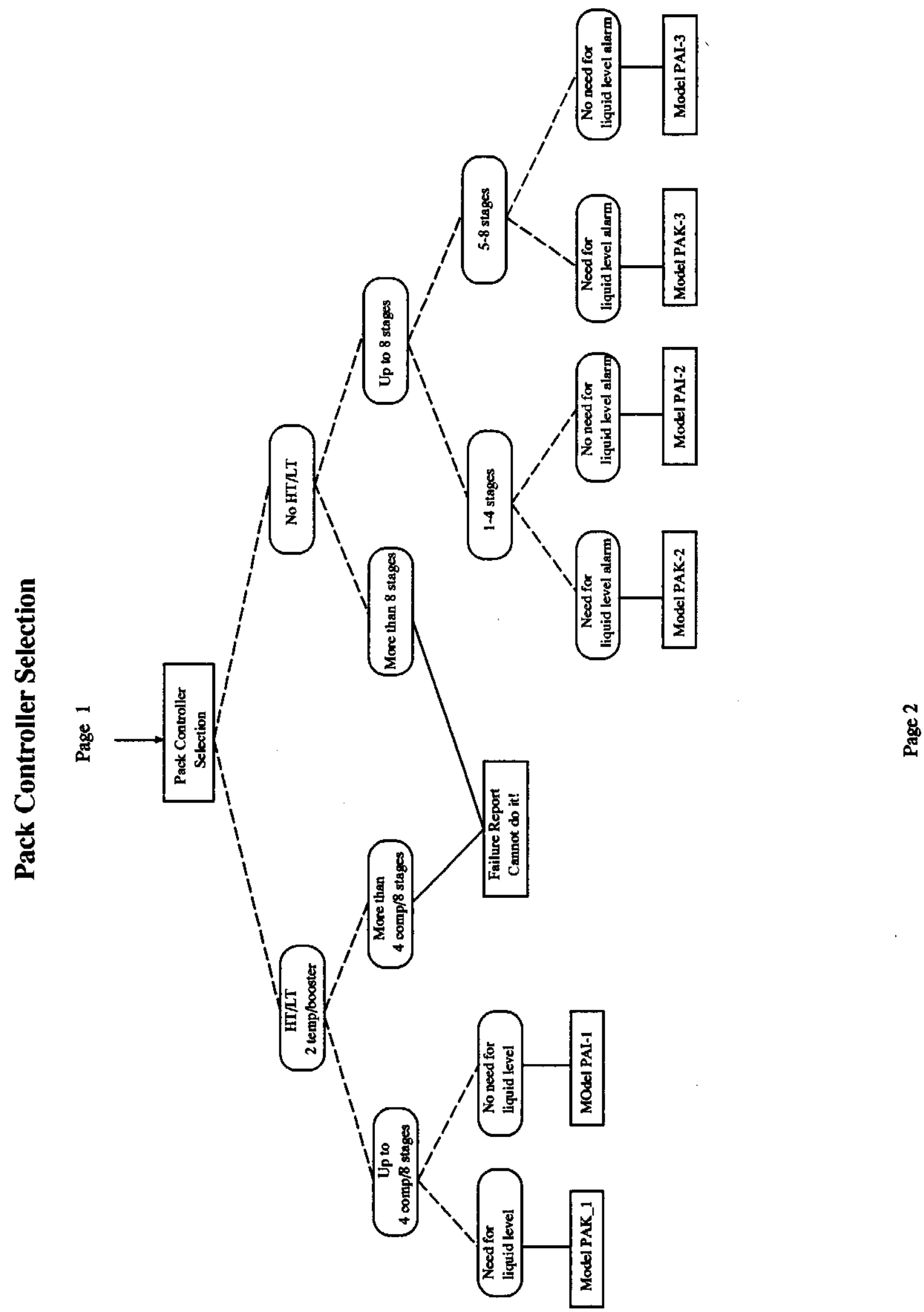


Figure 6: Part of the Decision Network for the Sales Configuration

8. Conclusion

The work presented here has shown that although it is possible to construct product structures based on a formalism there are many difficulties. Once a product structure formalism has been developed, configuration design and management can be supported and associated with an effective reasoning engine[Yu 1994].

The decision network is able to quickly create a customised product configuration. The PFCTs and PBS can help designer to re-use and share existing product information from the abstract level to the concrete level.

Documentation can also be improved by using the product structures. The product structures have shown a better way to organise and manage the existing product ranges.

The conclusion from this work is that it is feasible and valuable to have product structures when design process needs to be innovated, especially for the configuration process. It also indicates the potential benefits of the use of product structures. From the research point of view, this case study validates the hypothesis of product structures.

Acknowledgements

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