Designing Mechatronic Product Families

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Commercial variety and internal manufacturing efforts
Product families are designed to improve the ratio of

An increasing number of products use a variety of technologies

W.B. Years
How can we know the dancer from the dance?
O body swayed to music, O breathing glance,

Product structuring and design processes
Design research should consider the relationships between

Introduction
Contents

- Design considerations (modularity, integration, concurrency, etc.)
- Extending the productive reasoning model
- General product structuring concept
- Developing product families

- Productive reasoning model
  - Physical domain
  - Technology domain
  - Functional domain
- Different domains and modeling languages

- Non-compositional systems
- Consequences for product structuring and design processes
- Definitions and examples
- Compositional systems
[Albers' 1993] Components and the components' relationships are understood. The behaviour can be expressed if the behaviour of its

Example

the system within the context of the theory. Theories from natural science are able to predict the behaviour of

Product models which are based on mathematical principles or

Compositional systems - 1
Much research focuses on an automated derivation of implementation from functionality:

- Mechanical engineering [Pahl & Beitz, 1984] [Johnson, 1991] [Aymer, 1988]
- Hydraulic engineering [Lee, 1992]
- Electrical engineering [Albores, 1993]
- Software: predicate calculus, constructive programming [Dijkstra, 1976]

Design process is supported by a product modelling language which integrates functionality and realisation on different abstraction levels of the product.
technologies applied.

Physical implementation is closely related to the manufacturing and logical realisation.

Step-wise refinement of functionality (expressed as interfaces)

Compositional systems - 3
Non-compositional systems - I

For mechanistic products, there is no grand theory which links...
Each domain has a product model which structures the product.

In that domain:

- Each domain has dedicated modelling languages.

Product is developed.

There is a need to distinguish different domains in which the

Non-compositional systems - 2

( ) ( ) ( ) ( )
Product functionality or a product. It is strongly related to the use of the product.

The functional model is a consistent description of the functional domain - 1.
Functional domain - 2

- Functions on one level of abstraction.
- The functional architecture defines the relationships between
structured in this model. Development creates most of the information application of technologies to ensure the operation of the

Technology Model is a consistent description of the

Technology domain - 1

( ) ( ) ( ) ( )
of the product.

realisation of a system. It is strongly related to the conception.

- The **Physical Model** is a consistent description of the physical architecture.

  In a similar way, there is a physical model and a physical module on one level of abstraction.

  The technology architecture defines the relationships between

  **Technology domain - 2**
It can be used between different domains and on different levels.

- Problems, solutions and sub-solutions. The productive reasoning model [March, 1984; Cross, 1989]
Productive reasoning model - 2

Technology modules are realised in physical assemblies
Function is allocated to technology modules
Specifications are formalised in product models
Developing product families - 1

- drivable=yes => umnatable=yes
- colour=blue => drivable=yes
- Constraints:
  - elbowrests: with, without
  - frame: soft, hard
  - drivable: yes, no
  - umnatable: yes, no
  - colour: red, blue, yellow, green

Office-chair

Model product families with the generic structuring concept.
Boolean conditions select the right primitive variants.

Decompose families till the level of primitive variants.

Developing product families - 2
Creating scalable architectures.

Options fit into it.

Product architecture should be chosen such that different

Mechanical product families are structured in these domains.

Developing product families - 3
Concurrent versus sequential design

Observations - 1
Modularity: Balancing problem
Integration requires product maturity, product families require fine-grained design with many modules
- Several functions are realised in a module

Modularity versus Integration

Observations - 2
Mature products become more integrated, however also require more variety, which asks for modular designs.

- The architecture of a product family should be such that different modules fit in this architecture to cater for customer variety.
- Languages for the functional, technology and physical domain.
- Non-compositional systems require dedicated modelling.
- Product descriptions.
- The design process cannot be described independent from the conclusions.