Relation Types in Machine Systems

Mogens Myrup Andreasen, Alex Duffy, Niels Henrik Mortensen
Institute for Engineering Design
Building 421, Technical University of Denmark
DK-2800 Lyngby

Summary
A structure is created when a design is synthesized. In the so called WDK school, the design of a machine system follows a pattern of causal related structuring activities which leads to a functionally determined structure.

Many aspects, especially product life aspects, influence the choice of machine system structure. The relations between product structure and the structure of a life phase system or an universal virtue (e.g. cost, time, quality etc.) may be identified as a DFX principle.

This paper illustrates basic synthesis aspects of structuring, it shows examples of the influence of product life aspects. The paper leads to the conclusion that a design may possess several superimposed structural principles to fulfil product life demands.

1. Structuring as synthesis

The WDK-school has chosen to follow a systems or cybernetic approach to the concept of structure. Structure is a characteristic of a system model. A structure is defined as the elements of a system identified by their type, and the relations between these elements.

A finished design or an artefact possesses a structure, created by synthesis. In design solutions (i.e. carriers of functionality), functionality is based on both structure and the element solutions.

The WDK school looks upon design of machine systems as a synthesis from four different viewpoints, namely the machine or design looked upon as

- a system of transformations (Process domain, P6)
- a system of functions (Functions domain, Fu6)
- a system of organs (Organs domain, O6)
- a system of machine parts (Assembly domain, B6)

In the enclosed copies of overheads, domains are explained, the nature of elements and relations are defined, and the structure class belonging to each domain is illustrated.

The domains are causally interrelated, and the design of a machine system may be seen as solving two causal chains:

- a horizontal causality chain following the process pattern related to the machine system, and

- a vertical causality chain establishing the effects necessary, from the organ and assembly structures.

2. Relations in a machine system

It follows from the approach above, that we may "read" more types of relations from a design or an artefact, depending on our viewpoint: process, function, organ or assembly.

When the design is finalised, the assembly structure is that which is directly visible and the carrier of other relation types. (See the overhead illustrations, p.19, 20 and 21.)

3. Structural influences

Experience shows that fitting the product to good performance in all life phases mainly means to adjust or design the structure of the product in accordance with the life phase systems' demands.

An area with well established knowledge, namely assembly and design for assembly as the fitting activity, is chosen. From this area structural rules and principles are shown. Several principles for single product and product family structuring have been identified. (See overhead, p. 24)

4. Structural design, conclusion

The expanded product model, the so called chromosome which has been developed by the Institute for Engineering Design, shows the structure of a design in the four domains (mentioned in section 1) and the relationships between these domains. The characteristics of this model may be grouped into two types of models:

- models for the product's (own) properties, and
- models for relational properties, (e.g. showing how the product's characteristics together with a model of the production system may lead to cost statements).

Structuring a machine system has two principally different features:

- finding a correct configuration (i.e. structuring the design for functionality)

- finding a good structure (i.e. optimising more product life aspects (e.g. cost, quality, recycling) related to the product).

This workshop paper has introduced the multi-system approach of WDK and introduced basic concepts of structure and relations. The following statements are central to understand the nature of "designing a structure":

"Other structural principles for specific purposes may be added to a functionally determined structure".

"Several structural principles may be superimposed on a design's structure".

References

Andreasen, M.M.: Syntesemetoder på Systemgrundlag - Bidrag til en konstruktionsteori. Diss. Lunds Tekniska Högskola, Sverige 1980 (in Danish).

Andreasen, M.M., Olesen, J., Rosenberg, R & Ferreirinha, P.: CADOBS konstruktionslogik. Instituttet for Konstruktionsteknik, DTU. IK-88.46-B. Lyngby 1988.

Hubka, V., Eder, W.E.: Theory of Technical Systems - A Total Concept Theory for Engineering Design. ISBN 3-540-17451-6, 3.edition, Springer-Verlag, Berlin Heidelberg 1988.

Mortensen, N.H.: Product Modelling in a "Designer's Workbench". Proceedings of ICED 93, pp. 1507-1514, Heurista Zürich, The Hague 1993.

Olesen, J.: Concurrent Development in Manufacturing - based on Dispositional Mechanisms. PhD-Thesis, Institute for Engineering Design, Technical University of Denmark, 1992.

What does "structure" mean ?

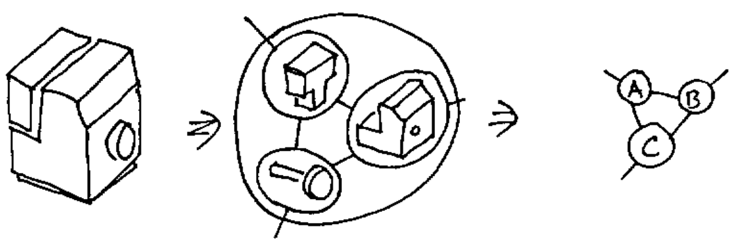
1. Daily life language concept:
   ..the way things are build up.

2. WDK-school / Systems Engineering / Cybernetics:

Structure is a characteristic of a system model.

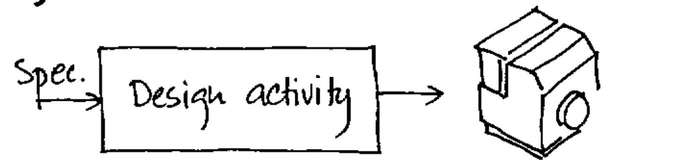
A system model is a model which look upon an artefact or design as a set of elements and their relations.

A structure is the elements identified by their type, and their relations.

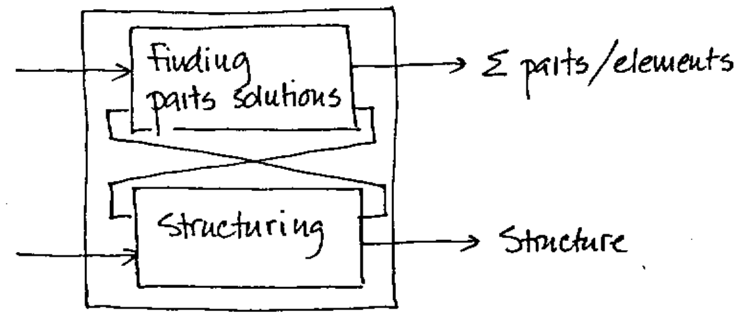


Artefact or design ⇒ System model ⇒ Structure

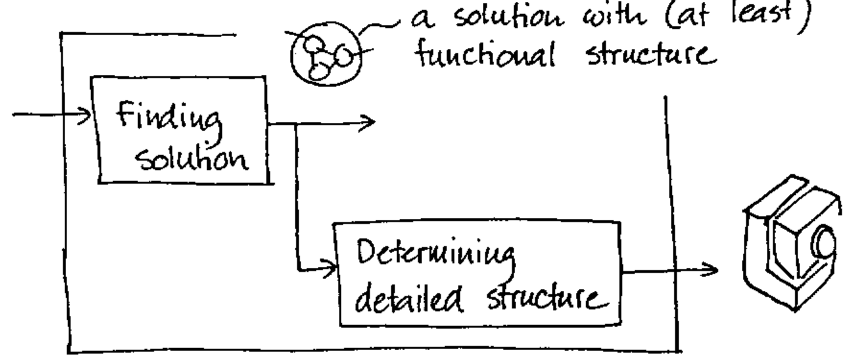
Designing a structure ?



A:

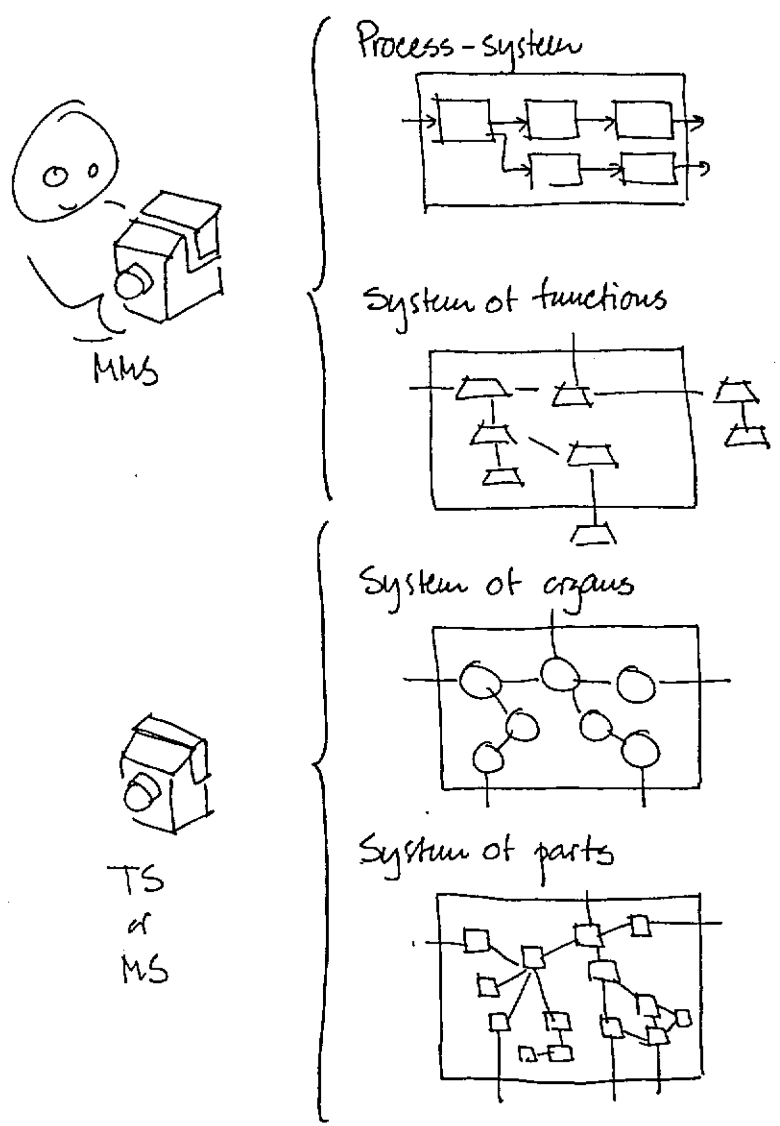


B:



Function = Fu (elementary solutions, structure)

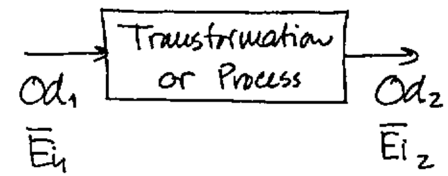
Theory of technical Systems



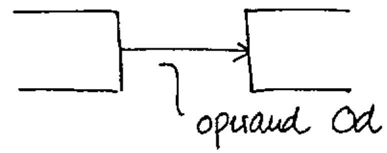
Process System

Elements: Transformation of Material/Energy/Information

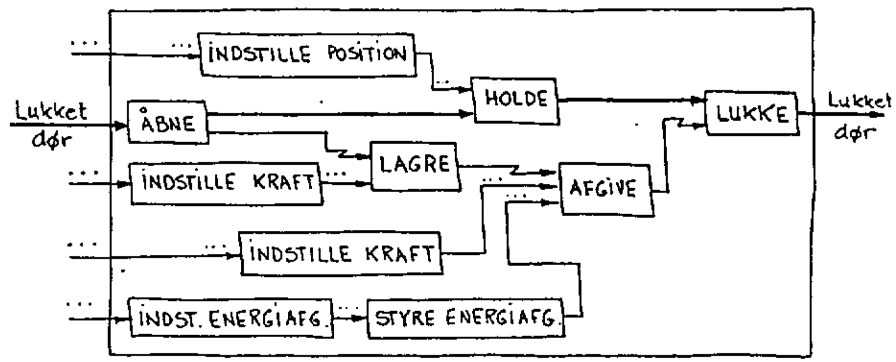
A transformation is a change of properties of an operand:



Relations:

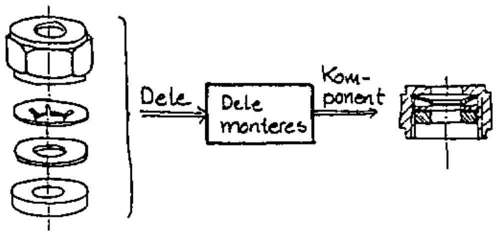


System model:

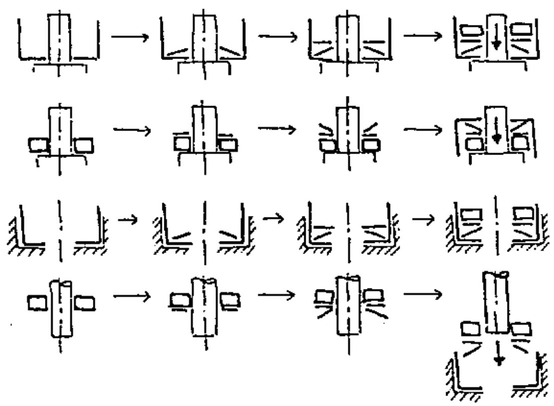


Structuring in the process domain (1):

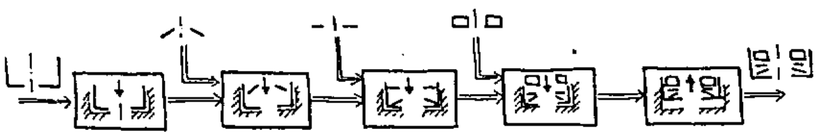
Task:



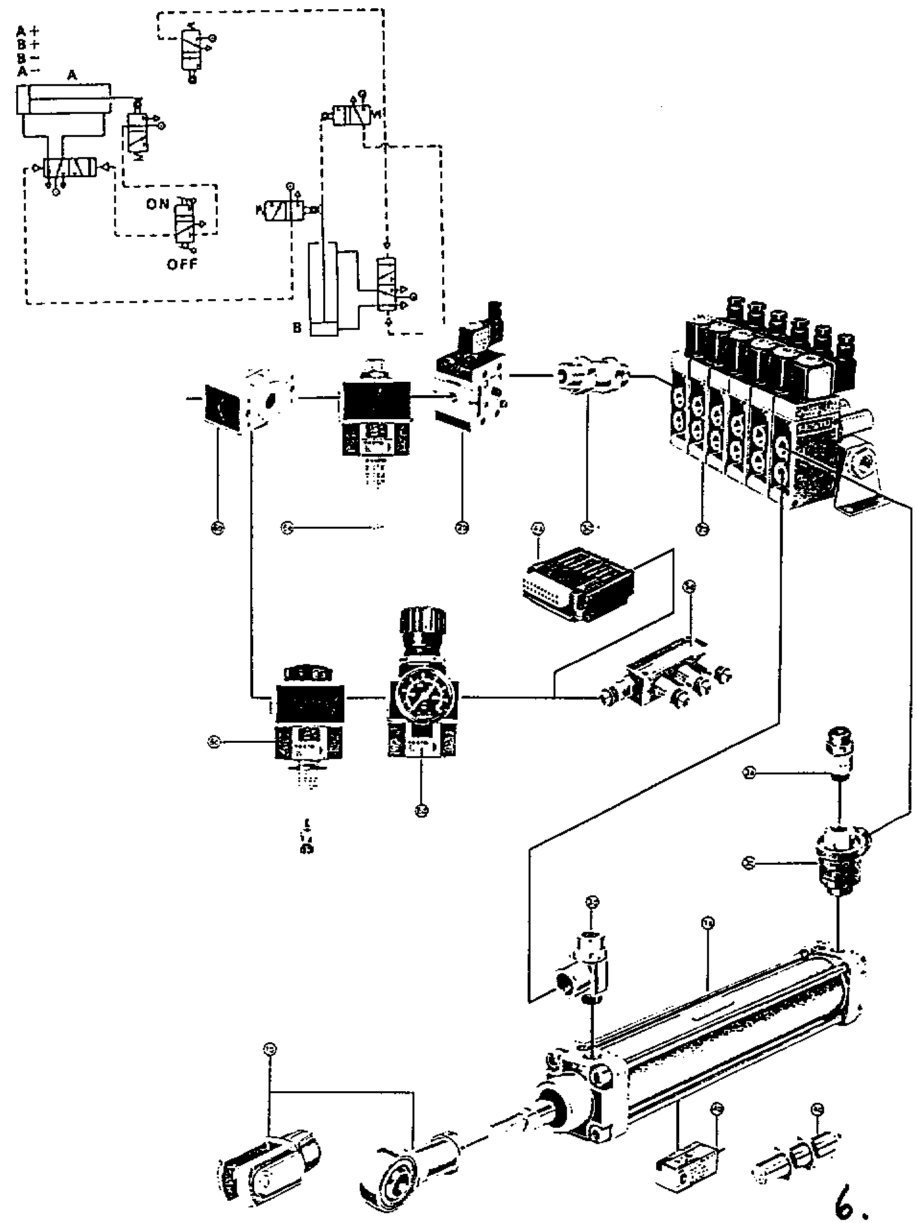
Variation:



Solution:



Structuring in the process domain (2):



Function

Function is a category of properties

Function is the ability of an artefact to create / deliver an effect.

Two types of functions:

Transformation function

{Object (noun)} is {transformed (verb)}

Purpose function

to {activate (verb)} {effect (noun)}

Rélation:

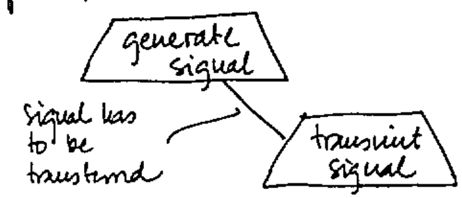
Component	*Transformation*	*Purpose function*
Motor	electric energy is transf. into rotat.	create rotation
Gear	rot.energy changes revolution/torque	ensure suitable speed of revolution
Electronic amplifier	signal is amplified	ensure sufficient amplitude
Battery	energy is stored	provide power
Diode	AC signal is rectified	reject signals of neg. polarization

System of Functions

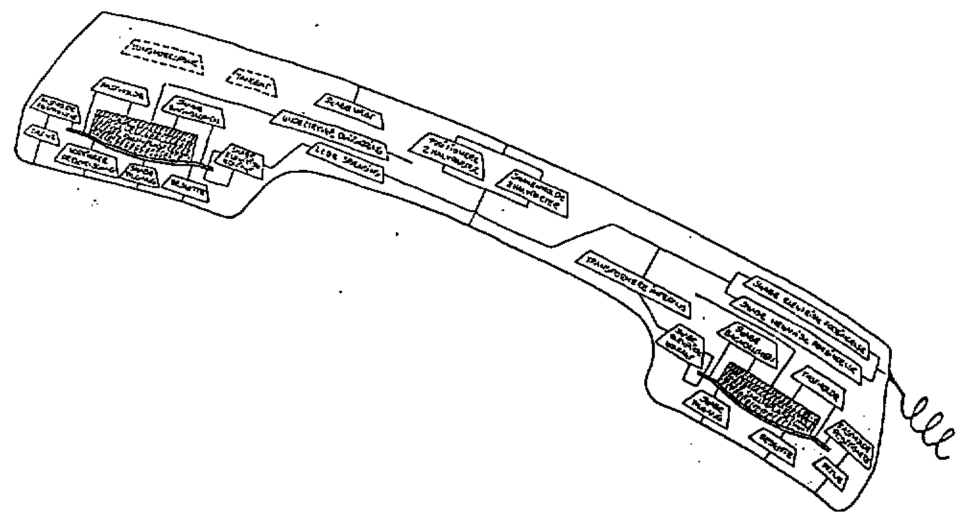
Elements: Purpose function

generate signal

Relations: Logical, causal relations

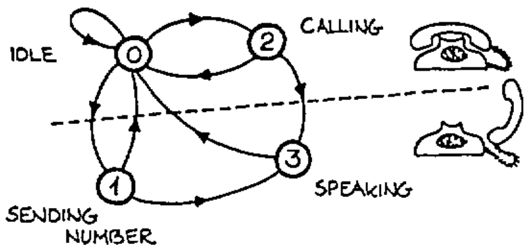


System model:

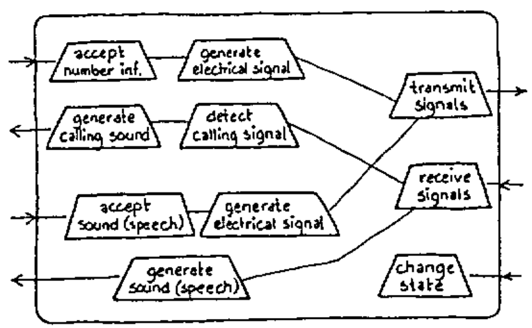


The functions of a Telephone:

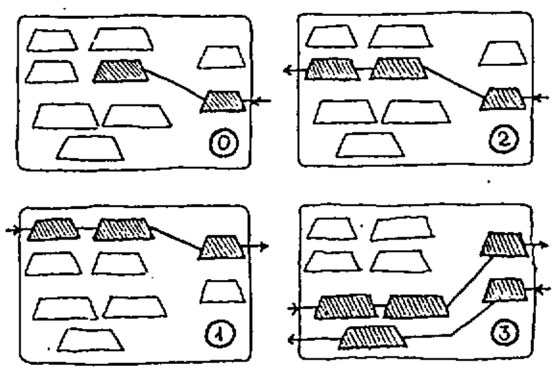
STATES & TRANSITIONS



PURPOSE FUNCTIONAL STRUCTURE



ACTIVE PURPOSE FUNCTIONS



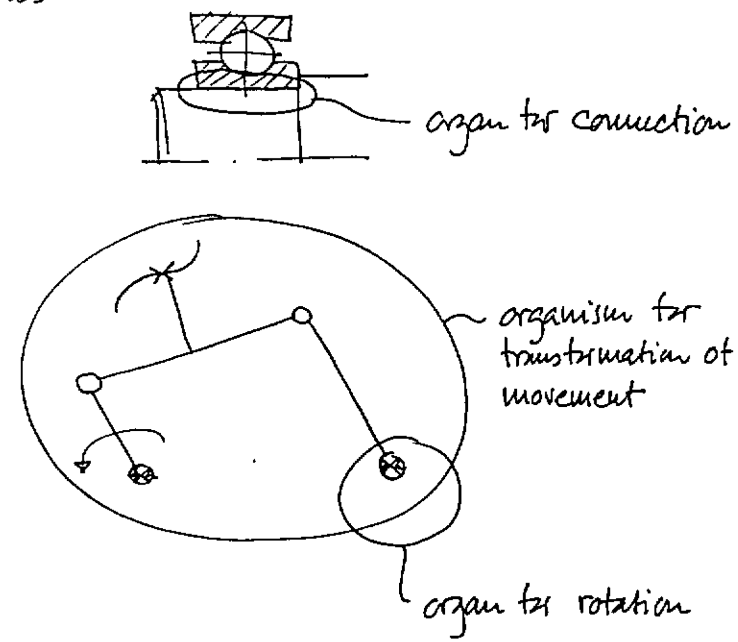
[Buur] 9.

Organ:

An organ is an artefact, characterized by its functional surfaces and their relations, able to create functions (effects), based on physical laws.

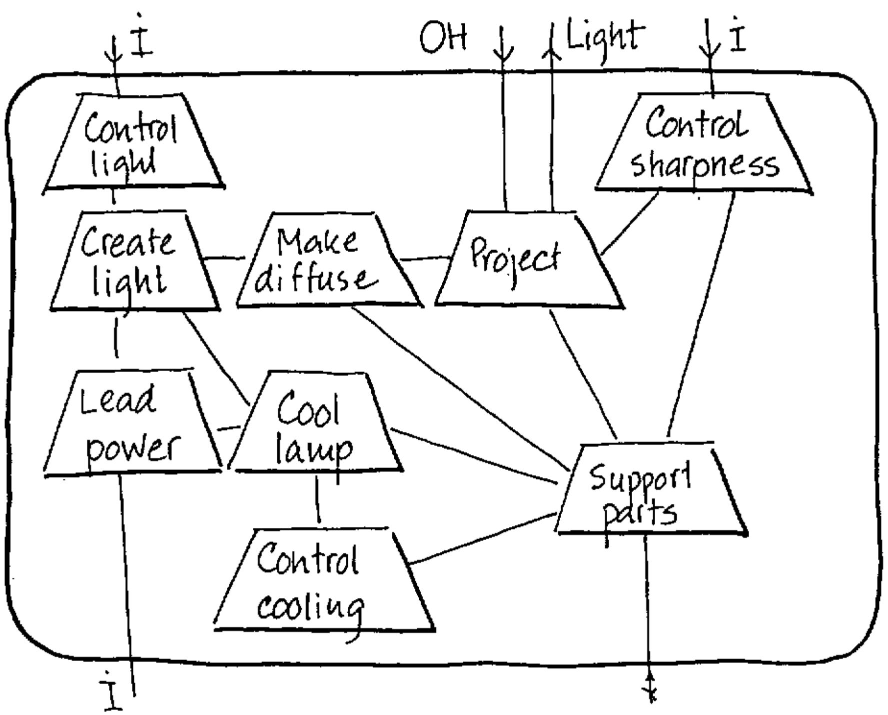
German: Funktionsträger

Examples:

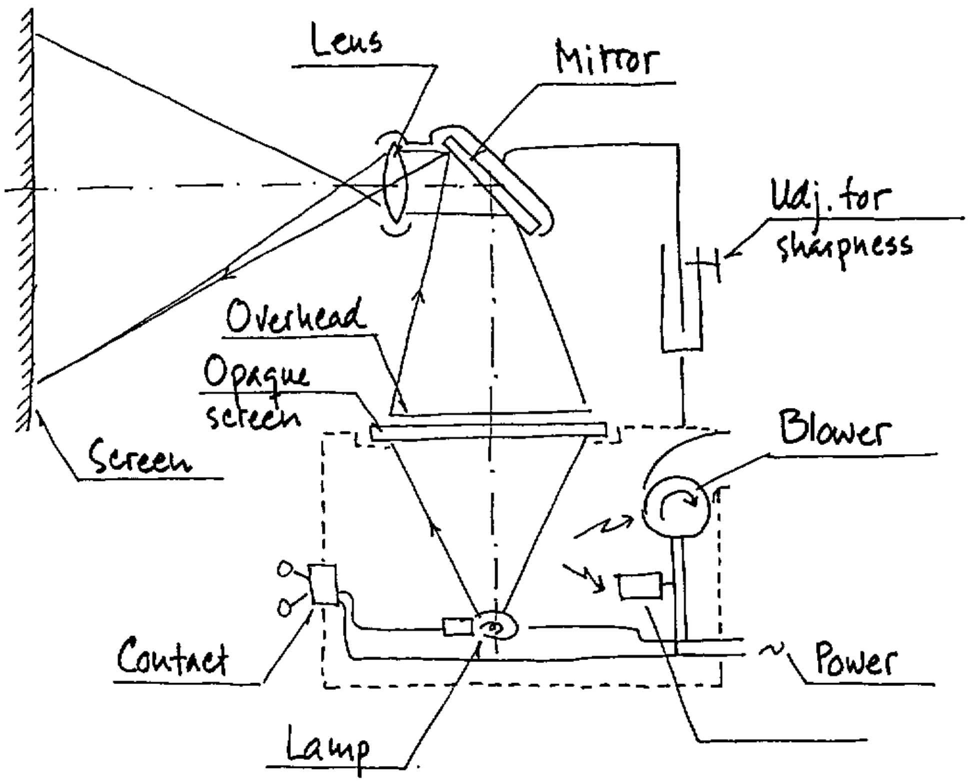


10.

Mode of Action described by Functions:

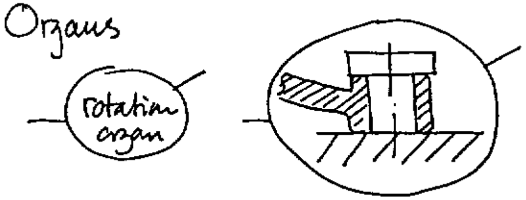


Mode of Action described by Organs:

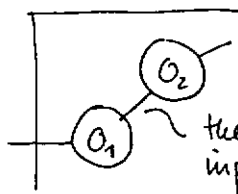


System of Organs:

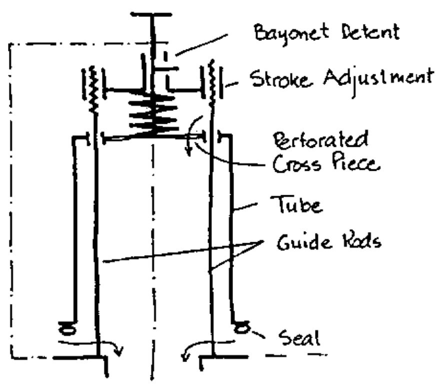
Elements: Organs



Relations: Functional (effects)



System model:

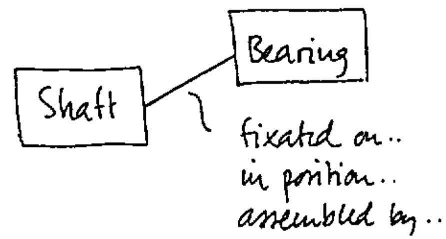


System of Parts

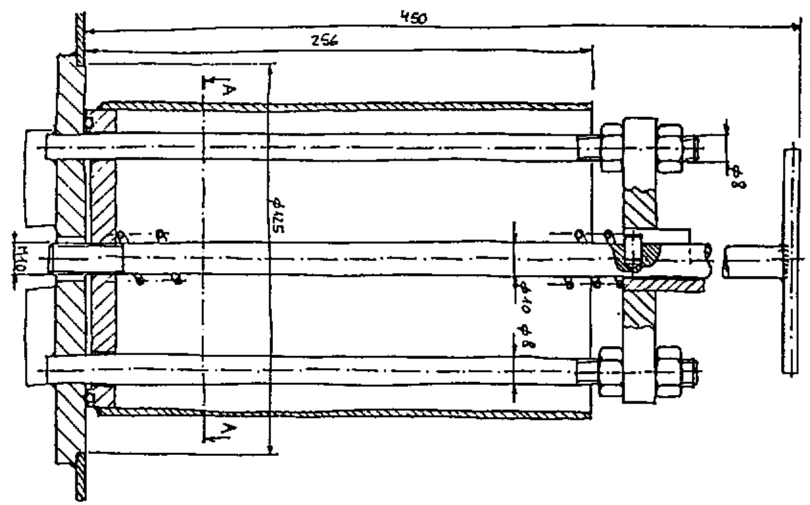
Elements: Machine parts

A machine part is a one-material, non decomposable element of an artefact (machine).

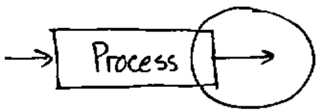
Relations: Assembly relations



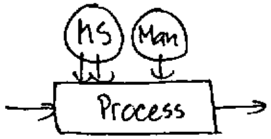
System model:



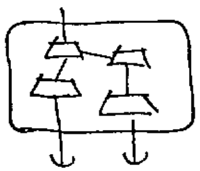
Domain relations:



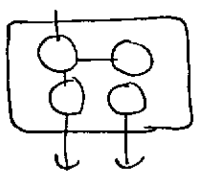
The purpose of a machine is to obtain its output or transformation



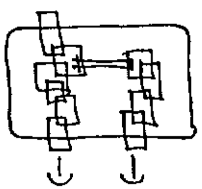
The necessary effects for the transformation are delivered by machine system and man (human operator)



Effects are created by the functionality of the machine

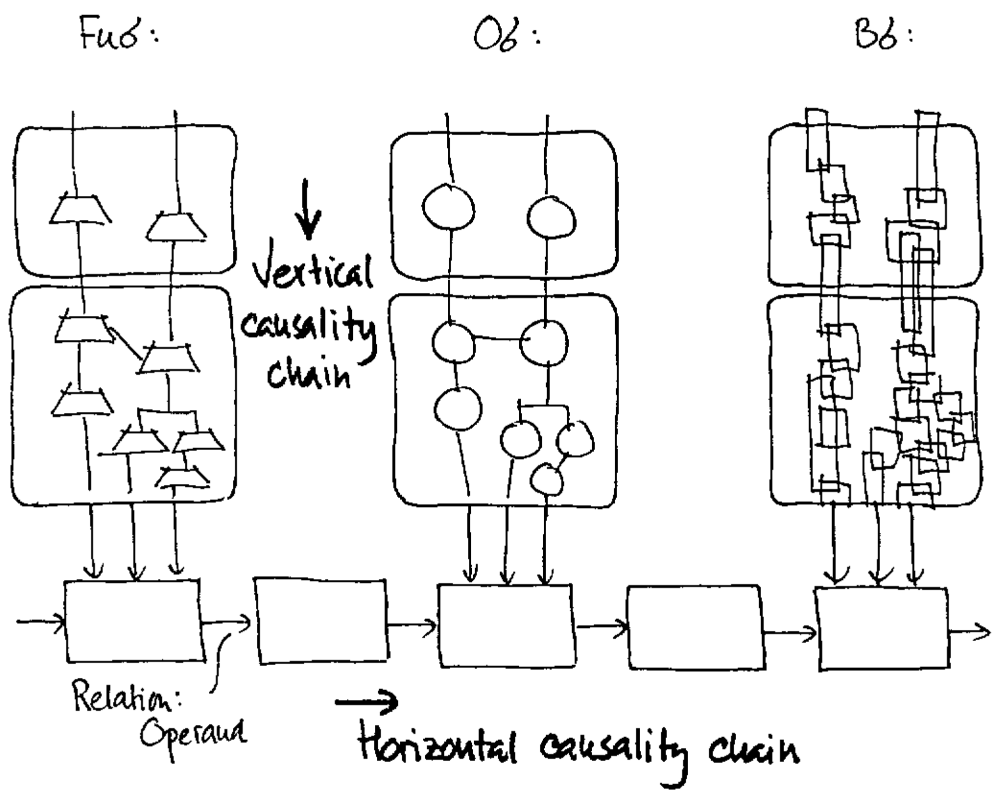


Functions/effects are realized by organs



Organs are materialized by machine parts

Overview:



Fuб relations:
Logical, causal

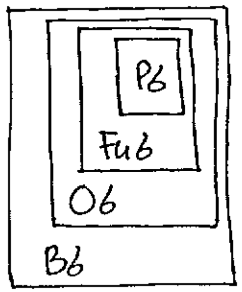
Oб relations
Functional (effects)

Bб relations:
Assembly

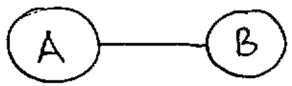
Relation types

In a part structure we may read the Ob, Fub and Pb

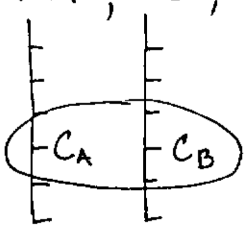
In an organ structure we may read the Fub and Pb



The nature of a relation:

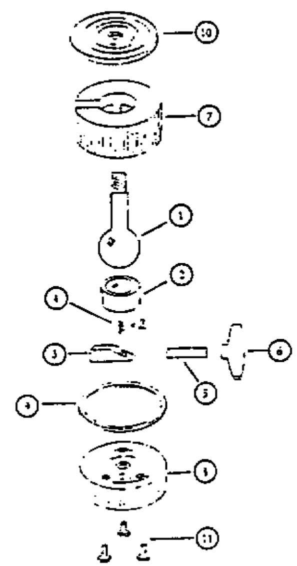


R(#A , #B , art , value , derivation)

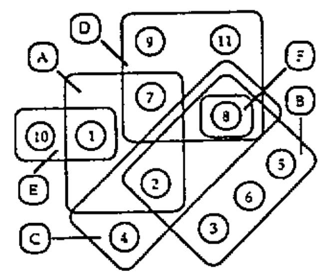


Characteristics of A and B are related.

Bb ↔ Ob relations :



Organ   Komponent

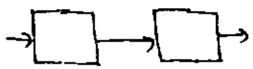


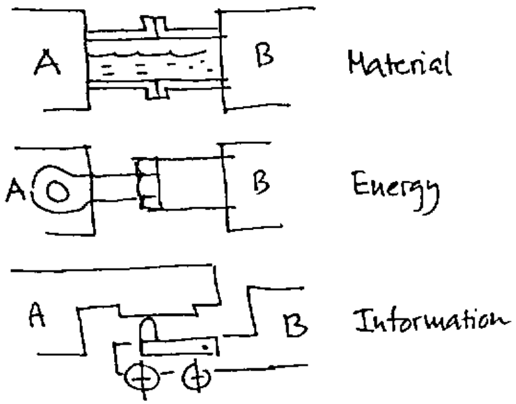
	Komponent	Styrkula	Styrlager	Låskil	Fjäder (2)	Låsskruv	Låsvred	Överhus	Underhus	Mellanring	Stopplatta	Skruv (3)
	Organ	1	2	3	4	5	6	7	8	9	10	11
A	Positioneringsorgan	●	●					●				
B	Låsningsorgan		●	●		●	●		●			
C	Förspänningsorgan		●		●				●			
D	Inkapsling							●	●	●		●
E	Fixeringsorgan (kamera)	●									●	
F	Fixeringsorgan (stativ)								●			

Relation types in an assembly structure (B6):

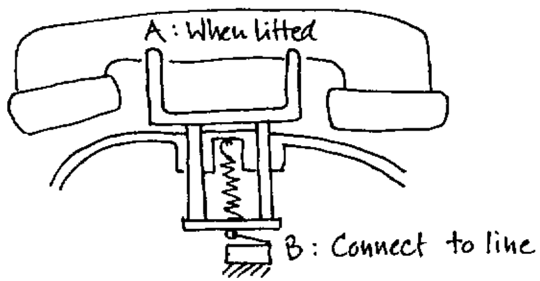
Relation as carrier of

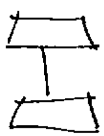
(1) Process relation

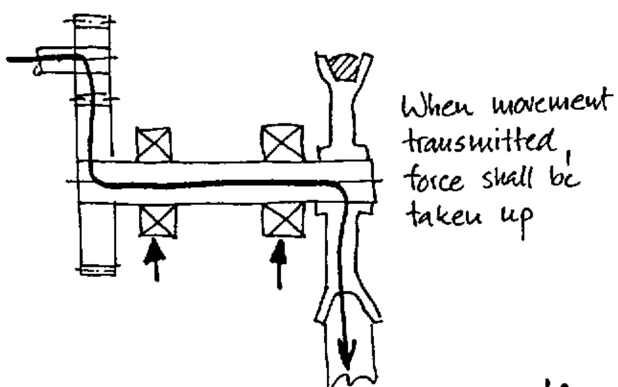




(2) Functional relation

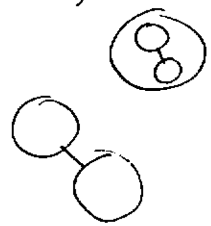


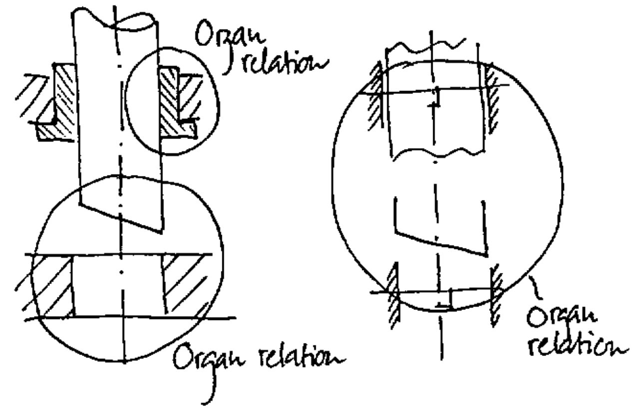


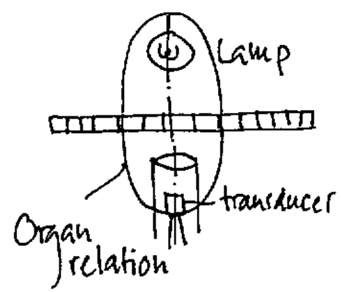


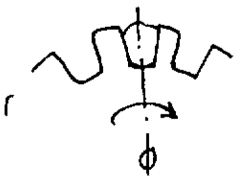
Relation types in an assembly structure (B6) : (2)

(3) Organ relation





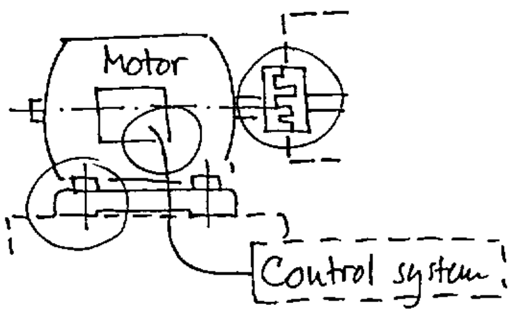




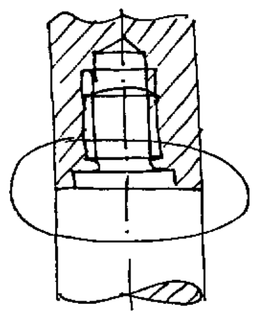
Relation types in an assembly structure (Bb) (3)

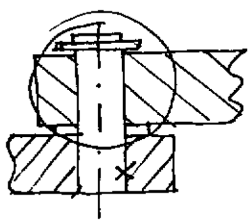
(4) Part relations (assembly relations)

- between sub-systems

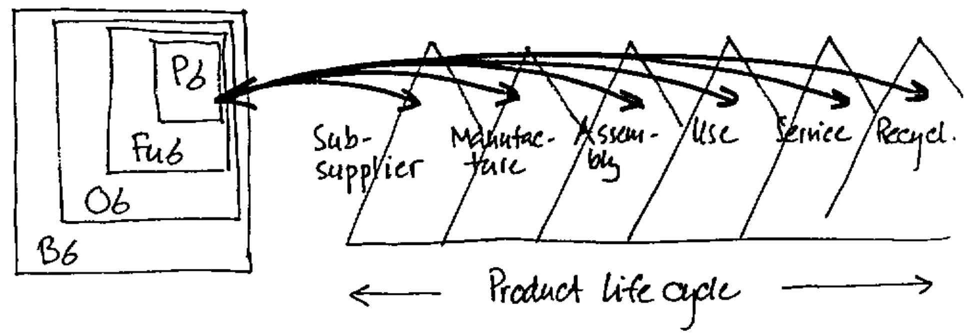


- between parts

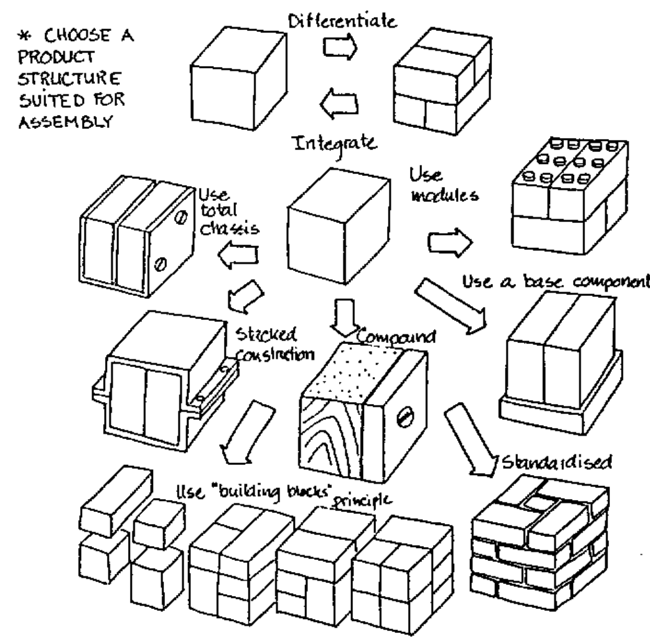




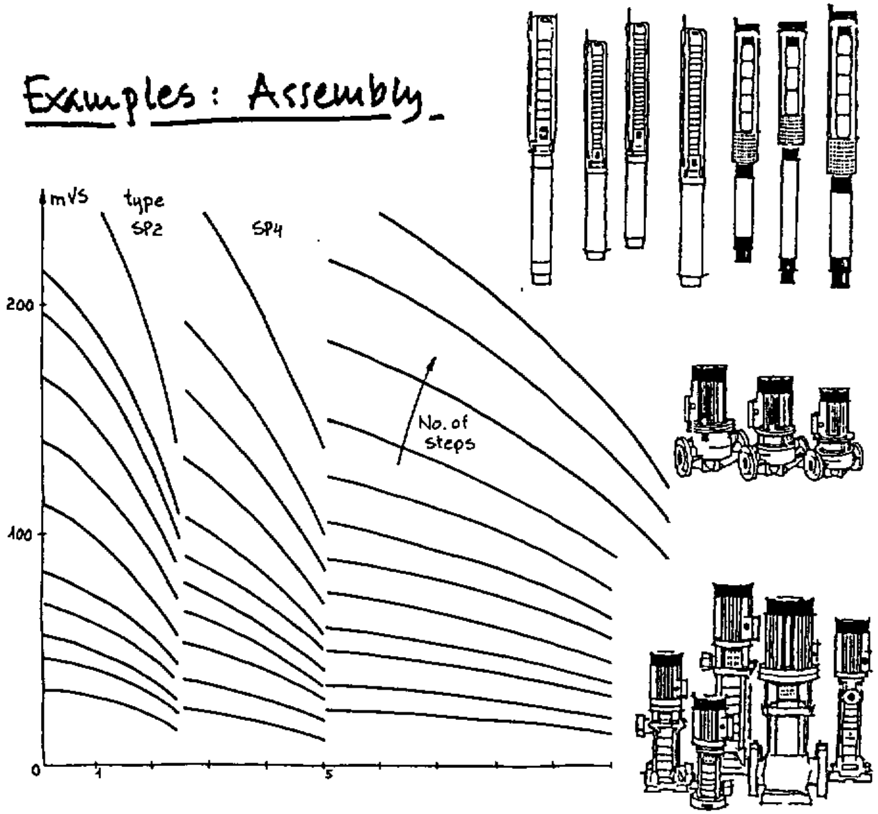
Structural influences



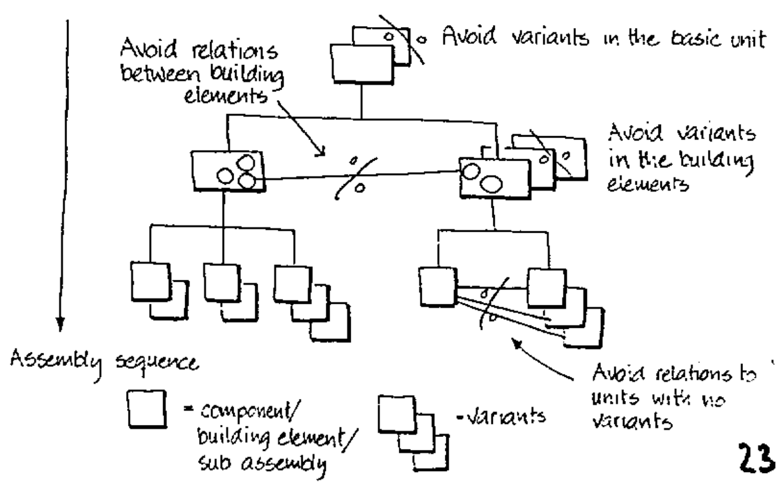
Examples: Assembly.



Examples: Assembly.



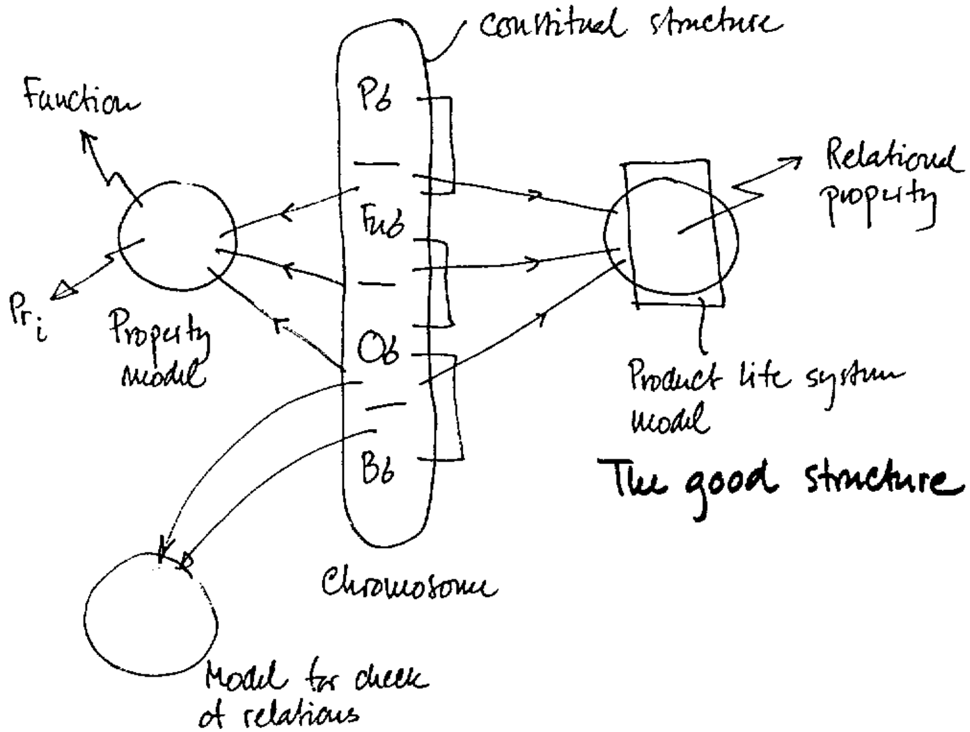
* PRODUCT STRUCTURE FOR FLEXIBILITY



Structural principles / Assembly:

Single product	Product family.
Integration	
Differentiation	
Total chassis	
Stacket construction	
Compound design	
Base component	
Building blocks	Building blocks
Standard elements	Standard elements
Modular elements	Modular elements
Re-use elements	Re-use elements
	Preferred numbers design
	Building block principle
Parametric design	Parametric design
Group technology	Group technology

What is a "good structure?"



The good structure

The correct configuration

Conclusion

To the functional determined structure may be added other structural principles for specific purposes.

Several structural principles may be superimposed on a design's structure.

If you want to make a process oriented ~~structure~~ variation/re-structuring, you have to solve the Fu, O, and B relations