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AN ADAPTIVE PRODUCT DEVELOPMENT PROCESS FOR ENGINEERS AND INDUSTRIAL DESIGN ENGINEERS

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SUMMARY
At first, the terms "engineer" and "industrial design engineer" will be clarified in this contribution. The competencies of engineers and industrial design engineers in a general product development process are derived from a general product structure. The adaptive development process will be worked out by the categorization of products.

Key Words: Product Development Process, Designer Engineer, Industrial Design Engineering, General Product Structure, Work Flow, Information Flow, Adaption

INTRODUCTION

Today's technical development of products is so far advanced that products of the same industry from different manufacturers hardly differ in their technical characteristics. The differentiation possibilities need to be found in other areas. The ease of operation and aesthetics of appearance become more and more important. Since many decades, this trend can be observed in the automobile industry. The image of a product, which is transformed to the customer over the product shape, became sales argument number one for many products.
Industrial design engineers deal with exactly these subjects. Intuitive operation and use as well as error-free perception and identification of products to increase the practical value [1] are the main focus of a product development from the industrial design engineers' point of view ([2], [3]). The product is to be tailored to the user's interests.
The unification of the two groups of requirements, technical requirements [4] and ergonomic requirements [1], and therewith their two representatives, engineers and industrial design engineers, represent a major and so far insufficiently solved task.

1 THE SPECIALISTS: ENGINEERS AND INDUSTRIAL DESIGN ENGINEERS

Due to the variety of products, many different specialists are involved in the product development process. Depending on the product, they can be designers, aerodynamicists, biologists, psychologists, physicians or others. Adapted to the focus, these specialists are included [5] in the product development. Good operational planning and co-ordination between them is required for a smooth product development process. As the product development process is, to a great extent, an information-processing and communication-intensive process [6], the co-ordination of these specialists is a complex and very extensive task.
In the following, attention is paid to two groups of specialists: engineers and industrial design engineers. Both disciplines give essential inputs in a product development. The challenge to coordinate or to synchronize the work procedures are often complicated by different approaches of these two disciplines.
Current product development processes mainly focus on the technical development of a product [4]. Here, the aspects of operation and use as well as perception and identification of a product are not integrated.
In order to get a holistic picture of a product development, it is helpful to look on the protagonists first.

1.1 Engineers

The engineers' main objective is the functionality of a product. The technical use of physical principles and scientific findings for a product is the center of their product development. Engineers can also be a very mixed group. All technical-oriented fields, ranging from material scientists to aerospace engineers, can be found there. In the following, all engineers who have to co-operate closely with the industrial design engineers so that functional and easily useable products can be developed, are summarized in this very inhomogeneous group.

1.2 Industrial Design Engineers

The future user of a product is the center of each product development of an industrial design engineer. Above all, the development of a product is based on scientific findings from work science [7]. The task to convert ergonomic and aesthetic aspects into a product can be adapted to the final user or to service or assembly persons.

According to Seeger, [1] ergonomic aspects can be classified into four main groups:

- Operation:
  Manipulation of a product. Indicators and control elements belong to this category(e.g. regulation of the feed motion, operation of the turn signal) [2], [3]
- Use:
  Use of the technical function of a product. Handholds, ladder, doors etc. belong to this category (e.g. seat of a motorcycle, door handle of a car)
- Perception:
  Visual, acoustic, haptic etc. positioning of indicators and control elements (e.g. speed indicator in the direct field of vision)
- Identification:
  Identification optimized product or interface shape (e.g. a car should look like a car, a turning button not like a push button)

These four fundamental directions, in which ergonomic development can operate, can occur in different order or simultaneously during the product life cycle. The operation of a product takes place, if parameters of the product are changed (e.g. switching on, increase of number of revolutions, adjustment of pre-settings). During the use, the technical function of a product is applied (e.g. sitting on a chair, hearing music in the radio).

Operation and use can also happen at the same time. This occurs if parameters are changed during the use of the product (e.g. driving with a car with simultaneous change of driving direction). Perception and recognition are dealing with the correct presentation of sensory impressions so that operating errors can be avoided.

2 THE OBJECT: GENERAL PRODUCT STRUCTURE

Products can be divided into the following categories [8]:

- Services (e.g. financial service)
- Software (e.g. operating system, software)
- Hardware (e.g. engine mechanical part, bicycle)
- processed materials (e.g. lubricant)

This contribution is exclusively dealing with products which can be found in the category “hardware”. These products are always manufactured by a production and an assembly process ([9], [10]).

A general product can be regarded and/or structured under different aspects. For the observations in this contribution, the following product structures were consulted:

- Component-oriented product structure
- Function-oriented product structure
- Characteristic-oriented product structure

2.1 Component-oriented product structure

The most common form of a product structure is the subdivision of the product into assemblies and parts. The result is a hierarchical arrangement of superordinate assemblies and subordinate assemblies or parts ([11], Figure 1).

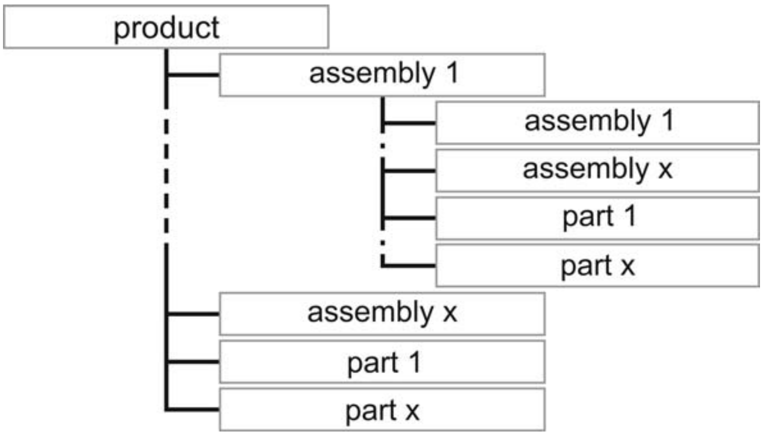


Figure 1. General component-oriented product structure

2.2 Function-oriented product structure

In general, a product consists of building groups, which have to fulfill different subfunctions (main, auxiliary functions). All functions can be summarised in the overall function of a product [9].
These functions are reflected, depending upon their type, in three sub-gestalts of a product ([1], Figure 2):

- Function gestalt:
  all elements which are necessary for the technical function (e.g. transport from A to B: wheels, engine, transmission, …)
- Interface gestalt:
  all elements which make the technical function usable for the user (e.g. seat, steering wheel, speed indicator); the man-machine interface
- Structure gestalt:
  all elements which are necessary for the adjustment and protection of the function and interface gestalt (e.g. chassis, housing)

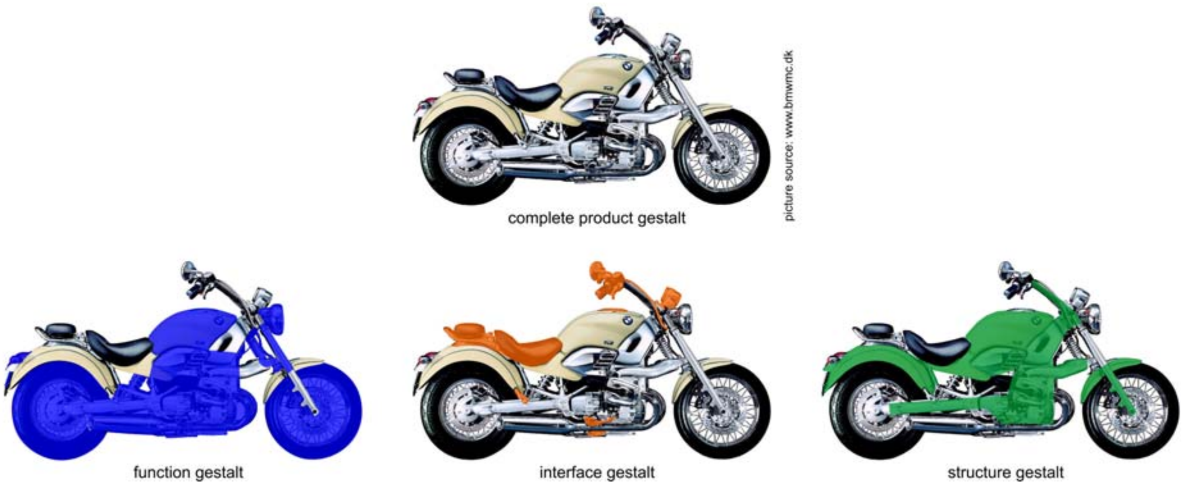


Figure 2. Function-oriented product structure of a motorbike

2.3 Characteristic-oriented product structure

The characteristic-oriented product structure includes, contrary to the two structures described above, the product characteristics which can be designed. Therefore, the viewpoint is the bridge to the concrete transfer of requirements to a product.

According to DIN 4000 [12] a characteristic is a certain attribute, which is used to describe and differentiate objects in a group of objects. This definition is used here to differentiate the group "products" itself. The characteristics used for the following differentiation are selected in a way to define a product completely. Other product characteristics (e.g. weight) can be reached by combinations of these fundamental characteristics (e.g. assembly gestalt, shape and material).

According to the characteristic-oriented product structure, the product can be divided (Figure 3) [1] into:

- Assembly gestalt: Elements (type, amount, size) and arrangement (type, number)
- Shape: Elements (type, amount, size) and arrangement (type, number)
- Surface: Elements (type, amount, size) and arrangement (type, number)
- Colour: Elements (type, amount, size) and arrangement (type, number)
- Graphics: Elements (type, amount, size) and arrangement (type, number)
- Material: Elements (type, number) and arrangement

Assembly gestalt, shape, surface, colour and graphics are according to [1] the sub-gestalts of a product.

The material plays a special role within this viewpoint. It completes the product gestalt (assembly gestalt, shape, surface, colour and graphics), i.e. the appearance of a product, to a complete product.

The definition of the materials during the product development process cannot generally be fixed. In some cases, a material is chosen that is suitable for production and according to which the product gestalt is developed. Or, materials are selected according to the developed product gestalt. As, due to this fact, the position of the identification of the material in the product development process is flexible, it is neglected in the following observations.

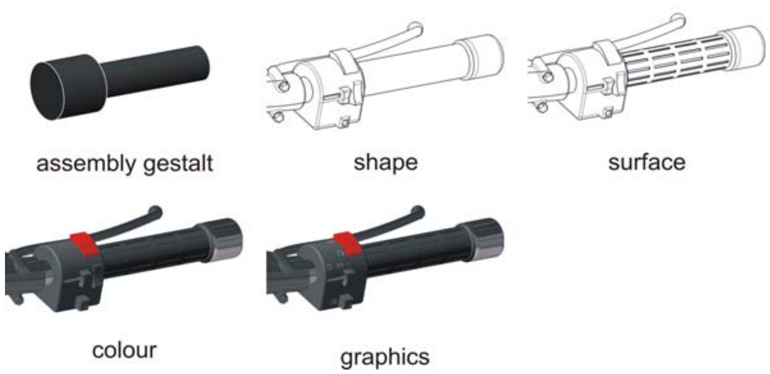


Figure 3. Assembly gestalt, shape, surface, colour and graphics of a motorbike hand grip

The characteristic-oriented product structure includes additionally to the structure, already a given order, in which the characteristics should be defined (Figure 4).

The most abstract form of a product is its assembly gestalt which defines the arrangement of the assembly groups and parts to each other. Subsequently, shapes (geometries) can be applied on this assembly gestalt followed by surfaces, colours and graphics. It does not make sense to turn around the sequence of these characteristics, e.g. specify graphics before shape, as this would require additional loops during the product development process.

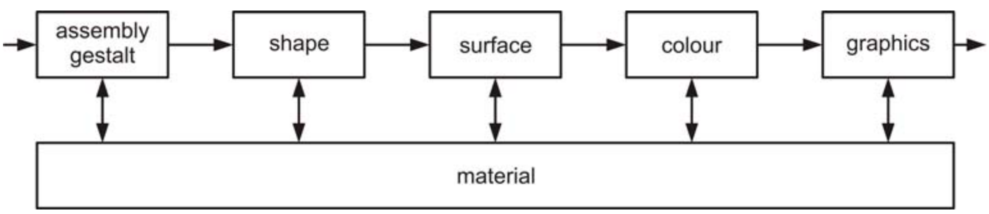


Figure 4. Process of the characteristic-oriented product structure

2.4 General product structure

Each of the presented product structures shows the product as a whole. To solve all questions, it is therefore possible to use them separately. However, the combination of these three product structures offers the most holistic view on a product (Figure 5).

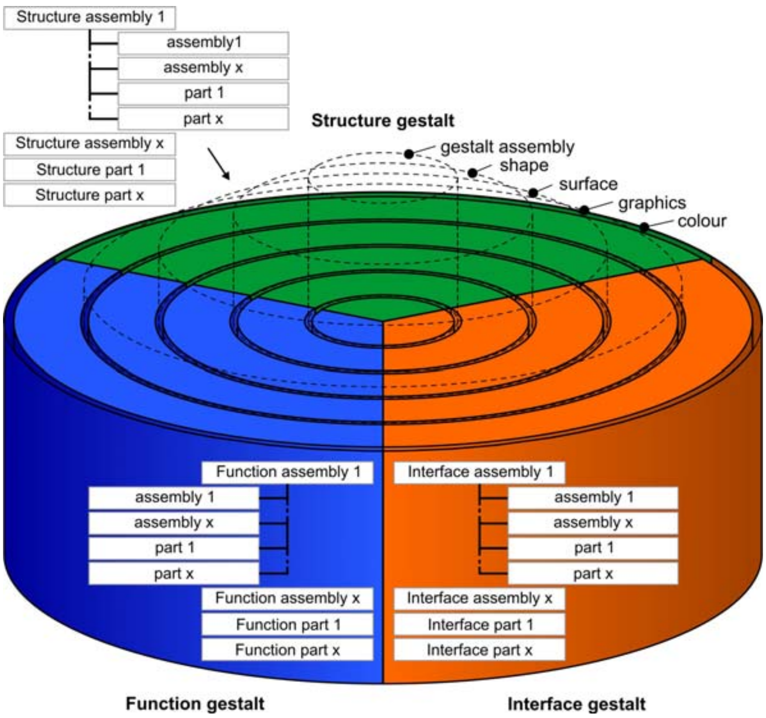


Figure 5. General product structure

Cylinder top surface:

- Function-oriented product structure:
  rough classification into function gestalt, interface gestalt and structure gestalt
- Characteristic-oriented product structure:
  sub-category of function gestalt, interface gestalt and structure gestalt, each consisting of the partial shapes gestalt assembly, shape, surface, colour and graphics.

Cylinder nappe:

- Component-oriented product structure:
  Function gestalt, interface gestalt and structure gestalt can be seen as assemblies which again consist of parts and assemblies. The assemblies and parts again have assembly gestalt, shape, surface, colour and graphics.

Now the product can be subdivided into elements by this general product structure (e.g. assembly gestalt of function assembly or structure colour of a structure part).

3 THE PROCESS: WHO IS DOING WHAT?

The approach of this contribution assumes that all elements of a product (see 2.4) have to be specified or defined during a product development. If this has happened and if all elements have been joined together, the product development is finished.

Now the competencies of engineers and industrial design engineers can be marked out.

The definition of the competencies is found on a general list of requirements of a product and their influence on the product gestalt [13]. Dependent on which specialist, engineer or industrial engineer, is able to transform and/or judge these requirements, the competencies are distributed. This, of course, results in a mixture of competencies, because none of the two specialists is trained to transform all requirements of a product element on his own [14].

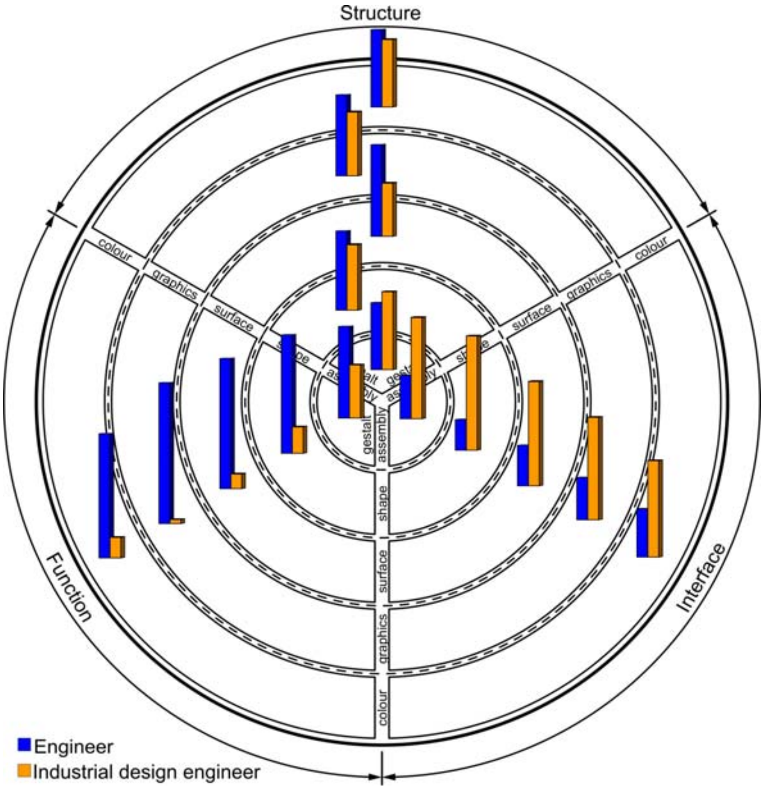


Figure 6. Competences of engineers and industrial design engineers

This is also reflected in Figure 6. There, the determined qualitative rate is presented on the cylinder nappe of Figure 5. The high columns can be interpreted as the main competences, whereas low columns are representing an advisory function.
The development of the interface gestalt is the main competence of an industrial design engineer. The engineer should be involved as advisor, e.g. for requirements concerning production or assembling.
In opposition to this, the main competence of an engineer is the function gestalt which could also depend on ergonomic requirements. This makes an advising role of the industrial design engineer necessary. For example, the assembly gestalt of a power drill can influence the point of gravity and therewith the handling (Figure 7, point of gravity and wrist should lie together as close as possible).

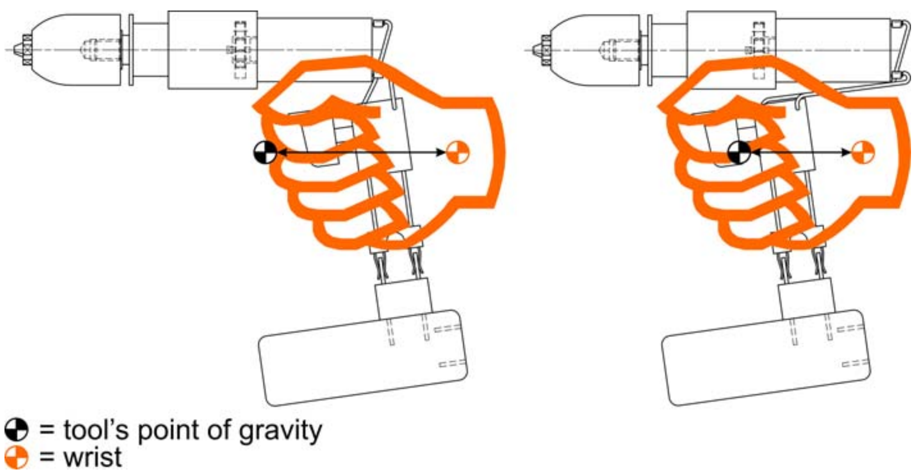


Figure 7. Point of gravity with different assembly gestalts of a power drill

The structure gestalt is an exception in this view. In this sub-gestalt, the technical and ergonomic/aesthetic requirements meet almost equally. Here, teamwork would make sense in order to detect and transform all requirements on the structure gestalt.

4 THE ADAPTABILITY: WHAT IS MADE WHEN?

The adaptability of a process can be understood in various regards. Generally, the objective is always the adaptability of a process to changing conditions, e.g. firm's structure, timing or costs. In this contribution, the adaptability of a process is understood in such a way that the process adapts to the developing product.

Products can fulfill different tasks, and, therefore, it may happen that the priorities assigned to the function, interface and structure gestalt are different for various products. Very high importance is attached to the exterior design of a car whereas the aesthetic component of a heart pacemaker is equal zero. Therefore, it is necessary to differentiate the products with regard to these priorities.

The major task a product has to fulfill always appears in its main function. Therefore, the main function of a product shows the prioritization of function, interface and structure gestalt. The auxiliary functions, i.e. the secondary tasks, inform about this as well.

In this view, the main and auxiliary functions are divided as follows:

- function-based
- interface-based
- structure-based
- function- and interface-based
- further combinations are neglected because of their rarity

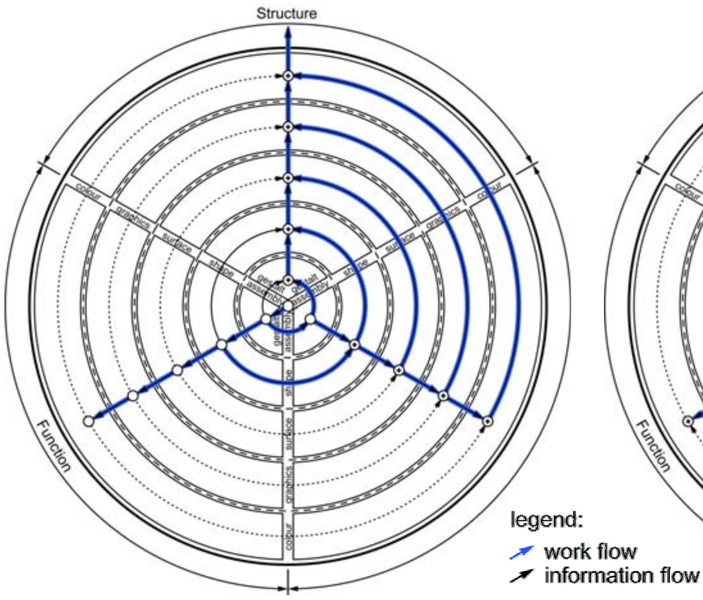
In the following, some products with their main and auxiliary functions are exemplarily specified:

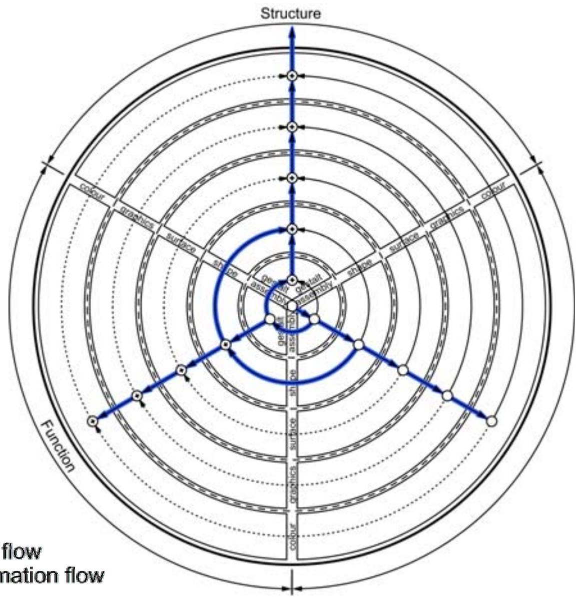
- Power drill:
  - main function: making holes in concrete, wood etc. (function-based)
  - auxiliary function: usable for one person (interface-based)
- Measuring instrument:
  - main function: indicate a measured value (interface-based)
  - auxiliary function: trouble free measurement (function-based)
- Model railway:
  - main function: smaller representation of a model (structure-based)
  - auxiliary function: remote controlled drivability (function-based)
- Car:
  - main function: transport of passengers and luggage (interface and function-based)
  - auxiliary function: security for passengers and luggage (structure-based)

The result is a sequence in which function, interface and structure gestalt have to process within these different products. Together with the sequence of the characteristic-oriented product structure, mentioned in section 2.3, processes can be derived for the main and auxiliary functions described above. In Figure 8 the cylinder nappe of Figure 5 is shown with the workflow and information flow steps.

Figure 8 shows how a product development process should take place. It is easy to recognize that each of the processes starts in the center of the cylinder nappe and slowly proceeds outwards. Assembly gestalt, shape, surface, graphics and colour are processed.

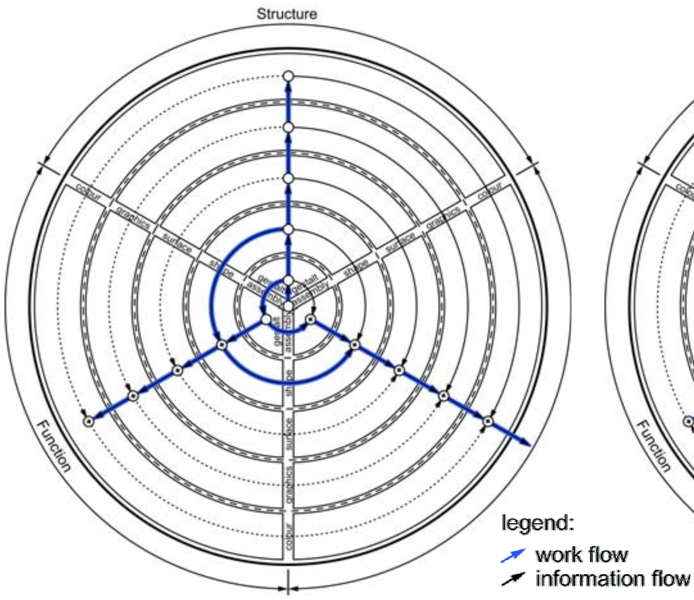
It depends on the preceding prioritization which sub-gestalt is worked out in the first, second and third place, but the sequence (assembly gestalt → shape → surface → graphic → colours) is always the same.

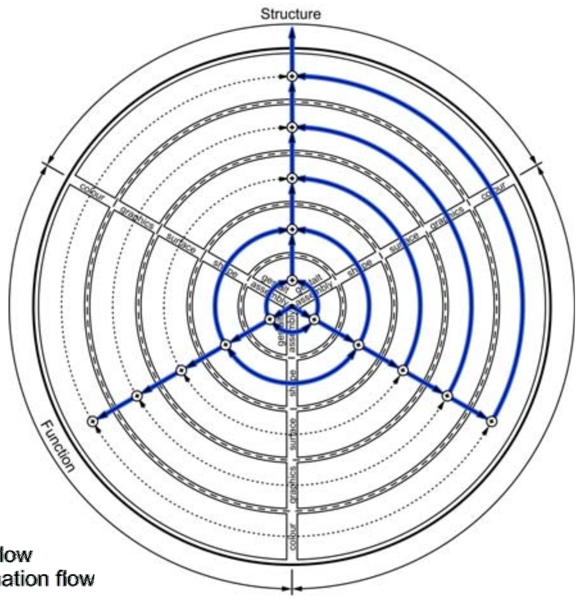




Process for function-based main function and interface-based auxiliary function

Process for interface-based main function and function-based auxiliary function





Process for structure-based main function and function-based auxiliary function

Process for function- and interface-based main function and structure-based auxiliary function

Figure 8. Adaptive product development process for main and auxiliary function

5 CONCLUSION

A general process, which integrates engineers and industrial design engineers, has been successfully created. Furthermore, the adaptability necessary to create products according to their emphasis in the product development is available.

The represented process supports the development of engineers and industrial design engineers by its concrete connection to the product. Contrary to other development processes, which are using relatively abstract names for the phases, the presented process always uses the concrete result of a phase as its name.

Additionally to the items specified above, a flow chart is not dynamic enough for the considerations which have been made. For this reason, a new way of noting a process has been chosen.

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