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TECHNOLOGICAL KNOWLEDGE EMBEDDED IN A FEATURE-BASED CAD MODEL

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1. Introduction

Among different information systems used in the product development, the most widely used are CAD systems. They are used for product modelling and for producing technical documentation. Current CAD systems include only a small part of the knowledge for product embodiment, usually in the form of specialized knowledge, for example in the cases of making bores, plate bending and producing moulds for casting. The possibilities of today's CA tools and computer-based support in the design process are not up to the designer's task to take into consideration not only geometric features of the product, but also the technology to be used for the manufacture of the designed product, properties of the used materials, conditions of exploitation and recycling of the product, etc.
Based on the theory of design presented in literature, the design process can be divided into the phases of problem clarification, conceptualization, embodiment, detailing and dimensioning. The latter is the final phase of the design process in which technical documentation is made. Detailing and dimensioning defines all the required information on machine parts produced in the manufacturing process [Pall and Beitz, 1988].
Researches into the improvement of CAD systems are based on the idea to provide computer-based support in all the phases of engineering design process. Such approaches are frequently reported in literature, for example the reports on *mfk* and KS*mfk* models [Koch and Meerkamm, 2001], [Koch and Meerkamm, 2002], [Koch et al, 2002], [Koch and Meerkamm, 2003], as well as on the FSB model [Labrousse et al, 2004].
The aim of this research is to make the information system as suitable as possible for the purpose of meeting the requirements of a real engineering design process by creating a computer model connected to the current CAD systems. The model can provide the user the required knowledge (stored in knowledge data base) and information (stored in the product information data base) during the process of product embodiment and detailing.
The basic concepts of an extended CAD model, which could come close to meeting the requirements of a real design process in the domain of 3D product embodiment, will be dealt with in the following chapter.

2. Extended CAD model

2.1 Grounds for research

The increased number of design and manufacturing processes which rely on the computer-based support has generated the designer's need for using large amounts of information. In other words, problems related to the limited availability of previously applied design solutions and to the lack of technology knowledge on the product embodiment occur during the design process. As young designers do not possess the experience and knowledge required for being immediately involved in the engineering design process, it is necessary to obtain that knowledge in the course of the process of product embodiment carried out by the current CAD systems.

In the process of coffee machine design [Koch and Meerkamm, 2003], the phase of product embodiment and detailing has been omitted. The authors, [Koch and Meerkamm, 2003], consider this process to be "a common design process". The product embodiment phase in a common design process poses difficult problems to inexperienced designers as it requires long experience. Inexperienced designers waste a lot of time on searching for the existing solutions and rules on technological shape giving (forming), which leads to the prolongation of the design process. It is quite obvious that there is a real need for a good computer-based support to design.

Using the rules on technological forming of the product, the overall cost of the product decreases due to:

- Shortening of the design process due to the implementation of quality design solutions generated by the rules on technological forming, which leads to the increased number of iterations in the design process.
- Savings in the course of the product manufacture, assembly, maintenance and recycling due to the designer's knowledge acquired in his long experience.

2.2 Model description

The model presented in Figure 1 is structured in the way as to give an adjusted and adequate knowledge presentation. It is intended to enable the designer to retrieve the knowledge on technological forming during the product embodiment phase by means of the current 3D CAD systems.

A considerable number of rules on technological forming have been classified in the form of tables and graphs in the available literature. From the known input parameters presented in these tables and graphs, one can get the output parameters referring to the final form and size of the structure components. The remaining rules, due to their complexity, are presented in literature in the form of sketch designs of details of the structure.

The information presented in tables and graphs can be inputted into the knowledge data base, while the information presented in the sketch designs of the structure details needs to be presented with finished characteristic details of geometry, which could be adjusted to the related structure by using particular parameters. The change of parameters would be compared to the known data from experience stored in the data base.

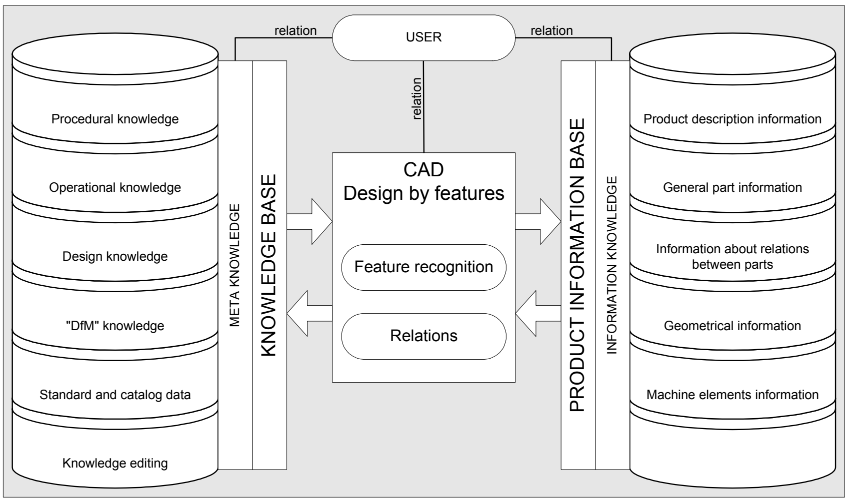

Figure 1. Structure of the model

The information describing the rules of technological forming will be stored in the knowledge data base (Figure 2) as “Knowledge on technological forming”. Other types of knowledge required in the engineering design process presented in Figure 2 are described in detail in the PhD thesis [Bojčetić, 2001].

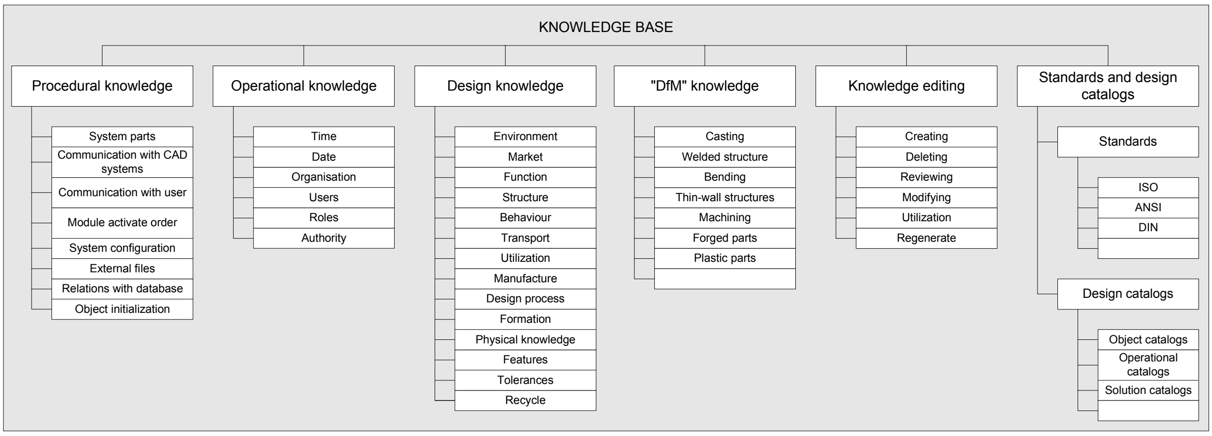

Figure 2. Structure of the knowledge data base

As the data base will contain a large amount of information, it will be necessary to provide the data base with the “knowledge about knowledge”, i.e. the “meta-knowledge”. The meta-knowledge will contain the information on knowledge, on the way how to use a particular knowledge type, on how to search the existing records of knowledge and on how to implement or delete the created knowledge.

On the other hand, the “knowledge on information” representing the basis of product information data base (Figure 3) will correlate the information on the product and machine parts designed by means of 3D CAD systems. The information required for the description of the product (machine parts domain) is as follows:

- Information on the product presentation;
- Basic data on the product;
- Information on the relations between components;
- Geometry data;
- Information on machine parts.

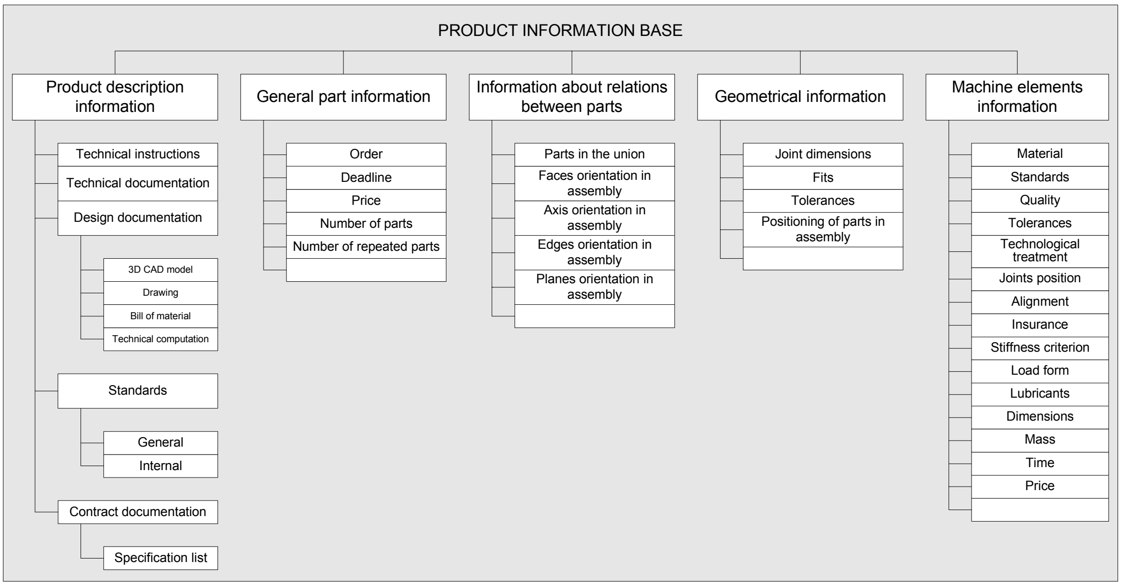

Figure 3. Structure of the product data base

2.3 Product embodiment

In order to embody the product to the rules of technological shape giving (forming), it is necessary to have permanent access to the existing knowledge and information, because the new product development is based on known physical and engineering principals [Clement, 2003]. Therefore, if the existing knowledge and information are properly systematized and available in any of electronic forms, they can be of great help in the design process.

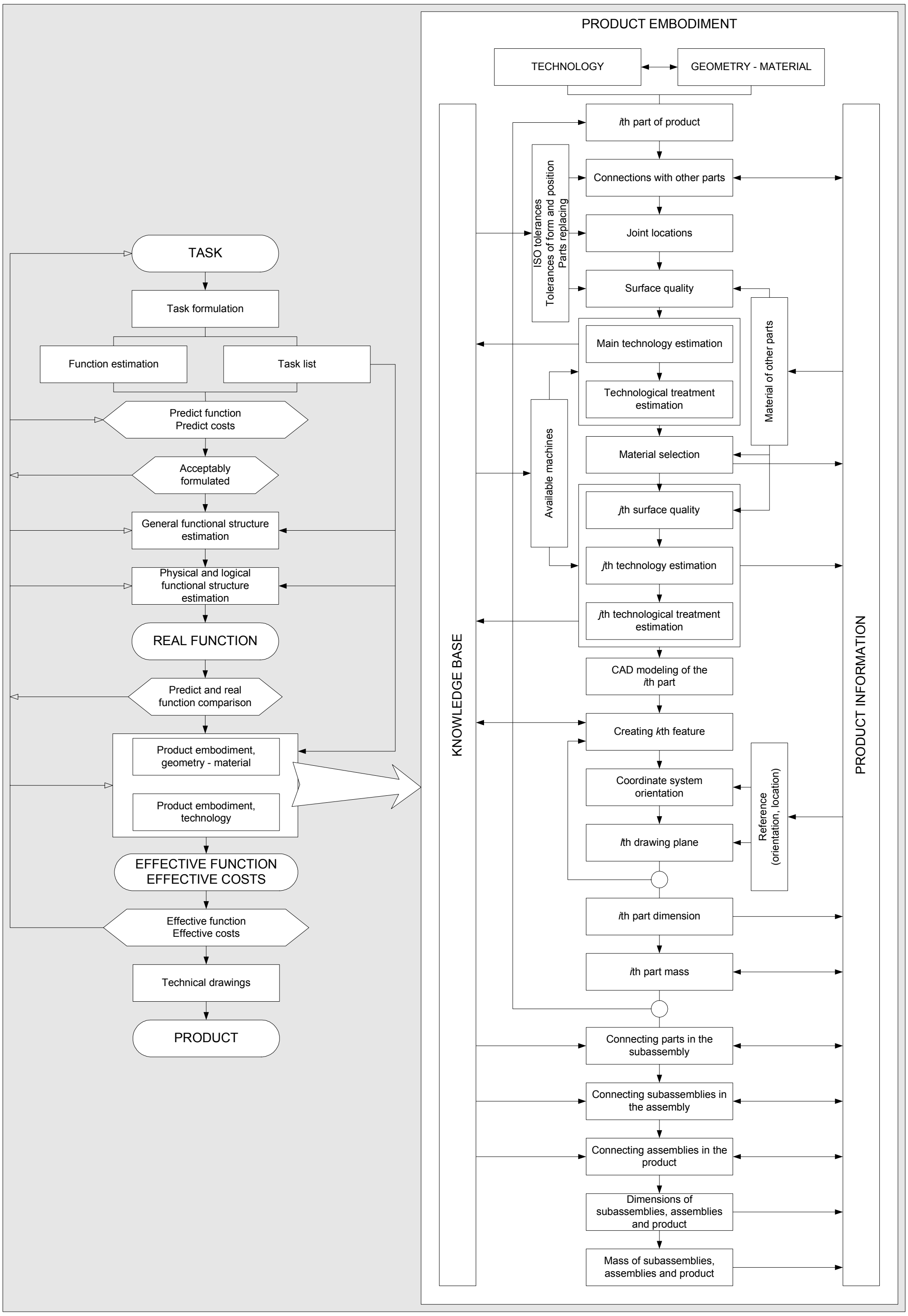

Figure 4. Product embodiment

In order to present the flow of knowledge and information during the product embodiment phase, a structure of the process of product modelling by using CAD systems (Figure 4) has been developed on the basis of the Roth design process model.
The product embodiment is the third phase in the design process during which the product is being embodied by determining its geometry and materials, and by determining the technology to be used in its manufacture.
The steps to be followed in the process of the embodiment of a machine part (Figure 4) are presented in a determined sequence which is vital for a full definition of both the machine part and the product as a whole.
Product embodiment is often presented as a strict sequence of events. This simplification dates from the time of algorithmic presentation of design processes, which is characteristic of prescriptive models of design processes considered in the 70s and 80s of the last century. Such approaches have been abandoned lately, and the dynamic and iterative nature of the design process is also being considered on one hand, as well as its variability as a consequence of the type of a design task, on the other.
During the phase of product embodiment, CAD system would give information to the product knowledge data base and information data base on the basis of feature recognition (Figure 5). Using the stored data, CAD system would get the answers, or suggestions, according to which the designer would be able to embody machine parts properly.

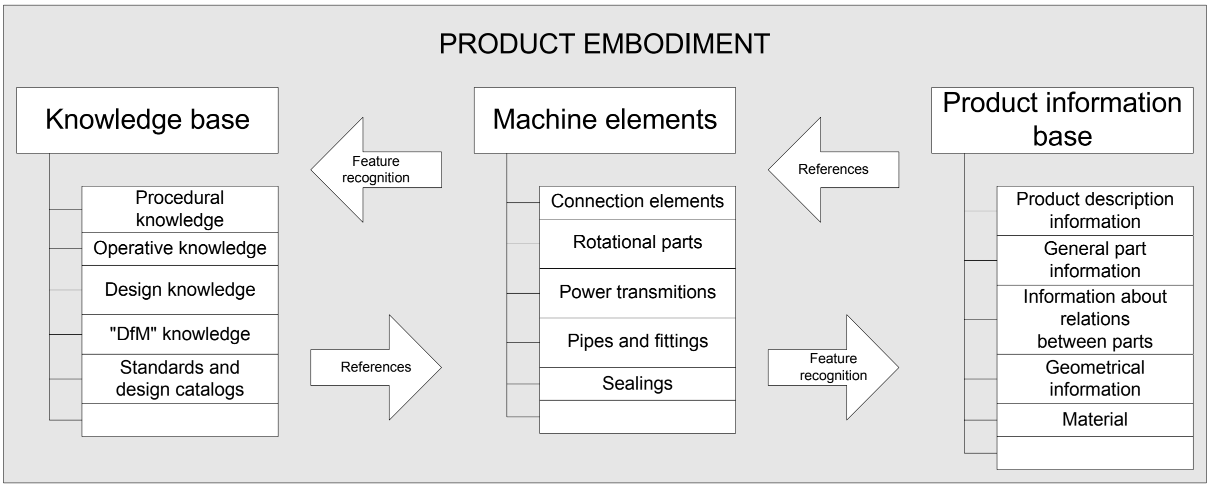

Figure 5. A machine part embodiment

As a matter of fact, the stored data and the data being stored during the design process should be accessible to the CAD system at any point of the process. Such a process of data exchange should be based on automatic feature recognition and references during the process of the machine part embodiment.
Automatic feature recognition and references would offer and interactive connection between the product knowledge data base, the product information base and the CAD system. It means that the system would follow the designer’s work and supply help during the process of product embodiment.

2.4 Classification of machine parts

In view of a large number of machine parts and technologies for their manufacture, it is necessary to systematize the knowledge used for their embodiment. Machine parts are classified into several levels, as can be seen in Figure 6.
The first level presents a classification of machine parts according to their general function. They are classified as connection elements, rotational parts, power transmission elements, ducts and sealings. The second level refers to the classification of machine parts and assemblies which have common general features (for example, joints that can be disassembled). The third level machine parts and assemblies are divided into groups with similar technical solutions, and a classification on the next level would lead to a comprehensive description of machine parts and assemblies.

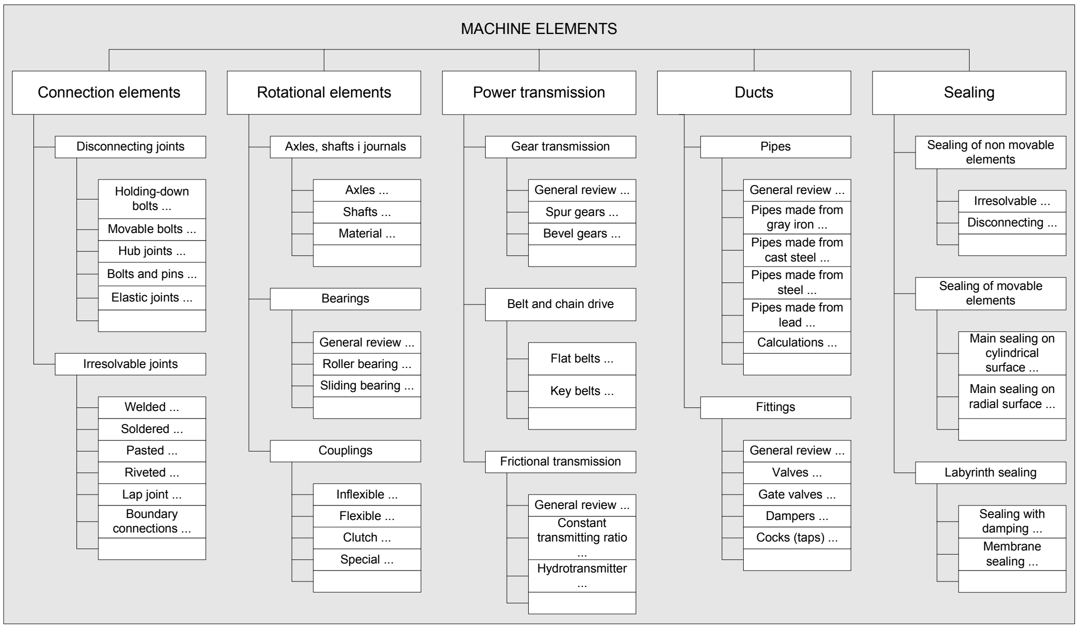

Figure 6. Basic classification of machine parts [Herold, 1997]

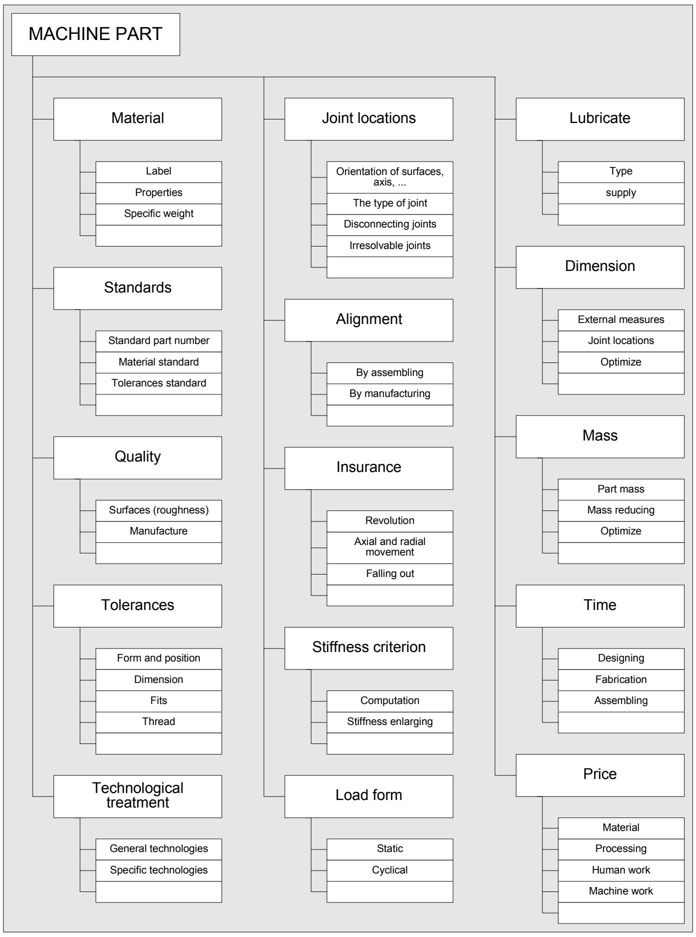

Figure 7. Machine part features

The machine parts, for each functional group, presented in Figure 6, should comprise all qualitative and quantitative knowledge required for the design process. A classification of the knowledge structure for the presented functional groups has been made up to a given level for the sake of a more concise presentation.

Each machine part has some features in common with other machine parts (see Figure 7). Features of machine parts are being stored into the product information base during the design process, and they can be accessed by the CAD system by means of references which are partially defined automatically (for example, the reference between the information on the material and the information on the machine part mass), and partially by means of the user (for example, determination of the joints in the assembly).

3. Conclusion

This paper presents the initial phase in the research into the CAD system improvement. The model whose structure has been presented and partially described is intended to enable the designer to access the knowledge on technological shape giving (forming) during the process of product embodiment using the existing CAD systems.

In order to present the flow of knowledge and information during the product embodiment phase, a structure of the process of product modelling has been developed. The developed structure gives the steps in the process of a machine part embodiment, as well as the interrelation of single actions with the existing product knowledge and information.

Since a product is composed of a great number of machine parts, it was necessary to give their classification. This classification was subsequently used as the basis for the systematization of the knowledge on the product embodiment. The systematized knowledge was then stored into the knowledge data base to be used by the designer at his/her convenience, thus speeding up the design process.

Achnowledgement

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