INTERACTIVE GRAPHICS IN CAD

Yvon Gardan and Michel Lucas

With Additional Material
by
Richard G. Budynas

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Introduction

In a society in which the use of information technology is becoming commonplace it is natural that pictures and images produced by electronic means should be increasing in importance as a means of communication. Computer graphics have only recently come to the attention of the general public, mainly through animated drawings, advertisements and video games. The quality of the pictures is often such that, unless informed of the fact, people are unaware that they are created with the help of computers. Some simulations, those developed in connection with the space shuttle for example, represent a great and rapid progress. In industry, computer graphic techniques are used not only for the presentation of business data, but also in design and manufacture processes.

Such computer-assisted systems are collectively represented by the acronym CAX. In CAD/CAM (computer-assisted design/manufacture), interactive graphic techniques have attained considerable importance. In CAD/CAM systems a dialogue can be established between the user and the machine using a variety of easy to operate communication devices.

Due to the recent developments in hardware and software (for modelling, visual display, etc), a designer is now able to make decisions based on the information presented (plans, perspective drawings, graphics, etc) with the help of interactive, graphic techniques. These constitute the most visible and perhaps most spectacular aspect of CAD/CAM systems. It should be noted, however, that the two are quite separate and independent of each other, and can be used both to complement each other and separately, to good effect. Some CAD/CAM systems do not involve the use of graphics and certain graphic applications (non-technical drawing, for example) exist independently of CAD/CAM. For this reason, Chapter 1 is concerned with the role of graphics in CAD/CAM. In Chapter 2 the components of a typical CAD/CAM system are described and considered from the point of view of graphics production. Hardware already commonly in use in other systems is not discussed at great length here, since information on these can readily be found elsewhere.

It is a common mistake to confuse the information displayed on the

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screen with the data stored inside the CAD/CAM system. It is the model that is of fundamental importance – whether it be of an object to be manufactured, a tool or a unit – and this is the logical representation of the object. The quality of this model (and particularly the geometric model) determines the quality of the CAD/CAM system. The graphical use of models can also involve simulations, based on information contained in the model. Chapter 3 considers the subject of geometric modelling, one of the most important aspects of CAD/CAM systems.

Chapter 4 is concerned with visual display techniques, and the different types of graphics (comprehension, communication) that are used. Algorithms associated with visual display are also explained (elimination of hidden parts, etc).

The dialogue techniques discussed in Chapter 5 depend, at least partly, on available hardware, but are treated here from the point of view of quality and levels of dialogue according to the operations of interest. In Chapter 6 examples are used to illustrate the points mentioned in previous chapters.

Chapter 1

The role of graphics in computer-assisted design/manufacture

1.1 Design procedures

The life of an industrially produced object, whether a car, a piece of furniture, a building or simply a bearing, starts with its design and ends with its manufacture. In the design and manufacturing process, two different sequences can be identified, depending on whether the product is *new* or *standard* (see Figure 1.1).

1.1.1 DESIGNING A NEW PRODUCT

This can be divided into five stages:

1. *the pilot study*: definition of external constraints, choice of technology, basic calculations, prototype design and trials;
2. *initiating the project*: product industrialization phase and establishment of definite plans;
3. *preparation for manufacture*: vital transitional stage between design and manufacture; requires close coordination between the planning and manufacture stages (1 and 4);
4. *manufacture*: product launch and manufacture; CAD/CAM techniques are used most frequently in this stage and will be increasingly so in the future, partly because of the expected increase in the use of robotic techniques and flexible manufacturing systems, which allow direct use of the data contained in CAD/CAM systems;
5. *maintenance and support*: mentioned only in passing here, this is an important factor to be taken into account should computer breakdown occur; the importance of an efficient and expert after-sales team should be stressed, as should the provision of replacement components.

1.1.2 DESIGNING A STANDARDIZED PRODUCT

Standard products can be based on existing products and this type of design is characterized by a much shorter pilot study phase. Generally, the components involved in the pilot study are already familiar to the

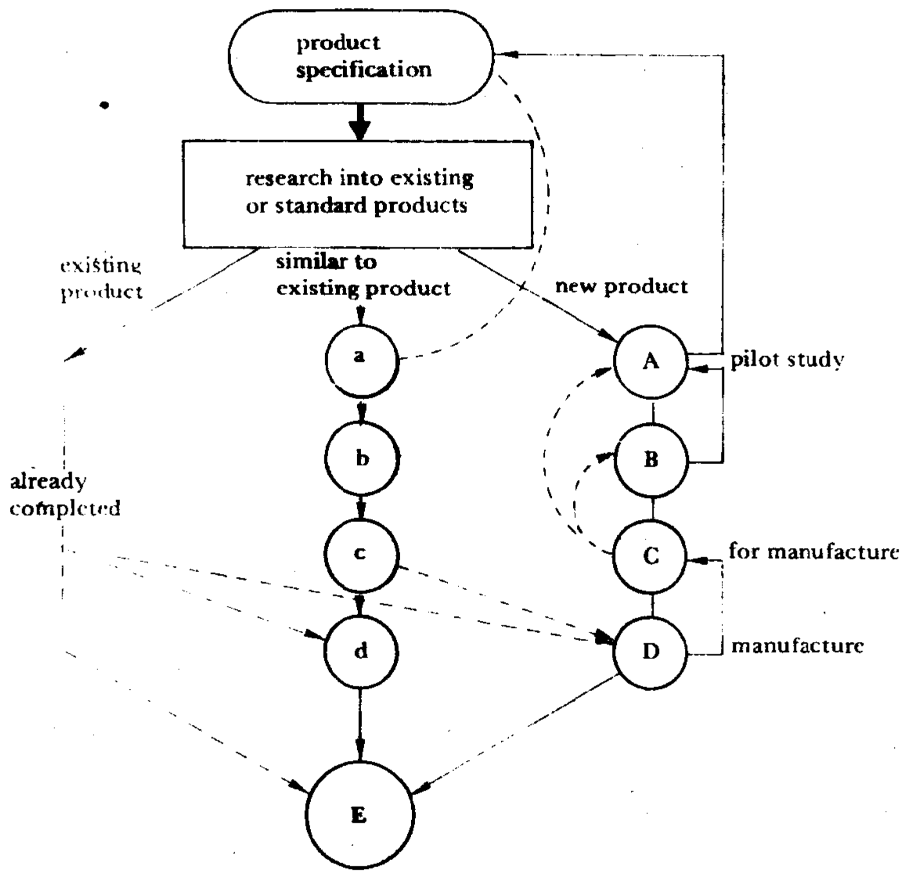

Figure 1.1. *The various stages in the development of manufactured products*

design team and development of a prototype, whether real or simulated, is not usually necessary. The main aim of a pilot study is to produce an estimate, based on previous research, to enable a solution to be found that comes to that set down in the product specification. It should be noted that there may be several attempts at each stage, and that the design process is not necessarily linear. Some technical choices may be thrown open to question as the study advances, causing the designer to reassess previous work. This situation can also occur when several possible solutions are being considered at the same time, with the best being retained, judged in relation to existing criteria. However, these criteria can change as the project progresses and the solutions which proved most attractive at one stage may be unsatisfactory in the light of other considerations established later.

Design procedures can also be analysed from a completely different viewpoint, without considering procedural sequences, but only the type of procedure followed. The following basic types of procedure can be distinguished (see Figure 1.2):

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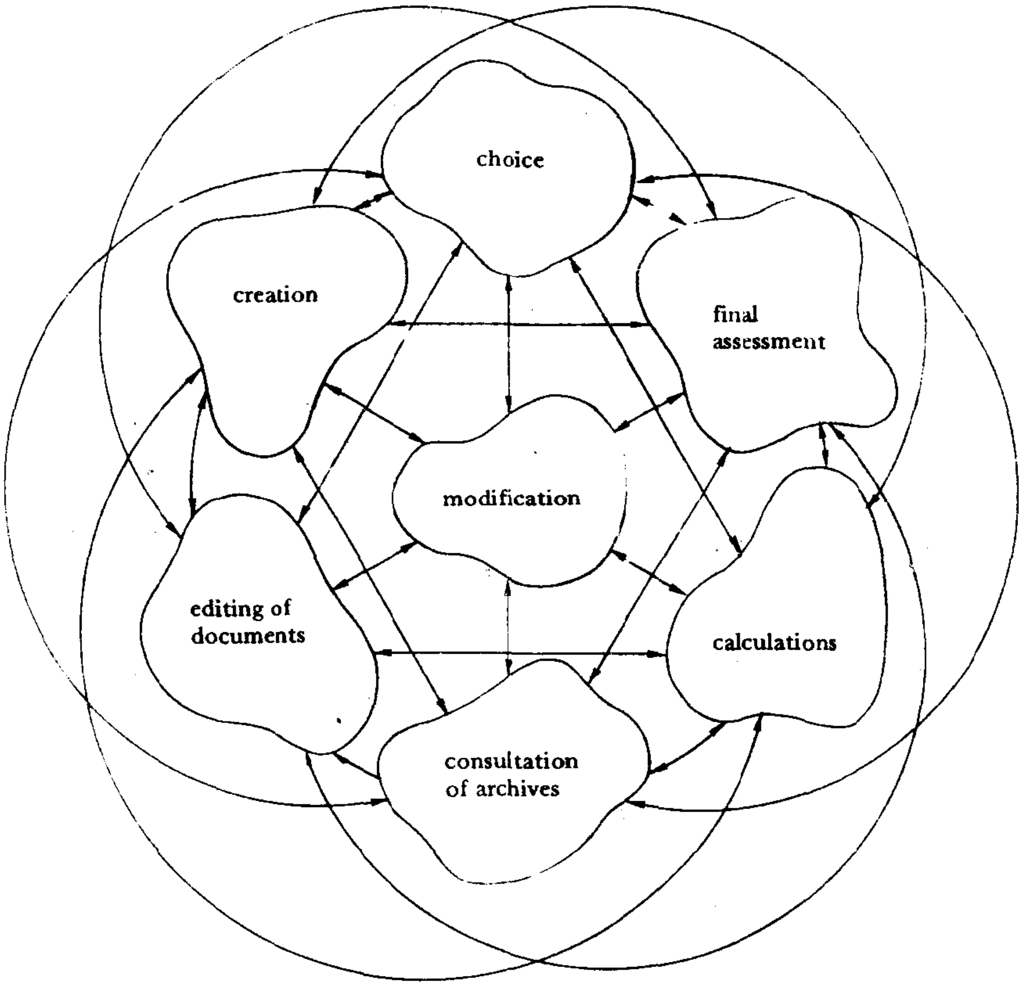

Figure 1.2. *The interrelationship between the various types of design procedures (the sequence of procedures is not relevant)*

1. *creation*: the invention of new objects or techniques to solve a given problem. It is necessary to be able to describe objects that have not actually been manufactured, and to store them for later use;
2. *modification*: with existing objects, changes and improvements may be necessitated by technological advances;
3. *editing of documents*: this concerns both alphanumerical documents (estimates, lists, etc) and graphical documents (plans, diagrams, etc);
4. *calculations*: the most important of these are the simulations which will be used to carry out work on potential prototypes;
5. *choice*: using the technical elements available (plans, calculations, etc) a choice must be made as to which will be retained, and in which direction the project will proceed;

6. *consultation of archives*: this involves the scanning of existing solutions as well as the use of individual items of information, and verification of a product's record of development;
7. *final assessment*: the stage during which the designer attempts to finally solve the problem, or choose between different solutions.

The following points should be noted:

1. The order in which these procedures are listed has no significance because, in practice, they take place in different sequences and combinations at different times. In Figure 1.2 the arrows are intended to signify this, showing that there is no real priority in the order in which these procedures are followed.
2. The amount of time devoted to each of the procedures can vary considerably. The concept of work pace has an important influence on this, and should not be seen simply as a function of financial return or of productivity, but should take into account that the rate of design may tend to vary. So, at certain times it may happen that the designer is working towards a certain idea and the pace of work may become rather slow. At such a time he will not, for example, be inconvenienced by a delay in response to a question concerning archive information. However, once he has fixed on an idea the pace of the work will increase, and he will require a faster turn-round from colleagues in order to achieve a maximum input of ideas.
3. It is evident that the procedures are not applied to a static object in the course of the design process, since the product is constantly modified. The fact that similar procedures are used in the various stages of development of an object suggests that CAD/CAM systems would be more attractive and acceptable if the tools they incorporate could be used in the same way for a given type of procedure, even at different stages of development. In other words, more emphasis should be placed on the type of procedure than on the type of object being handled.

1.1.3 CAD/CAM – TOWARDS A DEFINITION

From the concepts discussed above it is possible to attempt to define CAD/CAM. This can be said to take place when a computer system is used to facilitate the work involved in any one of the procedures described above. This definition raises a number of points that should be considered. In some ways, the idea of 'assistance' runs counter to that of automation. It concerns the provision of a number of carefully chosen tools intended to facilitate the work of the designer. In the final analysis, it is the designer who chooses which tool to use – the machine only provides the options. Sometimes, not all procedures are assisted, either because it is not necessary, because the amount of work to be done is not sufficient to make it worthwhile, or because the data processing involved would be too complex.

Of the task division between operator and machine, it is obvious that some should fall naturally to the machine (for example, everything concerning the storage of information and control of archives) whereas others are naturally reserved for the operator (for example, definition of new products to be developed). Within certain procedures there are some parts that could be assisted, and others which could not. For example, written documents may be edited automatically, but not with a CAD system.

This definition reflects the flexibility in the levels of integration of CAD/CAM systems. The introduction of CAD/CAM into a business can be carried out progressively by selecting specific areas of activity which would be particularly suitable for computerized assistance. Many businesses use CAD/CAM without realizing it, using specific computer programs to facilitate the work of designers.

1.2 Graphics and CAD/CAM

There is a common tendency to confuse computer graphics with CAD, a confusion often shared by industrial computer users, because even though they use calculation and simulation programs, they do not consider that they are using CAD/CAM because they do not produce graphics with the computer. This confusion arises for two reasons. In traditional design and manufacturing processes, information is communicated through text and plans. So, whether the products in question are new or standard, most of the documents used are in graphic form – plans, graphs, diagrams or other forms of graphic representation (see Figure 1.3). In research establishments, the breakdown of graphics activity is roughly as follows (see also Figure 1.4):

drawing 70%
archive work and updating 15%
design proper 15%:
- copying out 70%
- variations 20%
- errors 9%
- invention 1%

The production of graphical documents is the most impressive part of CAD/CAM. A demonstration of the interactive production of documents is considerably more striking than the execution of a simulation program that provides a numerical output. It would be useful to consider here the contexts in which interactive software can be used (see Figure 1.5).

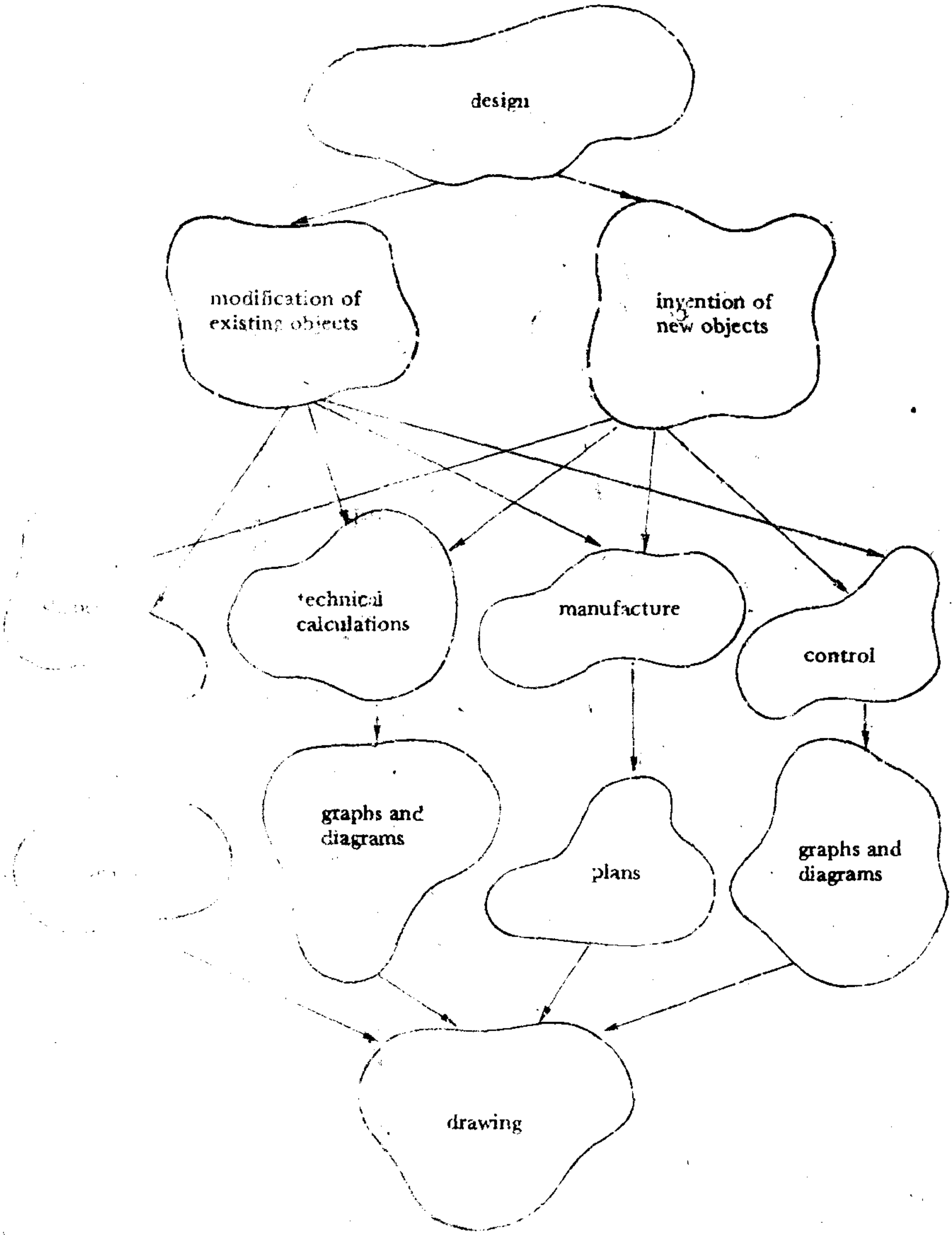

Figure 1.3 *The drawing, a vital input medium for CAD/CAM, is accepted in a variety of forms by the system*

The application program is central to the production of computer-assisted graphics, and carries out the calculations concerning a given area of interest. The program makes use of information stored in the computer's data bank. This data can be permanent (ie stored on file for

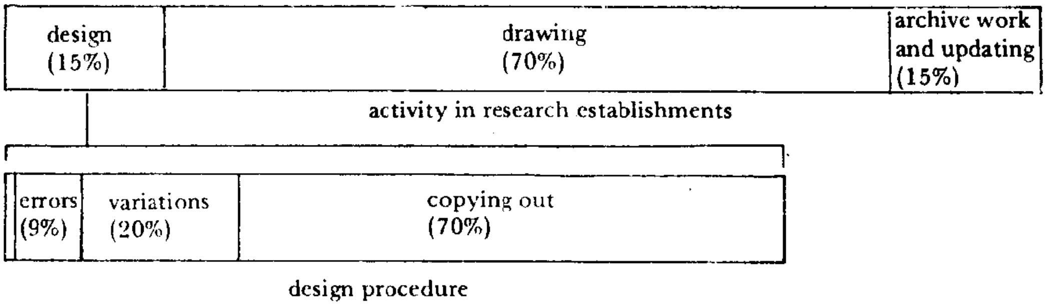

Figure 1.4. *The percentage breakdown of the different procedures in research establishments, showing further breakdown of design activities*

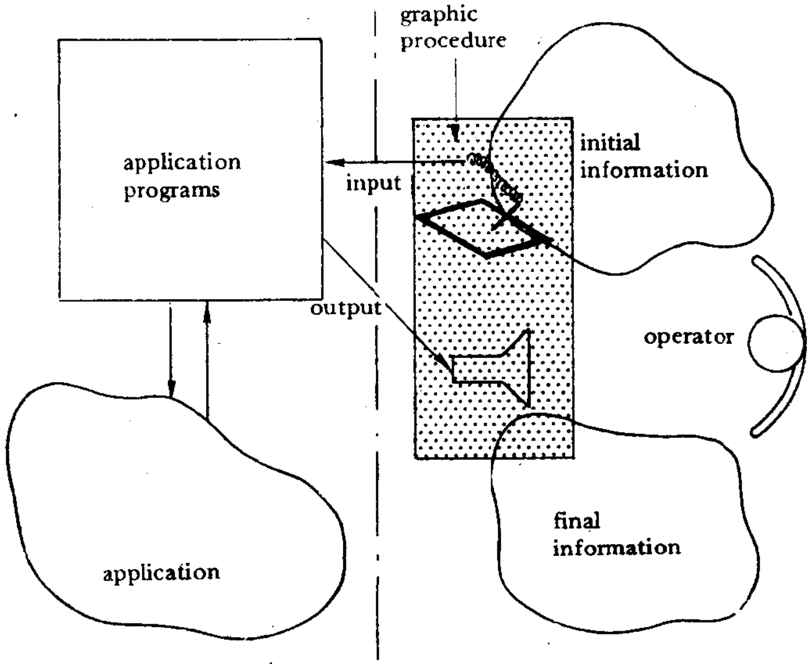

Figure 1.5. *Context in which interactive graphic software is used*

use in successive applications), or temporary (for intermediate calculations). The initial information is supplied through the input procedures and the results are obtained from the output. The input/output operations are instructions intended to create a link between machine and operator. Interaction or dialogue is characterized by the presence of an operator, who, having considered the output, will influence the program by inputting new initial information. This process continues until the required result is obtained.

Interactive graphic techniques are used only in a limited number of input/output operations. It is clear, therefore, that they have only a limited role, and, in general, the application programs themselves are the most important component. This is the way in which CAD/CAM can be used without any graphics being produced. On the other hand, CAD/CAM can take a more simple form, used to assist in the production of technical drawings. So, to maximize usefulness, it might be necessary to develop a number of programs which do not involve graphics.

To sum up, computer graphics are an integral part of CAD/CAM, but still represent no more than a part, and not necessarily the most important nor the most difficult to use. The following section is an attempt to analyse the various levels of assistance, and illustrates the range and complexity of systems used for assisted drawing.

1.3 Graphic processes in CAD/CAM

Assisted drawing systems are intended basically to ease the production of technical drawings. This means providing a description of the geometric primitives of the surface of an object so that the relevant documents can be produced more quickly. Increased speed is achieved in a number of ways:

1. the use of a more or less formal description of the drawing as a whole, leaving the computer to perform most of the line drawing;
2. the use of catalogues of symbols related to the work in progress and appropriate to the CAD/CAM system in use (the designer requests a symbol and the machine automatically draws it);
3. time is saved at the modification stage, when the designer needs only indicate what has to be changed and the computer readjusts the whole drawing accordingly; erasement and re-copying are thus totally avoided.

The first computer-assisted drawing systems involved the designer in virtual programming of the drawing to be made, through the use of parameterized geometric primitives. For example, a circle was produced by describing the coordinates of its centre and its radius. The use of collections of simple parameterized objects has come to be quite common. An example is shown in Figure 1.6; it can be seen that in order to draw a symbol, no matter how complex, it is necessary to give only the name of the symbol and a number of parameters which describe the symbol as a whole. The designer must think in geometrical terms, and organize the drawing according to the basic elements available. If a mistake is made the faulty instruction is deleted and the sequence of parameters modified accordingly. Producing a technical drawing thus becomes equivalent to writing a computer program, which means that the designer or draughtsman will require specialized training.

There are other basic operations which allow the designer to save time. For example, by introducing the concept of contour (and therefore of

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