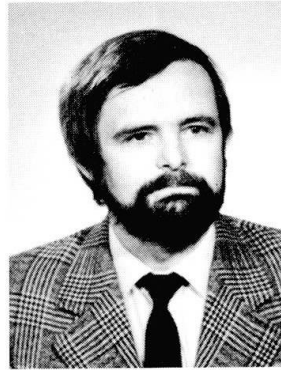# Graphical Expert Systems

Systèmes experts graphiques

Graphisches Expertensystem

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Jan Petr, born 1944, received his civil engineering degree and PhD at the Prague Technical University. He worked as a designer, for several years he dealt with structure analysis by computers. Now he is involved in developing CAD systems at PTU.

SUMMARY
Graphical Expert Systems represent a new generation of computer graphics tools, a kind of Intelligent Knowledge - Based Systems. Goals and constraints of such a system are presented. So-called graphical knowledge is defined. A language for graphical knowledge representation is derived. The structure of the system GES being developed at Prague Technical University is described.

RESUME
Les systèmes experts graphiques (GES) représentent la nouvelle génération des outils infographiques. Les buts et les limites de ces systèmes sont présentés. La connaissance graphique et la langue pour sa représentation son définies. La structure d'un système expert graphiques développé à l'Université technique de Prague est décrite.

ZUSAMMENFASSUNG
Graphische Expertensysteme repräsentieren eine neue Generation der Werkzeuge für Computergraphik. Die Ziele und die Ausgangspunkte des Projekts eines solchen Systems sind in diesem Aufsatz abgeleitet. Das sogenannte graphische Wissen und seine Repräsentation wird definiert. Die Struktur und einzelne Bestandtelhate des graphischen Expertensystems GES, welches die Technische Universität Prag entwickelt, sind beschrieben.

1. INTRODUCTION

The paper presents some results of the efforts to develop a means capable of generating graphical information from object-oriented, not graphically expressed data. These data are the results (of a particular problem) achieved either through an artificial system or man. The goal is to make an object-independent programming system with the elements of artificial intelligence. System GES, a graphical expert system with inherent graphical knowledge, meets these requirements.

First some theoretical backgrounds of GES are presented: an analysis of graphical language, graphical knowledge definition neccessary for GES' knowledge base construction, and the language for graphical knowledge representation.

Second the GES' main components and structure are described.

2. CHARACTERISTICS OF GES

2.1 Purpose of GES

In many domains of civil engineering design the graphical form of information is used. We can say that the graphical language is one of the designer's natural languages. CAD systems respect this fact, too. Different types of computer software generate graphical outputs of these systems. Some of the software are special, problem-oriented, one purpose program moduls. Today's integrated systems for interactive computer graphics represent very sophisticated and effective tools of a designer. But even with such systems a designer must communicate in words of graphical language syntax, that means in words "how to draw"; usually it isn't possible to communicate with them in the language of the problem domain, that means in "semantic" terms "what to draw". The ambition of GES (or rather of its authors) is to understand "what" is to be drawn and to be able to draw it in a proper way, using "graphical" knowledge. Systems like GES are domain independent exept their knowledge base. The contents of the knowledge base assigns a concrete GES to a certain domain.
The main object of GES is to convert information expressed in non-graphic form (a description of a construction for example) into usual graphical form ("to draw" it). The "intelligence" of GES consists in "how to draw" it. Figure 1 shows the typical situations of GES applications.

2.2 Nature of GES

GES is designed as an expert system. To construct it knowledge of three branches is made use of:

- civil engineering designing; from this branch practical demands and constraints are drawn,
- classical computer graphics, from which graphical algorithms and programme moduls of geometric-graphic operations are borrowed,
- artificial intelligence, which gives data and procedures for knowledge processing; from this branch also the principles of expert systems are borrowed.

a) conversion of non-graphic data into graphic form in CAD complex
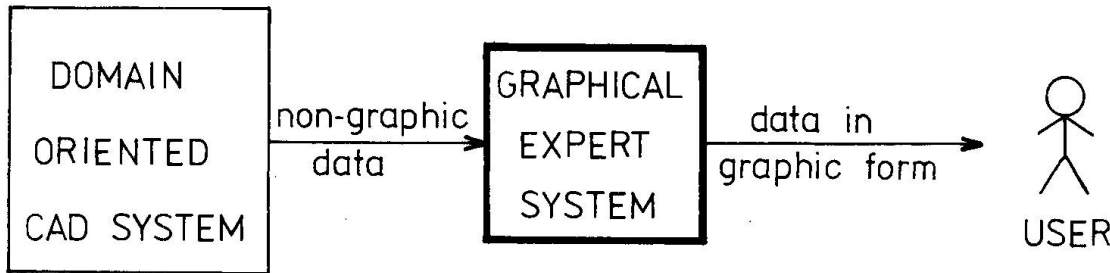
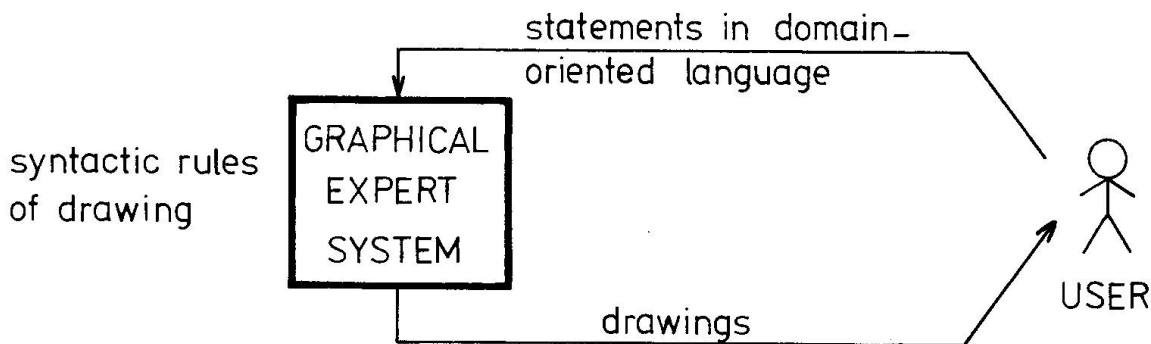b) dialogue designer - „intelligent" drawer

Fig.1 : Typical applications of GES

GES has typical attributes of classical expert systems. It uses the expert knowledge base (e. g. how to compose and construct particular drawings) and universal inference mechanism for knowledge base evaluation based on concrete input data.

What makes GES different from classical systems is that it works with graphical knowledge, depicting graphical entities and graphic-geometric relations between them. The GES inference mechanism is also based on specific graphic-geometric procedures.

To realize GES a host graphical system is used capable of handling graphical objects, e. g. keeping and drafting. Typical examples are AutoCAD, DOGS and others. GES presents superstructure over these systems.

GES is programmed for PC-AT computers equipped with graphical display.

3. GRAPHICAL KNOWLEDGE

3.1 Semantic entities in graphic information

Some parts of concepts, which reflect objects of real world in human mind, are connected with visual image. If these parts privail, then such concepts are conveyed by graphical language. From the semantic point of view these parts represent in the

commonly used graphical languages the following semantic entities:
- iconic characteristic,
- geometric characteristic,
- symbol of the object,
- scalar characteristic.

Let's call them **graphic entities**. Another kind of semantic parts are the **relations between graphical entities**:
- distance,
- rotation and
- superposition.

Iconic characteristic presents perceived or designed appearance of the object.

Geometric characteristic describes how the object is set up in space.

Symbol of the object is either an established figure or an instantaneous one depicting the kind of the object or identifying the object.

Scalar characteristic of the object is a visual image of the value or the course of values of a certain scalar variable typical of the object.

Relations depict manual distances and rotations of the objects.

Superposition describes the composition of graphical entities. By means of superposition the quality of the whole composed of several concepts is generated.

Graphical entities and relation between graphical entities are the **basic semantic entities** of graphical information.

3.2 Graphical Knowledge Definition

The use of computer in generating graphic information is of prime interest to us. From this point of view also the definition of graphical data and graphical knowledge is derived.

Graphical data are the elementary parts of graphical information. They represent values of the basic semantic entities. Let's formulate the following definition:

> **Item of graphical data** is a graphical figure or a graphical structure describing a part of real or potential world in values of the basic semantic entities.

Syntax of the item of graphical data is determined by the syntax of a graphical figure or a graphical structure. Its semantics is derived from the semantics of the graphical entity whose value it represents.

Graphic figure is an arranged composition of graphical primitives (abscissa, arc etc.). The arrangement of the composition must correspond to the iconic or symbolic depiction of reality. Graphical figure as an element of graphical language cannot be further divided. It is perceived as a whole.

Graphic structure is a composition of graphical figures. Between pairs of structure elements exist relations. The interrelations between all elements are determined by superposition. The graphical structure presents a complex visual information determined by the meaning of particular attributes and their

composition. All basic semantic entities are potential parts of
the graphical structure.
Graphic knowledge means to know "how to draw pictures". To put it
more correctly how to generate graphical structures from atomic
graphical data. When used in GES it can be defined as follows:

> **Graphic knowledge** is the ability to generate pictures from
> elementary graphical data.
>
> By pictures we mean graphical structures carrying graphical
> information about the existing or designed state of some
> part of the real world.
>
> The nature of graphical knowledge is that of nomological
> data over data, which represent visual reflection of real
> world. Graphical knowledge is expressed by instances of
> basic semantic entities.
>
> Graphical knowledge is a metalanguage system (syntax)
> enabling us to handle graphical objects. It has the ability
> to generate graphical structures.

3.3 Graphic Knowledge Representation

In this paragraph the way of notation graphical knowledge in the
GES knowledge base is described.

The **frames** used in classical expert systems were chosen as the
main principle of graphical knowledge representation. They were,
of course, modified for this purpose. The frames describe
structures. They could be interconnected into higher structures.
It satisfies our need to decompose complex structure of graphical
information into particular graphical structures.

With help of one frame graphical knowledge about generating one
graphical structure is denoted. Frames can form hierarchic sets
expressing the knowledge of complex graphical structures
composition.

Basic semantic entities are the semantic parts of frames. The
frames are arranged in a way enabling inference mechanism based on
methods and algorithms of computer constructive geometry to handle
them.

Let's mention some construction parts of frames to denote
graphical knowledge.

Graphic constant is a constant graphical structure related to
co-ordinates.

    <graphic constant>::=<identifier of graphic constant>

Graphic variable is a symbol, which can aquire various values -
graphical constants.

    <graphic variable>::=<identifier of graphic variable>

Typological graphical constant (TGC) stands for a typological
element of a drawing. Various constants can be substituted
for it. The choise of the constant depends on associative
connections between graphical constants, which are part of
knowledge base. For the arrangement of TGC set see Fig.2.

    <typological graphical constant>::=<identifier of typological
                                  graphical constant>

Fig.2 A set of typological graphic constants

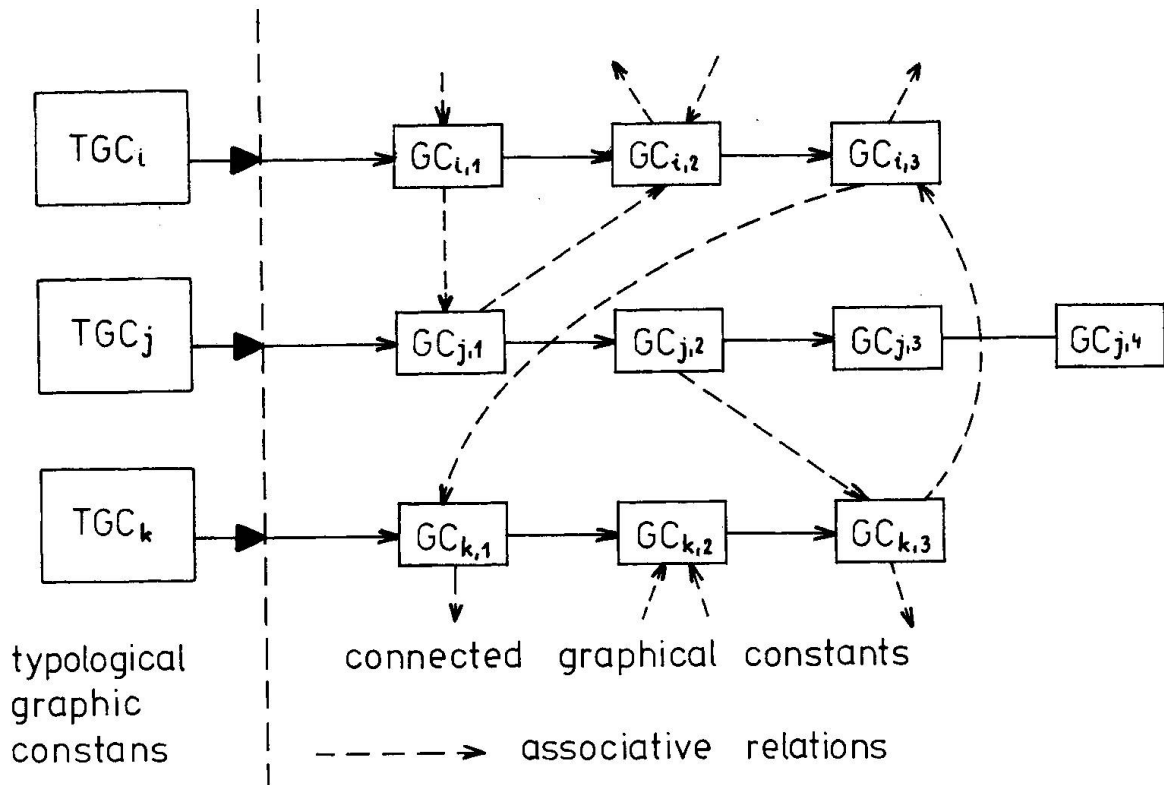**Geometrical operations** are traditional operations consisting in: moving, rotation and scaling.

```
<geometrical operation>::=<operator of geometrical operation>
                          (<argument of geom.operation>
                          (,<parameters of geom.operation>))
<operator of geom.operation>::=MOVE|ROTA|SCAL
<argument of geom.operation>::= <graphic constant>|
                                <graphic variable>
```

Logical operations evaluate expressions containing numeric parameters. Logical value is the result of this operation.

```
<logical operation>::=<numerical parameter><logical operator>
                      <numerical parameter>
<numerical parameter>::=<numer.constant>|<numer.variable>
<logical operator>::= <|>|≤|≥|=|≠
```

Superpositions. Composed graphical structures are constructed with help of superposition. Superpositions are based on principles of set operations with graphical objects. A graphical constant is the result of superposition. There are these kinds of superpositions:
- union where the order of arguments is not relevant,
- union where the order of arguments is relevant,
- intersection where the order of arguments is not relevant,
- intersection where the order of arguments is relevant,

- substraction.

The meaning of particular types of superposition is defined in tables. To illustrate them we give Table 1.

```
<superposition>::=<operator of superposition>(<1st argument>,
                  <2nd argument>)
<operator of superposition>::= ∪|∪∪|∩|∩∩|-
<argument of superposition>::=<graphic constant>|
                             <graphic variable>
```

Table 1 : SUPERPOSITION - type „UNION"

superposition	symbol	1st argument	2nd argument	definition
order of arguments is not relevant	∪			
	∪			
	∪			
	∪			
order of arguments is relevant	∪∪			
	∪∪			
	∪∪			
	∪∪			

Input operations perform a graphic constant input or numeric
        constant input.
    <input operation>::= **READ** <argument of input operation>
    <argument of input operation>::=<graphic variable>|
                                    <numerical variable>

Declarations, assigments and decision statements are constructed
from the above mentioned (and other) components. Net of frames in
hierarchic order, which is the basis of knowledge base, is
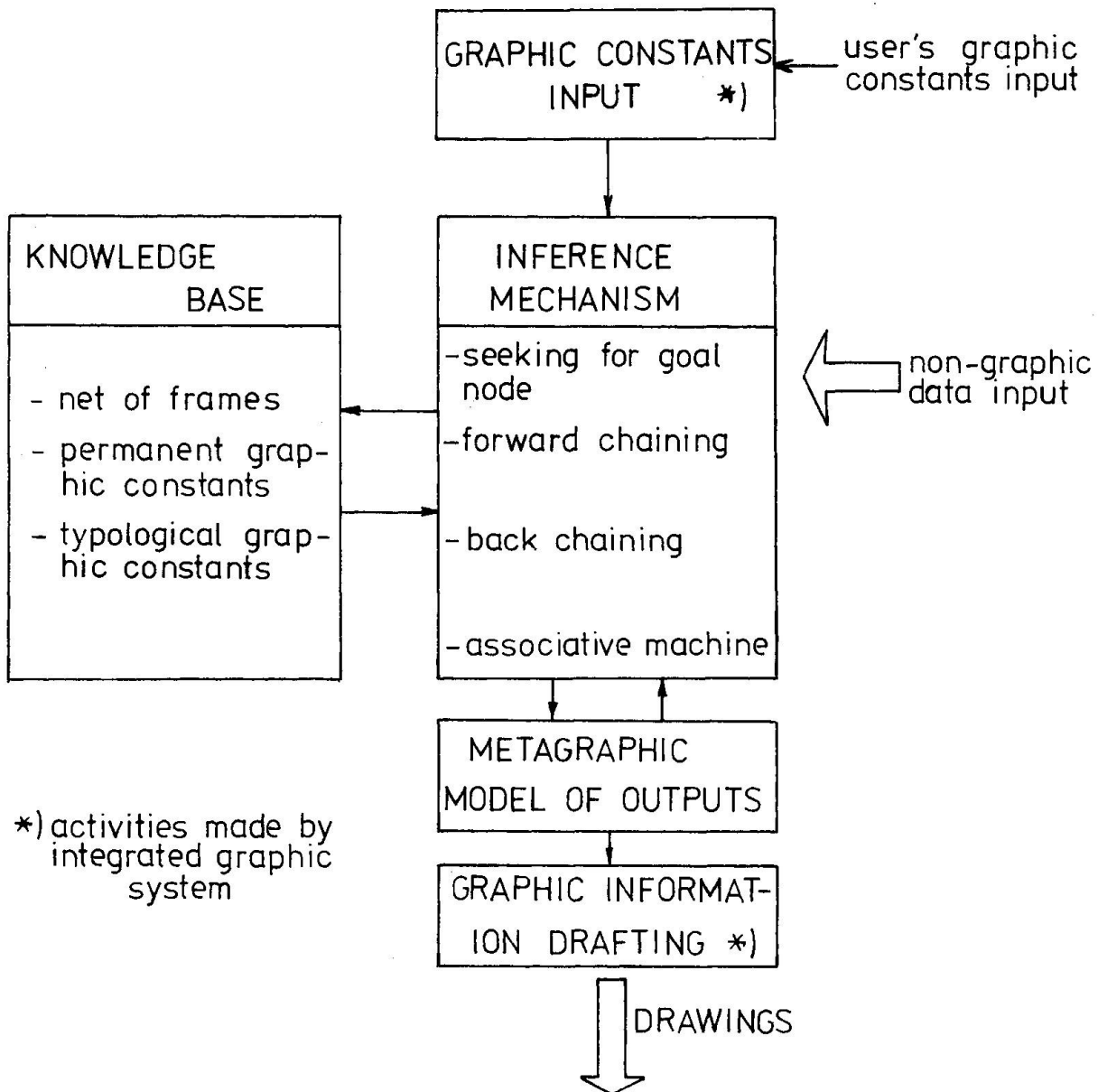composed of these frames.

Fig.3 GES structure

4. GES STRUCTURE

The graphical expert system GES consists of these main parts:
- knowledge base,
- inference mechanism,
- graphic constants input,
- metagraphic model of outputs,
- graphic information drafting.

Their arrangement we can see at the Fig. 3.

4.1 Knowledge base

Knowledge base consists of three parts: a net of frames, a set of permanent graphical constants, a set of typological graphical constants.

Net of frames is a hierarchic system. It is a directed graph. Frames are represented by nodes, hierarchic relations between frames are represented by edges. The graph is an acyclic one. Any node can be a goal node in a given task. The goal node produces resulting graphical structure. The precedents of this goal generate the components of this structure.

The set of permanent graphical constants contains those constants introduced and made by an expert in the course of knowledge base making. They are called from frames as operation arguments. They present in advance prepared "characters" of graphical language to be generated.

The set of typological graphical constants contains groups of graphical constants. The elements of a drawing are picked from them by the inference mechanism. The arrangement of this set see Fig.2.

4.2 Inference Mechanism

Inference mechanism reads input data, i.e. a description of reality in non-graphic form, and decodes them. It evaluates the knowledge base drawing from input data analysis. The result of the process is a metagraphical expression (written in a symbol language) of the drawing. We call it a metagraphical model of the drawing.

The inference mechanism performs these partial activities:
- input data reading,
- input data analysis; seeking goal node in the net of frames follows,
- forward chaining; during this operation the subgraph of goal node precedents is seeked. At the same time a record containing transformation parametres of each found frame is made. Also the associative machine seeking a suitable graphical constant may be activated during this process.
- back chaining proceeds from leaf nodes to the goal node. All operations required within the frames are carried out during this procedure. This way a metagraphic model of the drawing is created.

4.3 Graphic constants input and final drafting

In some cases the inference mechanism asks the user to supply a graphical constant. It is delivered by means of a graphical

display or other input graphical device. The whole procedure is carried out by the host graphical system.

It is also this system that carries out last GES activity - final physical drawing of graphical information. It is based on the metagraphic model created by the inference mechanism.

5. CONCLUSION

For PC-AT category of computers a graphical expert system is being developed. It combines both the abilities of advanced graphical systems and the abilities of expert systems. Theoretical preparatory work on GES, mainly graphical knowledge definition and its language expression, have been finished. Also the algorithms of the inference mechanism have been derived.

At present programming of GES modules is carried out.

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