CAAD: Education-Research and Practice ECAADE Conference 1989
School of architecture in Aarhus, Denmark

AUTOMATIC RECOGNITION OF GRAPHIC DOCUMENTATION IN BUILDING DESIGN

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Abstract

Automatic image recognition by means of Artificial Intelligence techniques poses some unsolved problems but it can be viable in technical drawing because standards allow the problem to be managed in terms of knowledge. The paper deals with the feasibility of a knowledge-based design. A semantic network is employed to model knowledge and an expectation-driven recognition strategy is used.

1. Introduction

Automatic image recognition still poses some unsolved questions at theoretical level but it can be viable in two dimensions within sufficiently limited ambits and classes of images. This is the case of that kind of graphic pictures in which it is possible to wholly formalize the scope of the problem.

The present paper is a contribution to the broader work on complete automation of graphic documentation input, particularly useful when large amounts of data must be input. In such cases, of special interest is the possibility of extracting complete data, as well as non-graphic ones, by merely reading the drawings. In this way, for instance, lengthy integration techniques normally employed to associate data of various nature with graphic output can be prevented. This is made possible by using a semantics that is connected to basic graphisms through ordinary technical norms.

The kind of drawing interpretation proposed here uses the outcome of scanner or camera reading, the latter is used in the more complex cases.

Using a scanner for image inputting involves image binary thresholding. In other words, a (bimodal) histogram of the grey shades of an image is generated, the value of the grey comprised between the two peaks is assumed as threshold value in order to separate the drawing from its background. A system connected to the scanner analyses the images received and sends out input graphic data in CAD/CAM format. Needless to say that thresholding problems affect data reliability. Image inputting by means of camera reading requires a large number of grey shades to be handled. Great care must be taken in source image illumination in order to prevent alterations in the distribution of grey levels. Camera reading allows restoring and filtering that are highly helpful in cases of bad-quality source images.

In such cases particular difficulties may arise in the process. This process sends out graphic primitives, also called 'segments', to the following process of interpretation. In fact, the segmentation process attempts to extract the significant parts, i.e. objects or parts of objects, from images. The process of segmentation is often conceived in literature as a process of pixel classification whose classes may contain, for instance, regions' grey levels, borders, edges, etc. While high-quality commercial scanners can generally solve most of the problems of locating significant parts in graphic images with various levels of grey are still difficult to manage. There is not an established theory for segmentation nor for clustering; generally, *ad hoc* techniques are adopted. Visual data are processed by grouping pixels on the basis of overall space features. In particular, the levels of grey on the whole image is first analysed assuming that different regions correspond to different resulting histogram peaks. Regions are then individuated by the pixels falling between two levels of grey around one histogram peak. Extending the threshold technique to multimodal cases [6] presents several drawbacks due to the fact, that global thresholds are hard to define. Such drawbacks, however, can be overcome by considering the influence of local factors [7]. This method has the advantage of, among others, perceiving different paintings of the background, different greys and different colours, thus making interpretation far easier. Finally, a set of grey shaders can be predefined by peak distances; in this way, CAD techniques are able to produce drawings that can be automatically read with greater ease than is possible with conventional drawings. A hierarchically organized taxonomy can meet all representative needs.

The present paper is as follows: chapter 2 deals with image recognition and particular reference is made to the strategies adopted. Semantic networks used as tools for knowledge representation will be discussed in chapter 3. Chapter 4 will present some applications of the proposed technique, including automatic definition of the dwellings' features. The last section is devoted to future developments.

2. *Image interpretation*

Several levels of image management can be distinguished in Computer Vision:

i) 'early processing' concerning the first transformation of visual data based on physical and optical properties through 'feature extraction';

ii) 'low-level processing', concerning the individualisation of intrinsic properties and object perception through general cognitive rules like those of ***Gestalt*** [3];

iii) 'object recognition': attempting to recognize object meaning. In essence, this is a process of matching a given model to any one of its instances. Models are nothing but knowledge gathered from previous situations, while an instance is a specific description of the object corresponding to the model;

iv) 'scene understanding': attempting to interpret a scene within its world.

Our research can be located at the 'object recognition' level, whereby we need a model to as the reference element during recognition. It is also necessary to define suitable strategies to direct recognition processes. As a general rule, strategies can be conceived as of 'plans', each of which may be made of two parts:

i) 'bottom-up' or 'data-driven' part, which starts from visual data and which attempts to recognize part of the object via planning rules;

ii) 'top-down' or 'expectation-driven' part which starts from the model and attempts to verify a hypothesis generated at the beginning via inferential rules.

We adopted a strategy that can be regarded as one of cooperation between the former and the latter. Recognition works through objects to the models stored in our system; experts are used for this and they process visual data and provide various features that are useful for recognition. The experts are procedures for visual data handling; two classes of experts can be distinguished: geometrical experts and relational experts.

Geometrical experts are procedures for visual data handling that individualise certain geometrical, morphological and dimensional features. Each expert is specialized in individual using a specific qualitative geometrical element.

Relational experts are procedures that verify spatial relations existing between two parts of an object, i.e. connection, position, inclusion relations, etc.

3. *The Semantic Network*

As we said earlier, the availability of one Data Base capable of storing and providing both descriptive and graphic information (for reference purposes, for instance) is one of our main issues. One way to tackle this problem is to resort to the knowledge captured during the analyses of drawings' graphisms (e.g. those of a dwelling). This is possible because, as far as technical drawing is concerned, there are standard norms for graphisms that ensure unambiguous correspondences between objects and their graphic representations. This allows us to build a formalized knowledge base for the description of everything contained in the drawing. These reflections led us to define a structural and geometrical model for our knowledge base. It seemed to us that a semantic network would be a suitable means of representation. A semantic network 12] is one made up of 'nodes' (drawn as points, circles or, generally, as closed lines) and 'arcs' (drawn as mono- or bidirectional arrows). Both nodes and arcs are labelled. Nodes represent concepts or objects, arcs represent their relations. In order to obtain our semantic networks, we concentrated on structural-geometrical knowledge. Our structure can now be described in the terms of those objects (but also rooms and subrooms) that are typically present therein, together with the frequence in which they can be found. Sub-rooms and objects are represented by nodes in the semantic network, while space relations are represented by arcs; the latter may be used to define mutual positions between objects. Moreover, both objects and object parts are nodes in the semantic network, it is therefore possible to carry out successive decompositions into sub-parts and create 'part of' relations.

As examples of concepts we will quote: external wall, internal wall, external area, window, door, partition, tube.

Relations are divided into:
i) structural relations, e.g. 'having', 'part of';
ii) spatial relations e.g. 'on the left' , 'on the right', 'near to', 'adjacent to';
iii) relations of 'specialization'.

A concept may have features of its own: these are described by attributes. Such features may be morphological and/or dimensional and they can be described both qualitatively and quantitatively: 'measuring x in length' , 'grey level', 'short' are some, examples. Moreover, a quantifier has been associated with each network are which shows how frequently a concept appears in the network. This helps reduce the number of copies of the same concept and of the network parts underneath. Quantifiers may be made of one value or a pair of values: in the former, the number of occurrences of the concept in the network is given, in the latter, the minimum and maximum numbers of occurrences are given. A minimum value which equals 0 means that the concept is optional, i.e. that it is not necessary to determine the object in question. The knowledge contained in the models adopted has been formalized by means of a network of the kind previously described.

For instance, figure 1 shows the semantic network which determines the technical drawing that represent the 'window' graphism. Here is the description of the 'window' graphism:

> adjacent to the external wall, adjacent to the external area, having three equidistant lines that, are parallel to the external wall, having one line that is orthogonal to the external wall and it is the avis of the three equidistant lines.

In our example the following items have been used:
i) concepts: window, external wall, external area, line;
ii) relations: having (structural),
adjacent to, orthogonal, parallel, axis
(geometrical-spatial);
iii) attributes: equidistant

Moving through our network, instances of the various concepts can be created by moving from the particular to the general. Moving downwards, one can find a concept and verify it [4]. There are no formal semantics for semantic networks; only semantics connected to the procedures implemented on a specific network is possible. Given a specific network, inferences using different procedure typologies can be made, thus obtaining different systems.

4. *Examples of applications*

Our first application was to implement a system capable of recognizing a dwelling's building objects given its plan. A system has been implemented that receives, as input, the complete drawing of a dwelling. After some preliminary processing our system is capable of recognizing the drawing's component parts. The system interacts with the user: it asks him or her which part is to be individualised ('window', for instance), then the system recognizes the part selected by the user and a graphic output that highlights it. Moreover, the system updates an internal Data Base that may be used for final syntheses of the information gathered during recognition.

It is easy to see that a system can be employed to lit all the graphic objects in a drawing (the list can be organized by the users at their will); to compute areas and perimeter, etc. The information thus gathered may be for instance, to fiscal and cadastral ends.

Figure 2 shows a typical work session of object recognition.

Another application of automatic recognition of graphisms concerns automatic determination of qualitative parameters used on technical documentation, in particular, on distributive features.

To this end, it is first necessary to integrate the system´s network graphisms with those of furnishings, fittings and pertinent spaces.

Having a knowledge of furnishings' and fittings' graphisms is very helpful for, among other things, room recognition, as it significantly cuts computing time. Some writings [5] adopt statistical techniques to the classification of rooms, according to typological features (e.g. 'kitchen'). This makes a set of room triggers possible (even a degree of confidence) which can lead and simplify room recognition processes. Once a room has been recognized, the system can easily recognize some morphological aspects of the same room. More particularly it can:

i) recognize possible paths after considering physical and functional spaces occupied by furnishings into;

ii) spot furnishings interference and determine the degree of functionality of use;

iii) analyse visibility features, e.g. if the day area can be screened from the entrance.

5. *Conclusions and _future developments*

The present paper put forward a method for inputting graphic data into a computer system that employs Artificial Intelligence techniques. This method is characterized by its ability to recognize the meaning of both base graphisms and derived complex ones. Obviously, such ability is not open to any drawing; in fact, it is applicable only to drawings with certain standard features that allow the domain to be managed in terms of knowledge. We have shown the possibility of implementing a system based on such principles that can work on operational drawings.

The future will see a better definition of structural models and an extension of the domain of knowledge bases. The method's extension to three-dimension representation is also foreseen, which will imply the use of stereo vision. Future systems should be able to store volume data by means, for instance, of an octree code.

The guided interpretation of perspective and axonometric two-dimension drawings is currently under development. In the near future, the system should be able to recognize volumes, corresponding to given structural models, on the basis of hypotheses and goals set by the system. Since the system is guided and the knowledge base is quite narrow, our work should be perfected in a comparatively short time. The prototype of room should be the tool, making guided instances of objects possible; this will allow us to focus on suitable areas of the scene from where recognition can begin.

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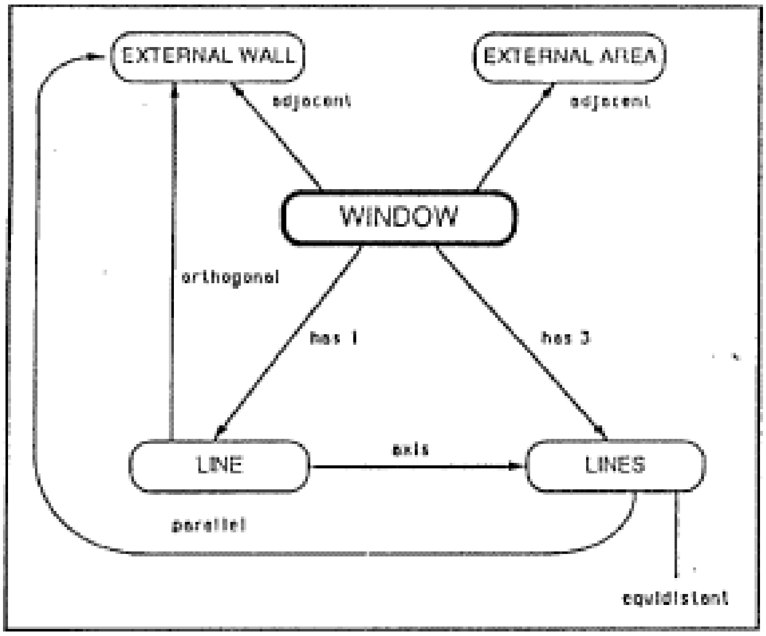
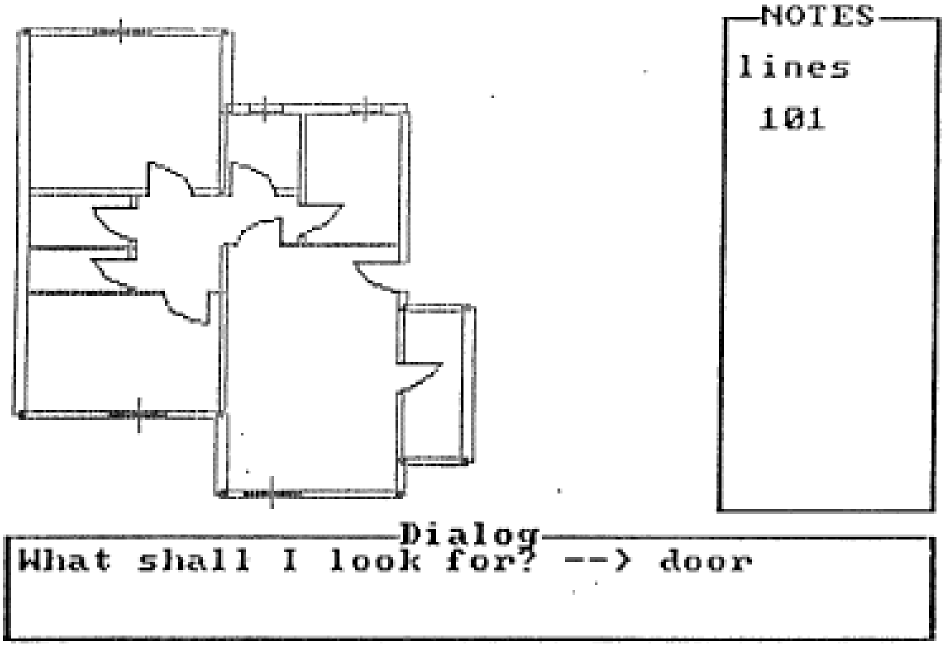


Figure 1: Semantic network for the graphic object 'window'



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Dialog
What shall I look for? --> door
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Figure 2: A typical interactive recognition session