A "HAHD-ETE" ROBOT-SIMULATING SYSTEM

G. Gimelfarb, E. Kushner, V. Rybak
Institute of Cybernetics
Ukrainian Academy of Sciences
252127 Kiev USSR

Abstract

A "hand-eye" system for simulating robots on BESM-6 computer is described. Peculiarities of the special operating system, problem-oriented software and hardware are discussed.

Elaborating of an "intelligent" robot is a versatile problem associated with the solution of various problems on information science, computing techniques, mechanics etc. The integrated investigation requires a special experimental system for physical and digital simulation of robotfunctioning.

In physical simulation real sensors and effectors of robot are used the control and "intellectual" parts of robot being simulated by the computer. The alternative kind of simulating system consists in digital simulation both the robot elements and the surroundings. But in the latter case the detailed and reliable modelling of surroundings is very labour-consuming and found to be highly far from reality.

Our physical simulating system is developing as a "hand-eye" project. The hardware includes the computers BESM-6 and M-6000, the TV input-output device PTU-102, a special adapter with a storage tube, AD/DA converters, and a multipoint manipulator with six degrees of freedom. The manipulator was designed by Dr.A.Ivkin. The hardware includes also some additional apparata increasing the capacities of the BESM-6 computer for non-standard peripheral devices to be connected to.

The general-purpose software contains a special operating system having been worked out to provide the next facilities:

1) hierarchical structure of the problem-oriented software with mutually controlled communication links between different levels of hierarchy and within one level;

2) real-time and time-sharing mode offunctioning;

3) direct man-machine communication with the simulating system;

4) special memory organization for processing of large volumes of information;

5) alternability and expandibility of the simulating system according to the tasks to be solved.

The operating system includes the available BESM-6 operating system DD-73 plus a specially developed block - ver". The subdriver allows to form a complicated routine as a complex of relatively independent branches (up to 48), ensures multiprogramming mode of executing the branches and provides the time-sharing mode of information transfer to and from the various non-standard peripherals. By means of the subdriver a programmer may synchronize the branches, change their priorities, exclude a branch when solving a definite task, etc. If no branch is ready to work the subdriver gives the processor up to the other Job.

The subdriver is composed of highly autonomous blocks. It makes it ready to further expanding. The quasi-parallel and hierarchical mode of branch functioning are organized by means of a special additional set of control statements for interrupting the processor.

The subdriver together with the special auxiliary register of interruptions [1] allows to connect BESM-6 computer up to 48 non-standard peripherals. The maximum processing time for the one peripheral interruption being only 80 sec One can consider the operating system to be a real-time system where input data call the corresponding branch [2]

Branches use a common memory that provides interchange of information. To overcome the difficulties involved with less then 32K BESM-6 core memory available a dynamic loading of the branches from magnetic drum is now under development.

It worth be noted that the operating system (OS) of the "Ryad" system gives many of facilities that the subdriver provides for BESM-6 computer. This ensures a natural transference of this simulating system from HESM-6 to the "Ryad" computer.

The problem-oriented software contains various subroutines for input-output, preprocessing, analysing the visual and distance information and for controlling the multi-joint manipulator. The problem of automatic description of 5-dimensional scene to draw up the purposeful behaviour of the robot is of the greatest interest for us. The scene description includes recognizing objects and measuring their location and sizes. In our opinion there is a significant distinction between the problem of J-dimensional scene description by the robot and the problem of recognizing J-dimensional objects using their 2-dimenbiouaI images (e.g. TV images). The distinction is caused both by the character of the information about the scene and by specific faculties of the robot.

The initial information for scene description includes besides the brightness of image points also the values of spatial coordinates corresponding to some elements of objects. Specific abilities of the robot come from its capacity for active interaction with the surroundings. Being active system the robot can change the location and direction of the image sensor and light sources, remove objects and obstacles overlapping another objects with the help of its manipulator, measure the spatial coordinates of the different elements of the object, set parameters of sensors in accordance to results obtained during processing of the previously received information, etc

It is expedient to regard the sensory system of the robot as a specialized system oriented on a specific class of objects. Knowledge of this class of objects and the robot abilities for the active interaction with surroundings symplifies the scene description problem and gives ground to contend that this problem is solvable in spite of comparatively low success in recognition of 2-dimensional arbitrary patterns.

One can note three basic features of the scene description process:

1) a complex usage of the information obtained from the different sensors (image, space coordinates);
2) a hierarchical organization of the image processing with feed-back links between different levels;
3) a possibility to separate the whole scene description process into autonomous parts.

These parts are the following: a static scene description, a dynamic correction of the static scene description, a detection of dangerous situations. The first task in the most complicated one but after obtaining its solution the second and third tasks can be achieved in a real-time mode.

The multichannel sensory system of the robot permits to use simultaneously the information obtained from the different channels; in such a way a reliable scene description would be achieved in acceptable time and expenditures of computer resources. For the present it is difficult to point out the final criterion of using the each available channel. But temporary unability in choosing the optimal criterion should not be a stumbling-stone for the research in multi-channel sensory systems. The point is that an isolated utilization of channels often prevents to describe the scene observed correctly.

TV image is the most informative channel but one can easily list examples of uncorrect scene description based on TV picture only. For instance, if small blocks are drawn on the visible sides of real block (see Fig-1) the most part of known algorithms based on the edge extraction will describe 4 blocks instead of the real one. The description of the latter will be found with the least confidence. The similar situation arises when sides of 3-dimensional object are pictured by a twisting lines forming camouflage. In such a case the edge detection is useless.

The traditional methods that used only 2-dimensional pictures to make the scene description meet considerable difficulties even in more idealized cases when the scene containes only polyhedrons with single-coloured sides. To illustrate this words one can use the results of picture processing with the method being proposed by M. Suwa, S. Tsuji from ETL (Japan; [3] These results presented on Fig.2 demonstrate clearly all the complications in choosing valid threcholds for contour extraction (Fig.2c), line thinning (Fig.2d) and tracing (Fig.2e), joining the neigbour line segments (Fig.2f), reconstruction the vertices and edges of sides (Fig.2g), etc. The subroutines implemented this method were worked up by us and included in our problem oriented software to be used for comparative investigation of the scene description algorithms.

From our viewpoint it is impossible to make scene description out from real noisy TV pictures without additional information about spatial coordinates of certain elements of 3-dimensional objects. One approach to receive this information leads to develop automatic methods of stereovision. We have investigated several problems in stereovision system hardware and software, some of the results being represented below.

The hardware of binocular stereovision system has no specific features to be marked out. The calculation links the values of system parameters with the culminating accuracy in measuring spatial coordinates using a digitized stereo pair of TV images. The basic characteristics of the stereosystem were chosen in accordance with the parameters of manipulator and manipulator jaw and are the following:

- interval of distance measuring: 1 to 2,5m;
- the least distance between optical axes of the stereochannels: 300mm;
- TV-picture frame: 24 x 30mm^2;
- the least overlapping between right and left frames of the stereopair: 15mm;
- resolution of TV-picture digitizer:

20 points per mm;

- the least frontal-size of the object observed: 50 x 50mm^2;
- the least number of resolved points for an object of the least size: 20 x 20;
- light diffusion circle : 0,05mm.

In this particular case one can show that an absolute accuracy of spatial coordinate measuring needed to distinguish a decahedron from a octahedron and from a cylinder ought to be less then 1mm (i.e. a relative accuracy being less than 0,1%). The attainable relative accuracy of the system described is not less than 0,3%. Thus to achieve the accuracy required the stereovision system must be furnished with the moveable image sensors to approach the objects observed and have changeable distance between the optical axes of channels. Using objectives of variable focus length only cannot solve the problem. The travelling image sensors can overcome difficulties associated with a high sensitivity of the binocular system to turning angle of the polihedron observed relative to the optical axes of the system (due to the different perception of parts of the objects by the left and the right channel of the system).

The optical and geometrical design of the system takes into account the apparatus errors, besides it there are abilities of the algorithms for automatic recognition of corresponding points on the stereo images that influence the accuracy of spatial measurements. The principal field of application of these algorithms is the photogrammetric automatization (the problem of automatic reconstruction of the Earth relief). For the last problem we have proposed a few algorithms based on the assumptions about connection between the neighbour elements of the relief and proportional changes of the brightness in the corresponding points at the left and the right images of stereo pair. Under these assumptions and some hypothesis about the characteristics of noise the problem can be solved by dynamic programming [4] .

The robot stereovision has its own peculiarities: the distance being measured is short enough to break the mutual connection between the neighbour points of "relief"; the noise level is too high (due to noise of optical channels and image sensors). Thus an adaptation of the methods proposed to the robot stereovision becomes possible only on condition that one takes into consideration the content of the images compared. It means that the methods of fitting the corresponding points of stereo images should be combined with the techniques for the recognition of scene objects elements. Such combination of the different methods should simplify identifying the corresponding points. One possible approach to such simplification consists in generating an artificial "texture" and illuminating the surface of objects being chosen during the recognition with the help of this "texture".

The calculations corroborates a practicability of this approach. For the present special subroutines are developed for computer investigation of the peculiarities of object surface illumination under various locations of objects and light sources and different reflectance of the surfaces. The subroutines generates 2-dimensional images of the prescribed 3-dimensional scene for the various location and illumination conditions. A few examples of the such images are presented on Fig.3. The subroutines described are included in the problem-oriented software of the system.

The problem-oriented software containes also a Guzman-like algorithm [5] for describing scenery composed of the ideal objects. An example of scene and result of the decomposition this scene obtained are shown on Fig.4.

An integrated algorithm for combined processing of the information from the different sensory channels of the robot is now under development.

We are grateful to Dr. I. Basilevich for his principal contribution to subdriver working out, and to our collaborators A. Boldyrev, V. Gaiduk, G. Golovin, V. Krot, Y. Lanbin for their participation in the hardware and software elaboration.

References

1. Ю.М.Коростиль,Э.Ф.Кушнер,В.И.Рыбак, Ю.В.Старченко,В.П.Шишкалов. Аппаратурная реализация подключения к ЭВМ БЭСМ-6 группы нестандартных внешних устройств. УСиМ, №5, 1973.
2. В.М.Глушков. Введение в АСУ. изд-во "Техника", Киев, 1974.
3. M. Suwa, S. Tsuji. A method for feature extraction and recognition of solids. Bulletin of the Electrotechnical Laboratory. Vol.35, No.3, 1971.
4. Г.Л.Гимельфарб,В.Б.Марченко,В.И.Рыбак. Алгоритм автоматического отождествления идентичных участков на снимках стереопары. Кибернетика, №2, 1972
5. A. Guzman. Decomposition of a visual scene into three-dimensional bodies. Proc. Fall Joint Computer Conference, Washington, DC: Thomson Book Company, 1968.

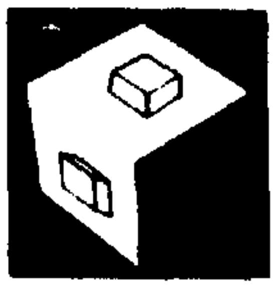
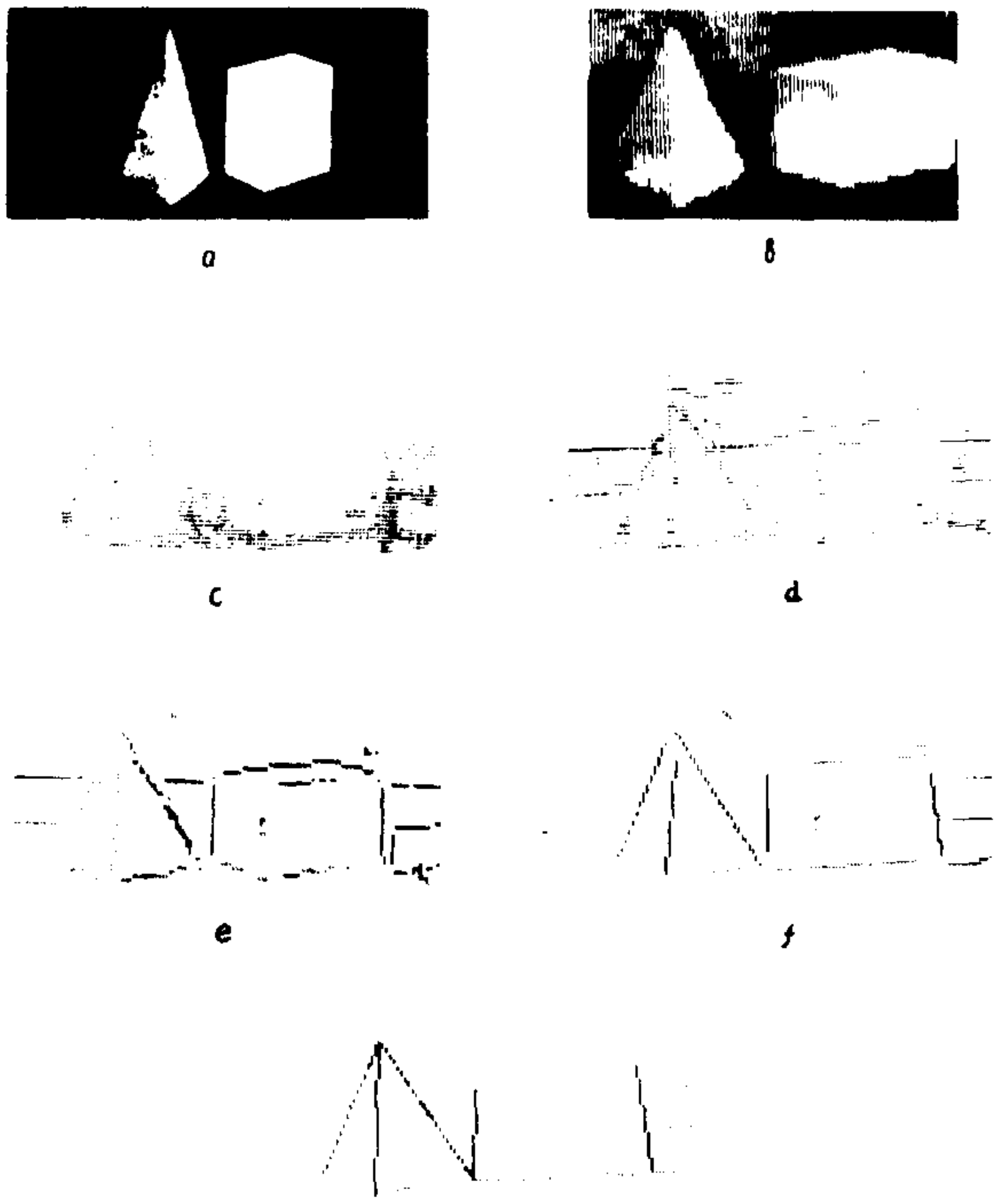


Fig 1



a б

c d

e f

g

Fig.2

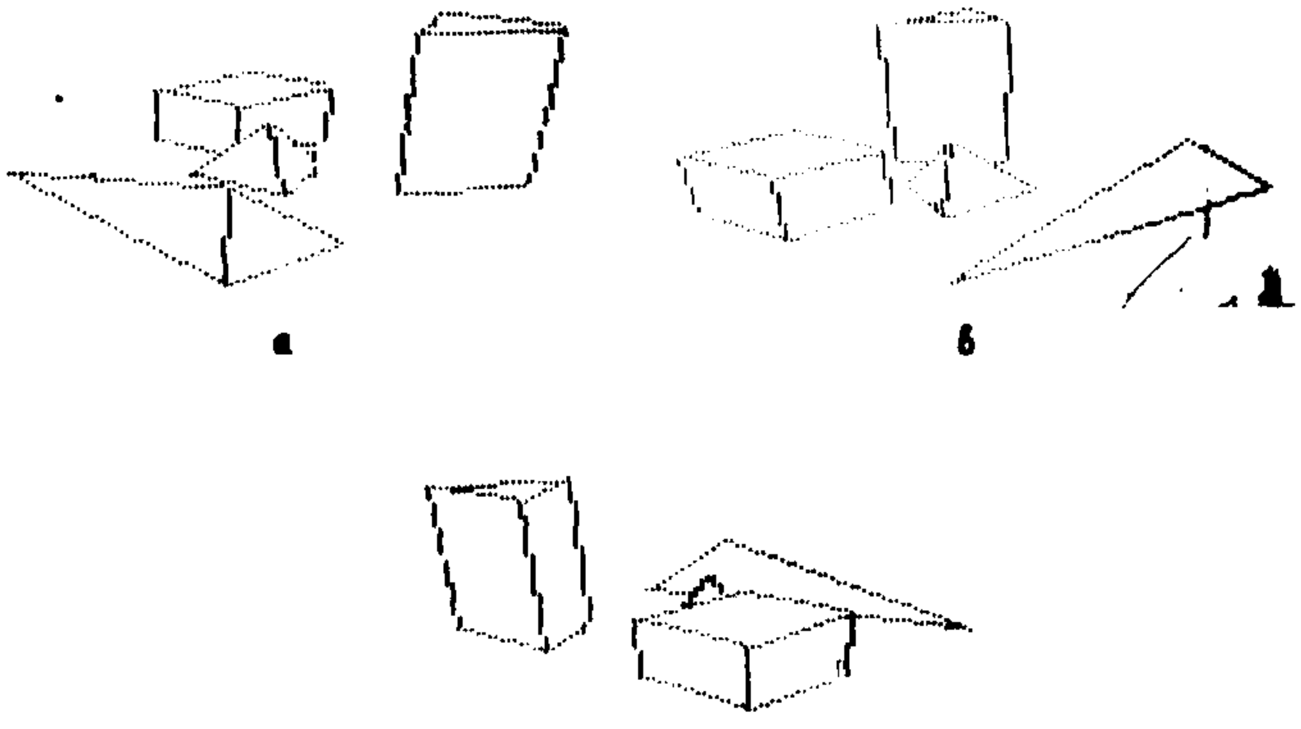


Fig.3

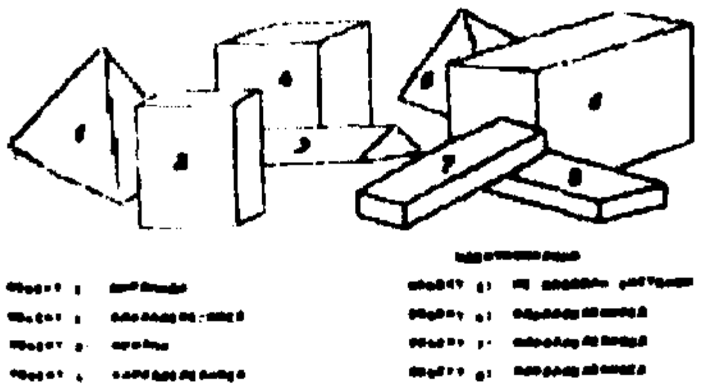


Fig 4