Photomatrix computer interface : on line registration of optical configurations for visual pattern recognition

PHOTOMATRIX COMPUTER INTERFACE

on line registration of optical configurations for visual pattern recognition

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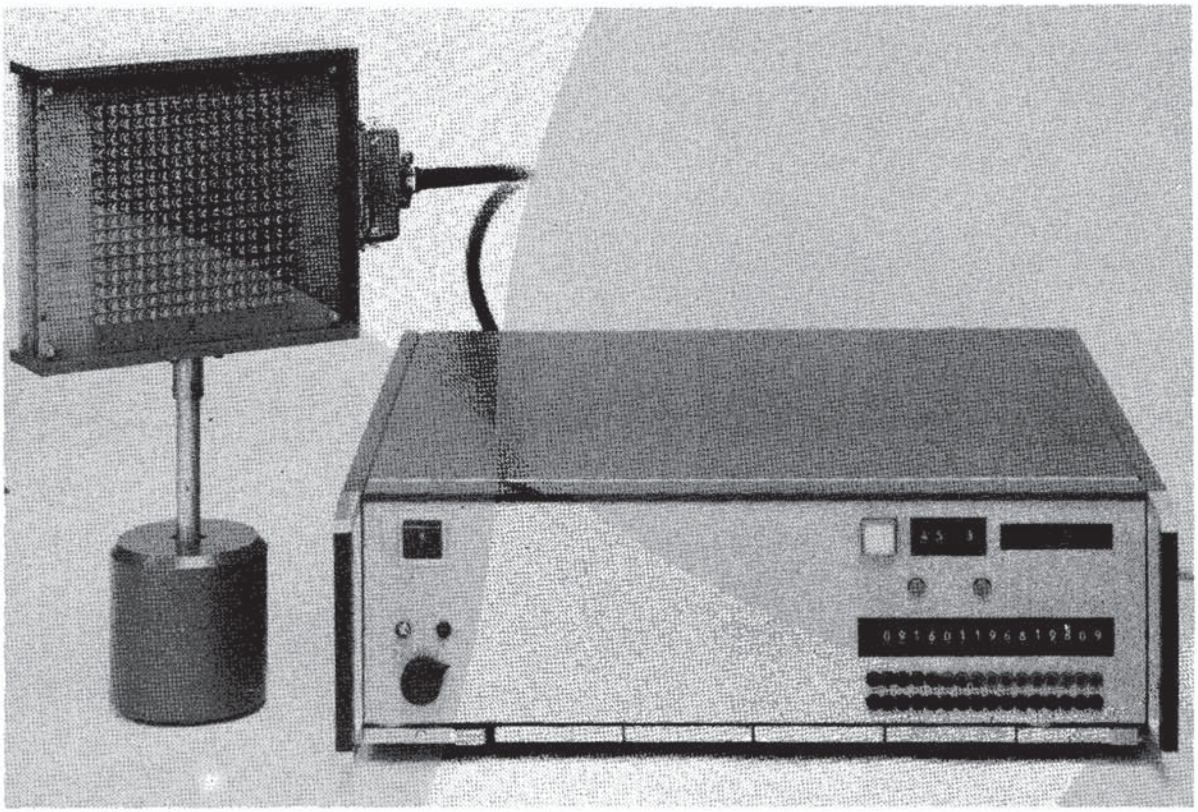

introduction

Research on human pattern recognition has led to several hypotheses on the analyzing properties of the visual system. An important theory has been put forward by Hubel and Wiesel (e.g.1965) based on physiological experiments. They found cells in the animal visual cortex that were sensitive to the orientation of a line or edge projected on a part of the retina connected to such a cell. Starting from further research, they supposed these direction-detecting cells to be a part of a hierarchically analyzing mechanism. Bouma and Andriessen (1968, 1970) of our Institute supposed from results gained with psycho-physical experiments on human slant perception that, in case of simultaneous excitation of many such cells, the cell with maximum excitation decides the perceived orientation of the stimulus. Research on human pattern recognition is, however, still in its initial phase. In this situation the need was felt for a model making possible simulation of such hypothetical analyzing functions of the visual system. A few years ago Cosijn and Hoeks (1970) built a model in hardware, consisting of 16 light sensitive cells (LDR's) together with some electronics circuits.

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Their apparatus essentially 'recognized' one out of 4 orientations of the stimuli projected in the receptive field (horizontal, vertical, and + or -45 degrees), independent of stimulus position in this field

In carrying on this kind of work, a choice had to be made between hardware and software models. Pure hardware models necessitate fairly complicated electronic circuits, the sheer number of which leads to voluminous constructions. These are not flexible in the sense that modifications are difficult to realize.

On the other hand a purely software model is not attractive because of the problems encountered if complex stimulus patterns have to be programmed. So it was decided to build a hardware receptive field consisting of many light sensitive cells, connected on-line to a computer through a special interface. The hardware part of the system is purely passive, it only converts light into voltages compatible with the computer system.

Analysis of the voltage patterns resulting from a certain stimulus configuration projected on the receptive field will be performed by appropriate software programs. In this way it is possible to experiment in an easy and tangible way with many different, simple or complex, stimulus configurations; in addition, the model itself, now being a software computer program, is easy to modify.

The matrix input to a computer has, of course, a much wider application than just for the detection of a slant.

practical design

The P9202 computer in use at our laboratory is provided with a modular Input-Output System (MIOS), described in the previous issue (Muller, 1971).

It contains 16 analogue and digital input and output modules.

For our purpose only the 16 analogue inputs (AISM) and the 16 digital outputs (DOSM) are of interest.

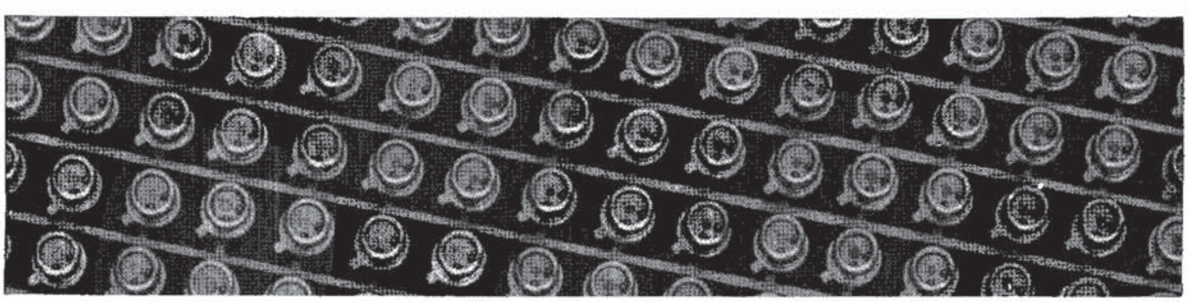
Because of the number of inputs available, the receptive field is built as a 16x16 matrix, consisting of 256 silicon photo-transistors (BPX29).

Each column of the matrix is connected - via the interface amplifiers - to one of the AISM inputs. By switching on row after row of the matrix by means of the digital output information programmed, all matrix elements are successively connected to the AISM for reading in the corresponding voltages of the column amplifiers.

So the photomatrix and the interface have two general functions:

- Translation of the luminances on each receptor cell into appropriate voltage levels for the 16 analogue input channels of the MIOS.
- Translation of the 16-bit digital output information of the MIOS into operational functions, e.g. switching the rows of the matrix, setting the amplification of the column amplifiers, displaying the detected presence or absence of certain configuration properties, etc.

Fig. 1 shows the set-up of the system in general.



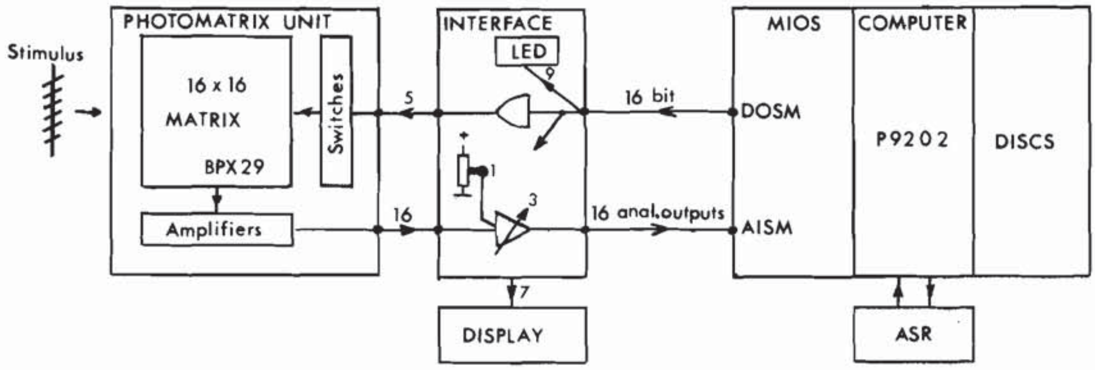


Fig. 1 General set-up of the system.

For practical reasons a part of the interface is incorporated close to the photomatrix. The photomatrix unit actually consists of 3 printed circuit boards, one containing the matrix on the front of the unit. The second contains 16 electronic switches (FET's) together with a decoder circuit, and the third 16 column preamplifiers. Fig. 2 shows the lay-out.
During the investigations we received information on commercially available integrated photomatrices from Reticon Inc. For our purpose however, these circuits are unnecessarily small, and, moreover rather expensive.

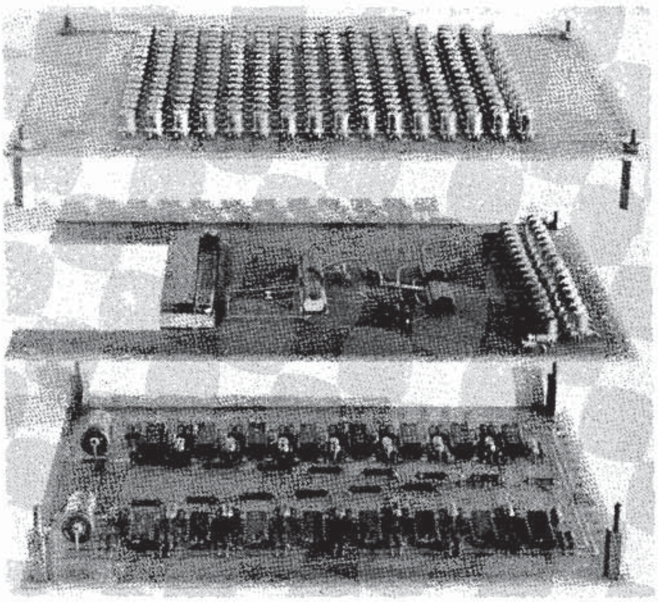


Fig. 2 Close-up of the photomatrix and lay-out of the matrix unit.

For the conversion of luminance into voltage we used the well-known linear photometer circuit shown in Fig. 3a. Here, a silicon photo-diode is connected to the feedback input of a simple operational amplifier. The diode current produces an output voltage across the feedback resistor, proportional to the light intensity on the diode. Because the dc-voltage across the diode is approximately zero, influence of temperature and leakage is negligible. Such a simple circuit is linear over about 3 decades of luminous intensity.
In one column of the 16x16 matrix, 16 photo-diodes can be connected to the same preamplifier, but each diode has to be provided with its own on-off switch, making for an unacceptable number of 256 switches. This can be avoided when a normal diode is placed in series with each photo-diode (Fig. 3b). The diode prevents leakage currents to and from other photo-diodes in the same row, resulting in only one switch per row.

Such a series diode is also formed by the base-emitter junction of a photo-transistor, which is in this case a normal npn-transistor mounted together with a photodiode, connected between collector and base (Fig. 3b).

The collector of the photo-transistor needs a few volts for suitable operation. The photometer circuit has, therefore, to be changed in the way shown in Fig. 3c. The additional resistors in the circuit make the collector supply possible without causing a dc-shift of the output voltage.
Owing to the current amplification of the transistor the circuit is much more sensitive with respect to the photo-diode circuit, but also more sensitive to changes of temperature. This, however, causes no trouble in practice.
Fig. 3d shows the set-up of a simple 2x2 matrix as an example. The actual 16x16 matrix is built up according to this principle, providing 16 preamplifiers and 16 switches. All photo-transistors have the same collector voltage of about 3 volts. Spread of transistor data (although selectioned) causes different sensitivity and gradient between the receptors for which a correction is made in the computer program.
The FET switches are operated by appropriate gate voltages to provide a pure on-off function. These voltages are delivered by a decoder receiving 4 bits from the digital output of the MIOS. One extra bit is used to switch off all the rows as well as the collector voltage of the photo-transistors, thus enabling the offset voltages at the amplifier outputs to be measured for correction purposes.

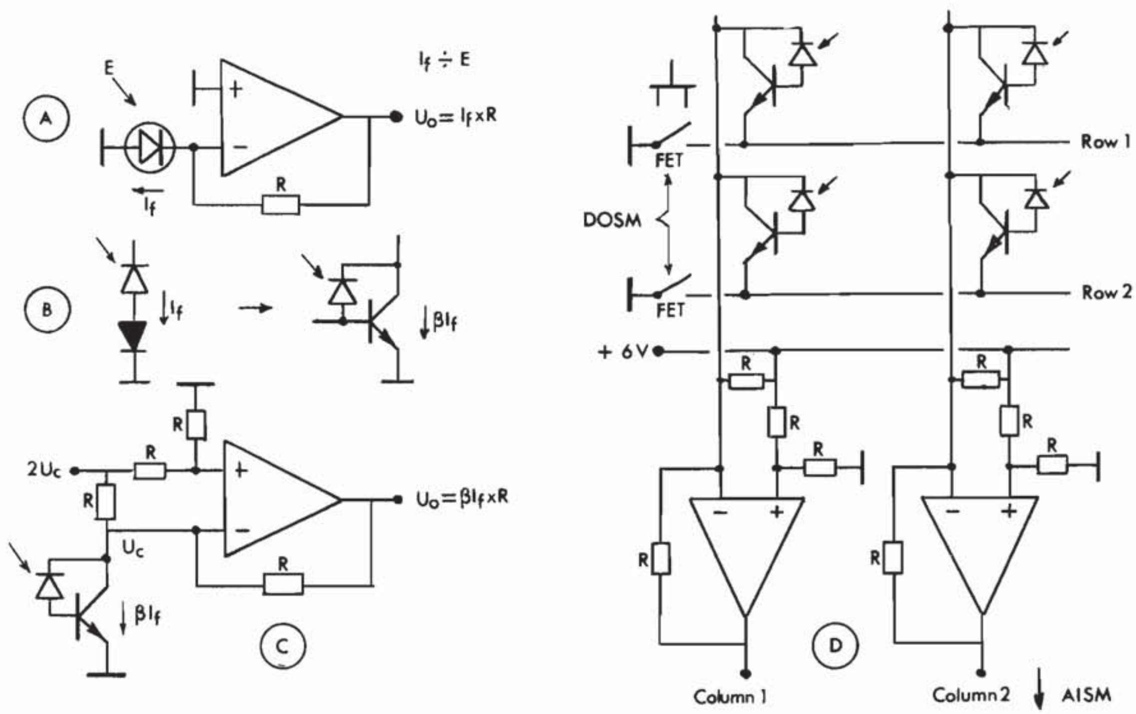


Fig. 3a Basic photometer circuit with photo-diode.
3b Photo-diode with series diode, photo-transistor.
3c Photometer circuit adapted for application of a photo transistor.
3d Simple 2x2 matrix

All signals to and from the computer are handled by the interface. This unit contains:
- A regulated power supply for all electronic circuits, including the photomatrix.

- 16 Line amplifiers, the amplification of which can be varied in six steps, identical for all amplifiers, by manual control or automatically by means of 3 bits from the digital information from MIOS. This makes possible the use of the photomatrix at very different light intensities.
Automatic adjustment of the amplification is realized by means of a subroutine in the program. The process starts from the highest amplification. If, during reading the matrix, overloading is detected on one or more outputs, the amplification is automatically adjusted to a lower value, and this continues till the overloading has disappeared.
- A bank of preset thumbwheel switches providing a range of constant voltages via the amplifier outputs. These voltages are used in the program as operational constants or for interruptions or alterations in a running program. Reading of the constants is performed during the time the photomatrix is switched off, and, during reading the matrix these voltages are automatically set to zero, thus not affecting the matrix output levels.
- Digital circuits receiving and translating the digital information programmed.
The 16 bits available are used in the following way:
Bit Nos. 1-4 : switching on and of the rows of the matrix successively .
Bit No. 5 : switching off the matrix for reading offset voltages.
Bit No. 6 : switching off the matrix for reading of preset constants.
Bit Nos. 7-9 : setting the amplification level.
Bit Nos.10-16: not in use yet, reserved for driving a hardware display.
The operational bits 1-9 can be inspected by an octal LED-display, mounted on the front panel of the interface (See photograph at top).
To correct for the individual differences of the matrix cells a testprogram is made providing a correction matrix which is always available by means of the computer disc memory. Such a matrix is derived by computing the least-squares line through a number of measured points on the characteristic of each matrix cell, corresponding to different levels of illuminance, e.g. 10-100-1000 lux. The individual line of each cell is then translated into a standardized line by computing the correction factors for slope and zero-level. Thus, a uniform illumination of the photo-matrix results in 256 computed numbers related to the individual output voltages of the matrix cells spreading only a few per cent.
Testing and trial experiments can also be done off-line, to reduce computer time.

acknowledgement

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summary

For the simulation of recognition processes of the human visual system a receptor field has been developed, the output of which can be analyzed on line by a computer. The receptor field consists of a 16x16 matrix of phototransistors with switching and amplifying electronics incorporated. It is connected to the analogue and digital I/O system of a computer, by means of an interface.
The interface decodes the instructions of the computer program and controls the operations of the receptor field. The analysis of optical configurations presented to the receptor field may be performed by appropriate programming techniques.

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