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INTEGRATED MULTISENSOR RANGE FINDERS[1]

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Abstract

Initially, the system presented was designed to increase the autonomy of robots working in difficult surroundings congested with obstacles. The system can have applications other than in robotics. The system combines: an ultrasonic telemeter for distance measurement, an optical device based on photovoltaic cells, allowing the classification of tints of plane obstacles in a group of colours previously defined by the user, and a range finding system composed of a monochromatic laser associated with a solid state detector used for the localisation of the vertical edges of polyhedral obstacles. Each of these base sensors delivers an elementary information (distance, tint, coordinates of vertical edges) which is determined by processing the echo from the obstacle of a previously transmitted signal (active detection).

Keywords: 3D perception, colour classification, multisensors, range finders, ultrasound, laser.

Presentation of the Problem

The determination of 3D measures and object surface profiles is a highly interesting subject for a wide range of applications. The used single sensor cannot provide all the above mentioned data. Physical constraints of the transducers employed clearly show that each one is only adapted to a specific situation of localisation or identification of objects. In one case this sensor is very well performing, in other cases the performance is very poor. This shortcoming can be overcome by increasing the complexity of the treatments of algorithms.

Our approach is different. We chose a maximum simplicity upon each sensor (software and hardware) and mixed the elementary information. The final range measure is better than each elementary measure. Each sensor thus becomes a module of an integrated multisensor range finding turntable.

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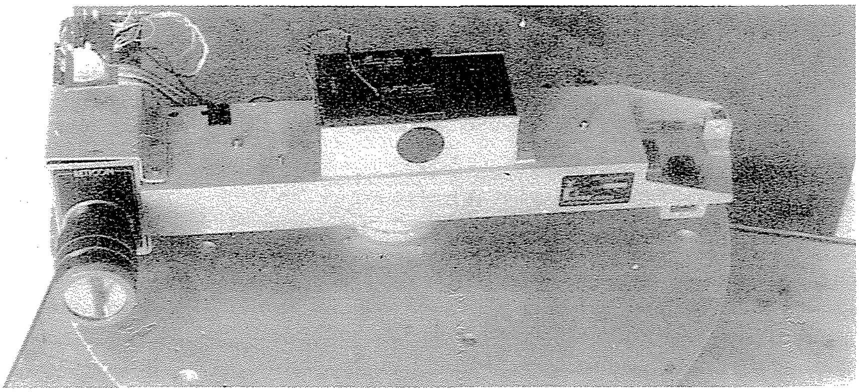

Fig. 1. Front view of the system

General Description

The system is made for 360° panoramic vision. It is composed of a mixed optical and ultrasonic range finder 'OPSONAIR'. The ultrasonic part is an active range finder. Pulses are emitted, echoes received, and the time interval separating them is measured providing the distance measurement between sensor and object (MONCHAUD and PRAT, 1981a, 1981b).

The optical part of the sensor is composed of photovoltaic cells with a sensitivity to the colour spectrum comparable to that of the human eye (MONCHAUD and PRAT, 1982). We obtain an electrical signal which depends on the surface tint of the object which reflects the ambient light. With stamping, we can classify these surfaces in a known list.

The OPSONAIR range finder is in the middle of the turntable. It has a laser triangulation based range finder which is an active sensor. The source is made of a He – Ne laser with a wavelength of 632.8 nm and an emission power of 10 mW. The reflected beam is received by one linear array Reticon camera formed of 1024 photodiodes. The laser is fixed but scanning of 30° is allowed by the rotation of a small galvanometer mirror. All these devices are put on a platform which can rotate around a vertical axis by an angle varying from 0 degree to 360 degrees. So we can direct the spot under microcomputer control with rough and fine adjustments. After stamping thus we can hope to achieve high accuracy in the localisation of the characteristic details of the object. The turning mirror and the solid state camera are on the extreme points of the rotating arm (*Fig. 2*).

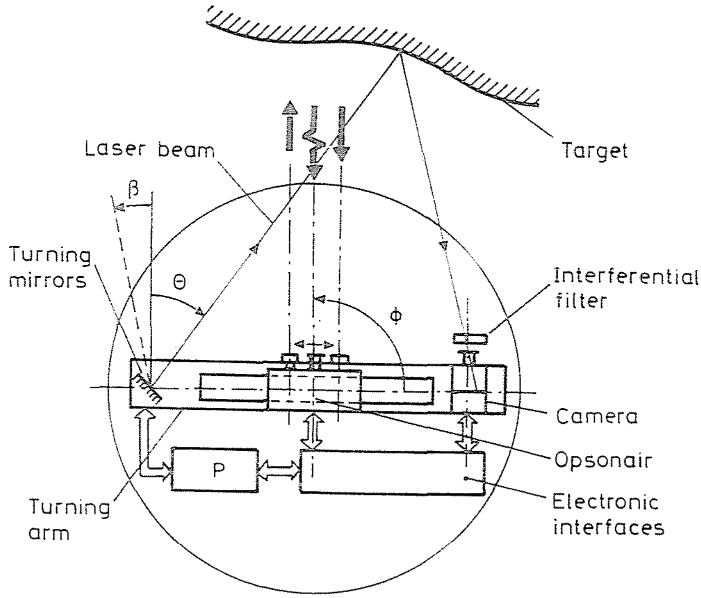

Fig. 2. General description of the system

Shortcomings of Each Individual Part of the Integrated Multisensor Range Finding Turntable

To understand the environment, the multisensor range finder must scan it, either by a rotational movement of its sensor organs or by moving itself in the environment.

Shortcomings of the Ultrasonic Part

With a transducer excitation frequency of 40 kHz, it can be seen that the ultrasonic sensor has a solid detection angle of approximately $\pi/6$ rad. It must be remembered that the target material and the angle between the sensor plane and the object plane modifies the measurement. All the experiments show that the sonair has many blind areas. The measurement is as simple as possible. The object detection is very fast but angular detection is effected (cylindrical objects or objects with right angles) (*Fig. 3*).

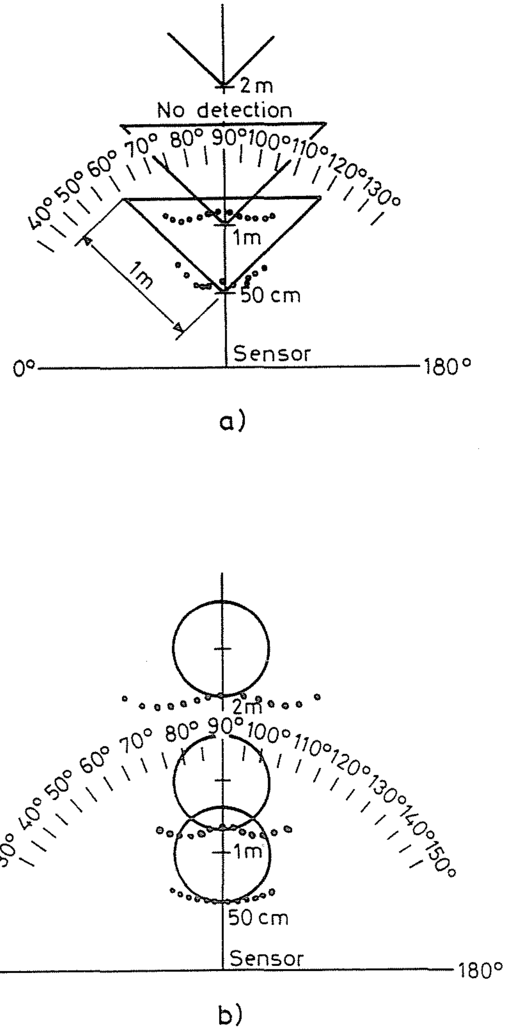

Fig. 3. Rotational scanning of a cornered object *a)* and a cylindrical object *b)* (MONCHAUD and PRAT, 1982b).

Shortcomings of the Optical Part (Tint Classification)

The software procedure allows, at present, a classification of the tints among eight different groups according to eight reference colours. The present system, despite its increased performance, still has certain shortcomings and implementation difficulties, first because of the tedious learning phase in choosing the reference colours and secondly in making the colour sensing self-adaptive to the large variations in illumination which may occur at different places. With a classical optical system, the vision angle is critical.

Shortcomings of the Laser Triangulation Based Range Finder

The laser beam is very narrow. Analysis of such range finders reveals a series of factors which limit their accuracy and performance:

— geometric factors depending on the mechanical arrangement,
— optical limitations,
— laser spot finding.

The analysis of our real case (the triangulation turntable) indicates that internal geometric parameters such as pixel and focal length do not affect the measurement accuracy of the system. But external geometric factors such as camera orientation and laser spot source position could produce significant relative errors. Satisfactory system accuracy depends on the precision of camera orientation and laser source position calibration. Other factors could produce errors, for example the objective focal lens (vision field of the camera), the localisation of the reflected spot on the receiver, the measure of the deviation angle of the laser beam, etc. We can minimize these errors but cannot suppress them. Besides the geometrical equations calculations require a lot of time and call for larger computers (minicomputers) which means slower measurements.

Coupling Different Information on a Multisensor System

Acoustic and Optical Telemetry

When the sensor rotates, it can locate the direction of the incident illumination. This allows positioning of the sensor and the classification of tints may then also be carried out in reflected light. A coupled interpretation of the distance and the tint allows zones crowded with objects and empty areas to be separated rapidly. Ultrasonic distance measurements calibrate the tint classification. Conversely, the tint recognition reduces the blind zones of the ultrasonic detector.

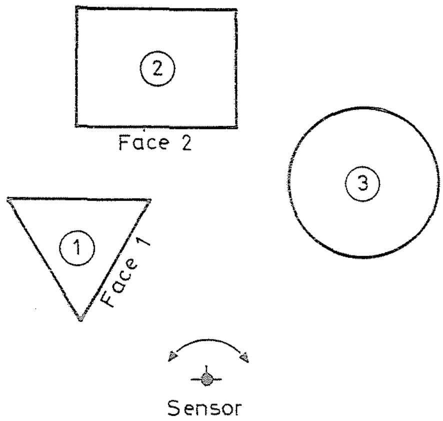

Fig. 4. Analysis by a rotational movement of the sensor

Acoustic Telemetry, Tint Classification and Laser Range Finder Measurements

Fig. 4 shows an example of scene analysis by a rotatory motion. First the ultrasonic range finder distinguishes the object zones and the empty areas. Secondly the turntable aims at each object zone. If the distance and direction of incident illumination are correct, we try to classify the tint of the face seen (for example face 1 and face 2). Object 3 also gives a tint classification. If the tint classification of the face 1 and face 2 shows that object 1 and object 2 are two different polyhedral objects, we give the precision shape of each one with the help of the triangulation laser range finder (particularly the position of the corners).

Industrial Process Control and Robotics

In this Section an example of scientific cooperation between French and Hungarian universities will be presented.

The French-Hungarian joint commission for Scientific and Technical Cooperation has selected for the years 1987–1990 the research theme: Industrial process control and robotics. The two cooperating bodies, on the one hand the Industrial Process Control Department of the Technical University of Budapest (Hungary), on the other hand the Electrical Engineering Department of the National Institute of Applied Sciences of Rennes

(France) have extensive experience in these activities which, in addition, are complementary.

In Hungary a group of researchers, led by Mr. József MEGYERI has built distributed networks for gas, water and heat distribution in Hungarian cities. The knowledge and mastership of the programming of parallel tasks for one or several central units of mini and microcomputers has been made possible by the use of specialised languages for the structured programming (MODULA II or PORTAL for example). In the case of industrial processes we have also used these techniques for programming in automation. The introduction of robots integrated into the chain of automata is a normal step of development. The group of Hungarian researchers is, in particular, responsible for preparing the educational materials and didactic software used in the training of new employees.

In France, the researchers of the Laboratory of Applications of Advanced Electronic Techniques (L.A.T.E.A.) design the third generation robots (sensors and effectors). The robots are mobile. Their development entails, at the control part level, the development of a multitask structure. At present the proposed solutions retain the principle of a hierarchical structure. Each central unit is designed to do a special task. This results in slowing down the operation and sometimes blocking it, when simultaneous actions are necessary to reach the goal. The use of parallelism is the only solution for this type of problem. The originality of this cooperation project lies in this mutual exchange of know-how to successfully approach the concept of intelligent robots, where the control part uses parallel programming techniques to increase its efficiency and to simplify the processing structure with optimum use of the capacities of the central units and memories.

This cooperation program will take place in three steps:

— In the first step we will make, in common, a selection of programming techniques and a selection of robots (or parts of robots) on which to test them. The concept and the construction of the project:
  - the real reflection of the collaboration research groups who collaborate
  - and suitable for use in the two countries,

  suppose that the cooperators go beyond the simple superficial view of the partner and integrate perfectly its specific situation.

— Thanks to this, the second step should allow the two groups to really work in parallel on the programming of the selected robot control part, to compare performances and to estimate advantages and costs.

— In the third step the result of the work will be evaluated and further plans will be proposed.

Currently we are at the second step, the first results obtained allow some examples of using MODULA II on an IBM compatible PC, to illustrate the conflicts which can arise in the execution of parallel tasks. A flexible structure to help diagnostics will be proposed. We used also TURBO-PASCAL to program the selected robot control parts.

Conclusions

With the introduction of the modular build-up of software and hardware which pilots a sensor, it is possible to build each sensor with a maximum reliability and also we can integrate them at a higher level in a multisensor assembly. The elementary sensor is a functional module of the whole system. The same thing was also observed with the human senses. The data are complementary and redundant. We could not exclude that a collection of objects can remain undetected, in real time, at medium distance by these range finding measurements. The example of our international scientific cooperation shows that robotics can be a cooperation theme and can draw lessons from the programming techniques developed for automation applications which lead to further progress.

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