Study of the Various Means of Perception in Mobile Robotics Applied to the Building Industry

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Abstract:

A project, named ROBAT, of design and realization of an autonomous mobile platform for the building industry, achieving tasks at the end of carcass work, is currently developed within the ECOLE DES MINES DE DOUAI. Generally, it is possible to give a model for third generation mobile robots, which is a chain with three links: Perception <-> Decision <-> Action. In order to analyze in detail this point, the first stage was the comparison of the various means of perception/localization existing on the market. The analysis of this classification results, allowed us to define some concepts of perception according to the problems of the environment and taking into account some variations of this one. Moreover, from this analysis, we released three systems, which can be classified in three different ranges, and have each one a single principal function.

1) INTRODUCTION

During the last ten years, mobile robotics has been characterized by a large phase of development. It was first reserved for research laboratories, but is now appearing in the industrial world. One can generally distinguish three steps corresponding to three generations of equipments.

The first generation was born fifteen years ago, in the market of handling machines. The purpose was then the automatic carrying of weights or tools, in order to increase productivity. The main equipments of this family are wire-guided carriages.

Mobile robots of the second generation have simple possibilities of perception and decision, and of course action possibilities. They are able to obtain some informations and modify their behavior according to variations of their environment. In this family, we find principally cleaning-robots.

From this date appears a new concept : " SERVICES". Indeed, the mobile robot is going to become a palliative for men in hostile places (battlefields, space, nuclear plants,...) and for repetitive and painful tasks (cleaning handling, building industry, agricultural works,...). For these new tasks, which are done in a complex environment, it is necessary that robots become able to apprehend autonomously the structure of the space around them.

All this leads presently the development of the third generation of mobile robots that can:

- perceive their *environment*,
- build a model of their *environment*,
- move intelligently in their *environment*,
- locate themselves in their *environment*,
- accost an object of their *environment*.

This means they are intelligent systems, we can describe with the chain:

PERCEPTION <-> DECISION <-> ACTION

Among the lots of tasks done by a mobile robot, the link "Perception" is certainly the most important, for it defines the limits of the "intelligence" we already spoke of. A further analysis of this aspect, allows us to detail the functions and methods with a tree as follows:

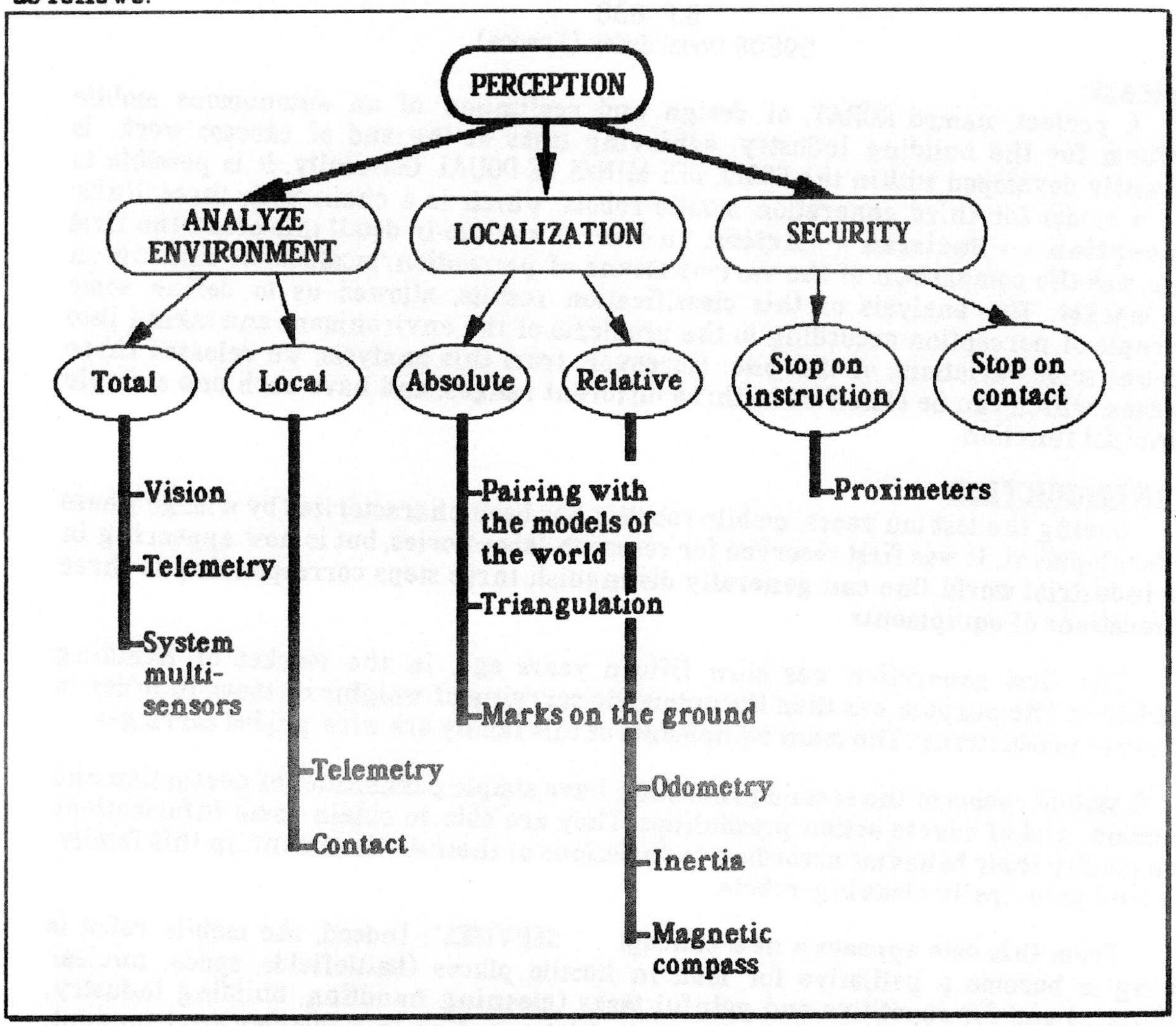

Fig1 : **Perception Tree**

The study we present in this paper concerns the analysis of the environment and the localization of a mobile robot. After presenting the project which generated this research (Chapter 2). We shall then detail the different physical principles allowing to perceive the environment (Chapter 3). Before concluding (Chapter 5), we explain our choices for this project (Chapter 4).

2) THE PROJECT "ROBAT"

This study concerning the industrial project "ROBAT" (ROBot mobile dans le BATiment) has been realized in the PRODUCTIQUE Department of the Research Center belonging to the "ECOLE DES MINES DE DOUAI".

It consists in studying and realizing a several-tasks mobile robot for horizontal works in the building industry. The main part is a small sized platform, able to go through a door and to carry various tools. We first selected two tasks to show the possibilities of ROBAT:

- Carrying weights on short distances (in buildings).
- Cleaning the floor during the carcass work (with small pieces of bricks).

This ambitious project will be realized by 3 partners who have complementary competences.

☐ A company which is going to use the robot : NORPAC which is also the leader of the project brings its experience of building industry and many experiment places.

☐ A company which is specialized in high technologies : CYBERG has already an experience in mobile robots for nuclear plants.

☐ A research center for robotics : ECOLE DES MINES DE DOUAI.

3) PERCEPTION

In order to do the best choice for the severe environment of building industry, we studied following principles :

☐ Acoustic (Ultrasonic)
☐ Optical (LASER, Infrared and visible light)
☐ Radio waves
☐ Mechanical technics.

The criteria of judgment and comparison are the size, the directional aspect, the distance of efficiency, the complexity, the solidity in the building environment, and also a secondary aspect , the price.

3.1) Ultrasonic systems

This well known principle is already industrialized for obstacle detection (mobile robot security). In an unknown environment, is ultrasonic guiding hitting itself against the problems of wave length of the radiation and also of the material which sends back the signal [YAN 87]. Indeed, the echo is generally coming from the specular reflection which generates several reflection problems and can create measuring errors.

For this reasons seems this principle more appropriate for detection than for localization, whatever it can be "intelligent", because it can indicate the relative position of an obstacle.

3.2) Optical systems

3.2.1) Infrared

This principle permits to decrease the problems, we met with ultrasonic waves, because of the wave length of the light. But, the principle is limited by the technics of "not in phase" measure between this waves (witch are modulated by a periodic signal). Moreover, the infrared is sensible to the outside environment: an intense light or heat source (for example : Electric welding or arc cutting) can perturb the measures in some events.

The localization system often based on the triangulation principle, is composed by a turning infrared post, placed on the robot, the angular position of which is known exactly. Infrared receptive buoys are placed in the room, at several points.

The infrared buoys are one of the rare interesting localization systems inside the room, unfortunately, their short distance of efficiency needs the use of many of them, which involves quickly important costs.

An other application of infrared is the infrared telemetry, but the price of this one is important to obtain a good precision.

3.2.2) LASER

The use of LASER is interesting because of four properties:

- directivity of the light and small size of an impact which allows very precise aims.
- coherence (same energy, frequency, phase and direction of photons).
- monochromaticity (very small frequency band).
- power of the radiation (result of the other properties).

Three techniques are presently existing to measure a distance with a laser (rangefinder in time of flight, rangefinder with dephasing, and rangefinder with triangulation). Other techniques are much more precise but need a reflector (LASER interferometer) [KIK 86], [WAL 87], and are therefore difficult to use.

Because of its precision, quickness and easiness, is the LASER technique very interesting for several applications. Unfortunately, these systems are expensive and fragile (as well as the Infrared systems).

3.2.3) Visible Light

Its use is very easy, but also very sensible to modifications of environment, and therefore it is not precise at all.

3.2.3.1) Artificial Vision

It can only provide a 2D information [VAN 86]. In order to get the third dimension it is possible to use an other sensor or put a camera on a mechanical system.

One solution is the" monocular vision". Its purpose is to obtain the informations with only one picture. It is possible for instance to recognize a shape thanks to the texture and the brightness. One can also analyze the junctions and angles. These methods are quite seductive, but can only provide relative distances and are influenced by the observation conditions. So, their use is limited only for the perception.

In spite of these difficulties, one method based on this principle has been developed[NAK 81];.

It consists in getting a panoramic image by making a whole revolution with the camera. Particular marks (alternative black and white strips) which are fixed on the wall of the room are identified on the binary image. By knowing the position of the camera while acquiring the image, it is possible to deduce the position and orientation of the robot thanks to a simple triangulation.

3.2.3.2) Stereovision

Its principle is the same than human vision. With two different monocular images, we deduce the third dimension [GEN 80].

These images can be obtained by:

- two or more fixed cameras,
- a moving camera,
- a fixed camera watching mobile objects.

One can distinguish active and passive stereovision. In the first case some particular spots can be seen in the environment (reflectors, fluorescent paint, LASER ray,...) and allow to find easily the concordance points of the two images. Only one example of use of this principle is available today, it is the mobile robot VESA. With the second method, it is necessary to develop specific algorithms, the purpose of which is to find remarkable elements, in order to calculate the concordance points [COR 83]. The important calculation times allow to apply this method for only a limited number of points.

To simplify the algorithms, we develop a passive stereovision method based on real time shape extracting, and we keep only vertical and horizontal lines, this permits to divide the processing times into 100.

These solutions are interesting, for they are not expensive, unfortunately they need complex algorithms whose results are not always good!

3.2.3.3) Dynamic Vision [SIA 86]

It is one of the most recent research topics. It consists in analyzing a sequence of images acquired during the moving of the camera.

It is based on the use of continuity of the image sequence in order to simplify the measuring of the displacement of apparently moving points (optical flow). The results can be used in two ways:

- the optical flow allows to calculate the translation and rotation of the camera.
- knowing the displacement, we can deduce the dimensions of objects (as well as with stereovision).

This method is seductive too, because of its low cost. But, it does not allow to correct the drifting with respect to odometrical estimations. Therefore one can only use this technique combined with frequent corrections made by another means of localization.

3.2.3.4) Vision with Polarization [BEL 85]

It consists in placing on the wall reflectors systems with a vertical polarizer. Two cameras (on the robot) on a symmetric position (at 90°) watch the same picture. The first has a vertical polarizing filter and the second an horizontal one. Only the first can see the reflectors, and by substracting the two images the only thing remaining is a picture of the reflectors. As before it is easy to calculate the position of the robot by triangulation (we know exactly, of course, where the reflectors are).

It is important to notice that such a system is easy to make, but cannot be used in building industry, for it needs a very clean environment (that is also true for any system using artificial vision).

<u>3.3) Radio-electric waves</u>

The principle of triangulation is made with buoys the positions of which are known by the robot. This system is expensive and difficult to realize inside of a building (it works generally outside), and moreover it is very sensible to parasites.

This can partly be solved by using the X-band that has several advantages:

- low consumption of energy for the buoys,
- very good directivity of the waves (few interferences).
- possibility of using small components with a good gains of aerial.

But, there is one major problem which is the very low distance of efficiency. It can only be used in very small rooms (15 m2). Above, one cannot get enough precision.

3.4) Mechanical systems

The mechanical hitting detection system is a security means that must stop immediately the robot in case of collision. It must detect obstacles that would not have been detected by the other systems. One can also use "cat's whiskers" for the same purpose and also for running along obstacles or walls, and so making a cartography of the environment.

These systems are generally not expensive, but their drawback is the increasing of the robot's size. This increasing is even more important if the maximal speed of the robot grows : the obstacle must be detected early enough.

The principle of odometry is the measuring of elementary movements of one or two wheels of the robot to calculate its theorical position.

This system is not trustful enough for several reasons:

- slipping of the wheels,
- accidents of the floor,

But, there are also important advantages :

- it is easy,
- it gives an information at any moment,
- it is very cheap.

3.5) Conclusion

The several systems we presented in this paper are not the exclusive existing solutions, but they give a general panorama of the situation of mobile robots in the building industry.

They can give informations about the presence of unexpected obstacles. But for the security, the frequency of acquisition must be in proportion with the maximal speed of the robot. That obliges us to take only the principles that allow this rapid acquisition (ultrasonic and mechanical systems).

At the opposite, for the recognition of a an "unknown universe" all the systems can be used. The optical ones appear as the most frequent but have major disadvantages: they depend on the lighting (except : LASER) and need an infrastructure.

Localization needs a quick and sure system. For "relative" localization is odometry the easiest, but for an "absolute" definition of the robot's position there are not yet existing equipments that are simple enough for our application.

4) OUR CHOICES

The purpose of "ROBAT" project, which is the origin of this research, is to realize a low cost mobile robot. This means we have to choose systems that are as simple as possible.

That is why we decided to make a second mobile robot much more expensive, used exclusively for the studies concerning perception and localization. The results of those are, of course, used to optimize the first one.

In both cases, the computer structure is based on a 68020 VME system. At the opposite the operating systems may be different: the research is done with operating system (OS9 by MICROWARE), while the final choice for the industrial robot is not yet definite.

The architecture of the "research system" is a multi-level , the supervisor of which is a card 68020 (TSVME 120-1FP by THEMIS). The lower levels have been designed, as specifical developments, for each kind of principle that is to be tested.

For our robots the several problems have been solved as follows:

• The cheapness and simplicity of ultrasonic proximeters pointed out this solution for security on both robots. Moreover, they fit perfectly to this function for they avoid a contact with the environment. Their particular disposition decreases the multi reflexion problems and also the diffraction of the reflected radiations.

• The absolute localization is more difficult. Two possibilities must be compared (ultrasonic proximeters and infrared buoys). As the first technique is already chosen for security, we are going to test and develop algorithms that take into account the phenomena of multi-echo, as well as the back of echo.

• Absolute localization is done with the polarization principle described in chapter 3.

• The relative localization is done by odometry, but our research with the second robot will test the whole tree we detailed in chapter 3 (except inertial).

• Perception (research robot) is based on artificial vision (card TSVME 630 by THEMIS). The method consists in acquiring one image with one camera (I2S) and getting the shapes (possible in real times). Informations are then treated in order to reduce and close the several regions we have found. Their positions are finally measured with an infrared telemeter (DIOR 3002 by WILD & LEITZ). The result is then a stylized three dimensional world.
Linear stereovision with the same card and two cameras will also be tested.

5) CONCLUSION

The ROBAT project, financed with the help of the French State, and the first steps of which are explained in this paper, is being done in the PRODUCTIQUE Department of the ECOLE DES MINES DE DOUAI with an active participation the companies NORPAC and CYBERG. Its purpose is to build a mobile robot for the construction industry that involves very severe working conditions.

We explained how it is possible to perceive an "unknown universe", but the main difficulty remains the impossibility of knowing the position of all the objects of the environment and their movements. The consequence of this, is that one cannot give a cartography of this universe, and so it can become dangerous and/or menacing against the robot.

We pointed out the advantages and drawbacks of the several means coming out from the basic functions. None can be considered as perfect, but all of them contribute in going forwards to mobile robotics of the years 2000.

The choices we did for the different points of the "Tree of Perception" aren't, of course, general references, but they are the result of our comparison between their possibilities, limits and efficiency.

As a conclusion, we can say that the solution to a perception problem can only be defined if taking into account the universe of the robot. It is evident that the ideal perception system (meaning it fits anywhere) does not yet exist.

The universe of the building industry is severe but not impossible to deal with. There are some solutions which are being tested. Their physical limits will be pointed out and analyzed in order to suggest orientations of the technical researches about perception and localization means.

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