Conception of a Multisensors System for a Mobile Robot Applied to the building Industry

Mr D. JUGE-HUBERT

Researcher
ECOLE NATIONALE SUPERIEURE DES TECHNIQUES
INDUSTRIELLES ET DES MINES DE DOUAI
and
UNIVERSITE DE TECHNOLOGIE DE COMPIEGNE

Dr A. SCHMITT

Head of PRODUCTIQUE Department
ECOLE NATIONALE SUPERIEURE DES TECHNIQUES
INDUSTRIELLES ET DES MINES DE DOUAI

941 rue C. Bourseul
B.P. 838
59508 DOUAI CEDEX, FRANCE

ABSTRACT

A mobile robot of the fourth generation requires an on-line, real-time sensory feedback system to guide the robot, to stay on planned path, or to avoid unexpected obstacles. The study we present in this paper concerns a multisensors' and multiprocessors' fusion in order to create a new model of the mobile robot's world. The solution we suggest for a dynamic mixed fusion is a spherical model with estimated sensors' data. After presenting this theory, we explain our approach concerning multisensors' fusion and we justify our technical choices for this project. At the end, we give an efficient computational model for multisensors' fusion, which consists in representing the data in a single and unified framework so that computation time can be significantly reduced and becomes compatible with a micro-computer.

1) INTRODUCTION

During the last twelve 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.

For the mobile robots of the fourth generation, a new concept appears. The mobile robot is going to become a palliative for men in hostile places and for repetitive and painful tasks. 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.

In that purpose, we modelize the mobile robot of the fourth generation with the architecture described in figure 1.

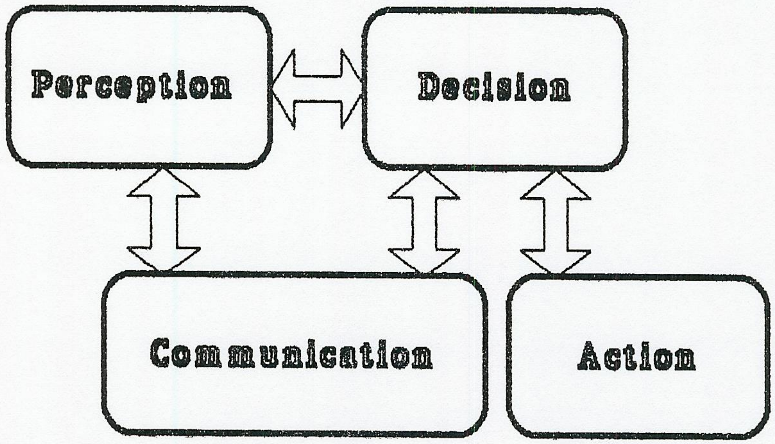

Figure N°1 : *Modelization of the mobile robot*

If Mobile Robots are to emulate human-operated vehicles, an on-line, real-time sensory feedback system is essential for guiding robots staying on course, avoiding unknown obstacles, returning to planned path from a detour, and even replanning the path if necessary. This is a difficult problem, because of dynamic and incomplete world knowledge and unknown obstacles. So, in some cases preprocessing world knowledge and using brutal computing power may not be enough to solve the problem. Then it is necessary to develop an efficient model and representation scheme that captures some human cognotive and subcognotive characteristics and yet is implementable in current computer technology. For these reasons, we create a new concept of multisensors fusion.

The main question of multisensors' fusion is to integrate many numerical and spatial sensory data to yield useful information about the object (or environment). One approach is to integrate different "images" (considered as partial and incomplete information) by artificial intelligence and evidential reasoning methods.

The study we present in this paper concerns the multisensors' and multiprocessors' fusion to create a new model of the mobile robot's world. After presenting the theory of this approach (chapter 2). We explain our approach in multisensors fusion (chapter 3). Before concluding (chapter 5), we justify our technical choices for this project (chapter 4).

2) THEORETICAL MULTISENSORS FUSION

Multisensors' fusion may be classified into three categories: complementarity approach, redundant approach, and mixed approach. In each category, there are two sub-categories : static and dynamic fusion.

In the complementarity approach, the data are complementary. For example, a vision system gives 2 dimensions and an infrared range finder gives the third. For the redundant approach, each sensor gives two or three dimensions, but these data are redundant, i.e. for the same point, we have the coordinates measured several times by different systems. The mixed approach consists in a complementarity approach used to create a world model and a redundant one, used to verify it.

For each category, static multisensors' fusion deals with a situation in which both the robot and the environment are static. Of course, this has a very poor interest for mobiles robots, that are rather concerned by the dynamic case. In static multisensors' fusion, we integrate different sensory data from possibly heterogeneous sensors. There are two possibilities : a single robot or a distributed system of robots or surveillance stations communicating sensory data among themselves. Dynamic multisensor fusion deals with situations in which robots and/or the environment may be moving. Dynamic multisensor fusion is temporal for it integrates continuously sensory data.

The solution to a dynamic mixed fusion is a spherical model (See figure 2) with estimated sensors' data (See figure 3).

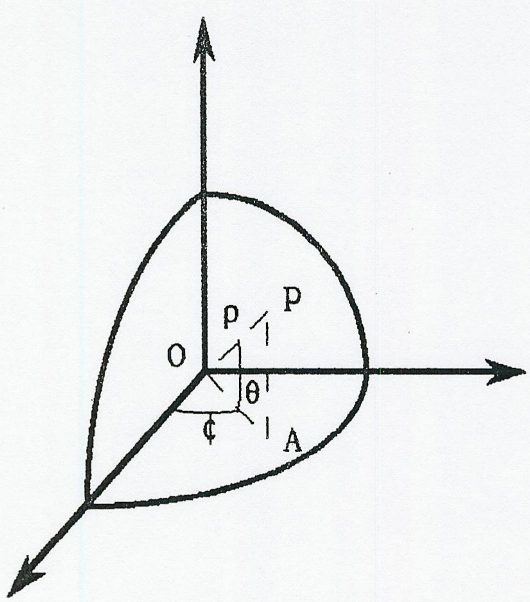

Figure N°2 : *Spherical Model*

A spherical sensory model is similar to human perception. Its spherical data structure provides and efficient and unified representation scheme for multisensor fusion and navigation.

This model is independent of different sensor types. Images of sonar, optical, radar, infrared, or other kinds of sensing may be integrated in the same model to enhance image understanding and object recognition capabilities. The spherical model eliminates some limitations of the usual orthographic and planar perspective models in optical systems. It is also the natural model for range data, because range values are radial distances from sensor to observed object (or world).

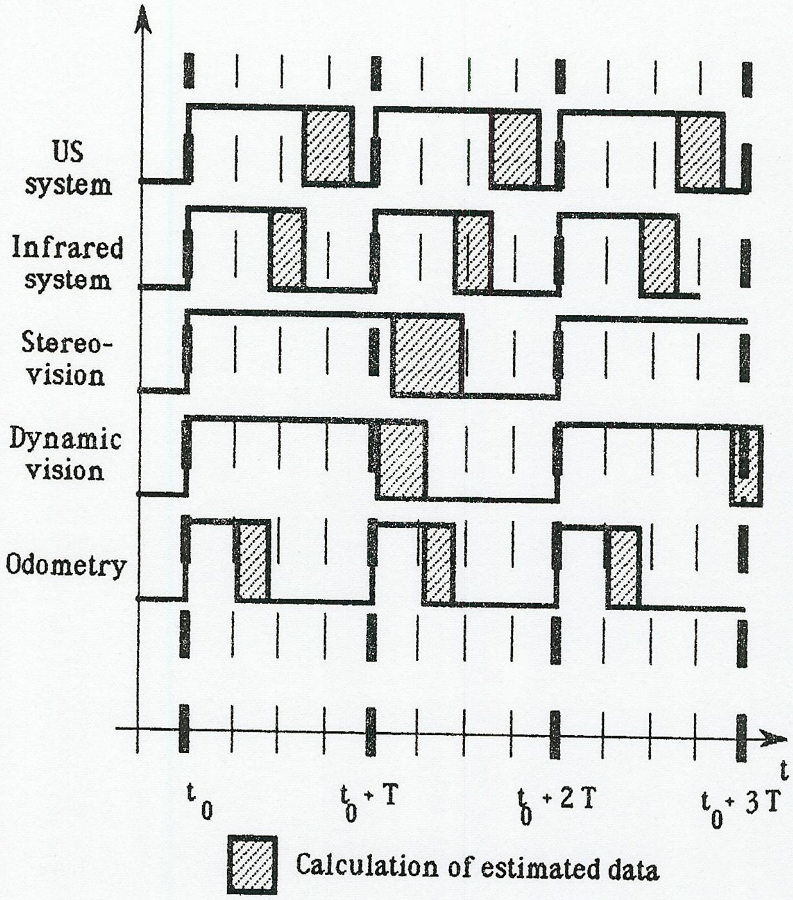

Figure N°3 : *Estimated Data*

After the spherical model, we build a spherical data structure. This one is a generalization of the octree data structure which is gaining popularity in computer graphics, computer vision. The octree structure divides the world space into eight octants. Each octant is again divided into eight octants. This recursive scheme provides a fine structure of the world space. For instance, collision avoidance may be treated as an intersection problem of two shaded regions in a sufficiently fine octree subdivision.

One disadvantage of the octree representation is that it is not rotational invariant. For each rotation, we must recalculate the octree representation. Our spherical model avoids this difficulty.

Before creating the spherical model and the spherical data structure, the key problem of the multisensor fusion is "correspondence". Even when using the same kind of sensors the correspondence research is sometimes difficult. Moreover, when we have different types of sensing systems this problem becomes really complex, because vision for instance is characterized by a sensing mechanism that is quite different of the radar's one.

For example, in the case of static multisensors' fusion, the main idea is first to reconstruct various object surfaces from various sensory data and then to integrate the object surfaces in the world space. This approach is different from previous methods which mostly are trying to do this integration at the image level. Different kinds of sensory data require different algorithms and provide different kinds of image data.

3) OUR MULTISENSORS AND MULTIPROCESSORS STRUCTURE

We showed that the choice and association of the detecting elements is very important for the realization of an immaterial guidance system. But it is not possible to dissociate a multisensors' fusion and a multiprocessors' data-processing structure treated on a hierarchical basis.

For these reasons, the department studies are divided into 5 topics, as follows:

- environment analysis by passive stereovision,
- localization with an infrared system
- safety by ultrasonic sensors,
- development of a control device with neural networks,
- integration of reflexes functions by a low level intelligent system.

This various research constitutes the base of the perception pyramid in which two components are missing:

- a means of regrouping and connecting information provided by the various basic entities,
- a support for evolution and development of these entities allowing a great modularity of the functions, in order to solve the tasks of these entities.

The aim of this program, is to find solutions for the multisensors' fusion problem. In order to allow the mobile robots to integrate perception and analysis means of the human, the difficulty is not into multiplying the tools, but into fusing and optimizing the exploitation of their data.

Now, with the technological possibilities, this objective ineluctably goes through a multiprocessors approach. The only reasonably possible data-processing architectures are characterized by a modular and flexible structure. Indeed, our objective is not to treat a particular case, but to lead to a mode of total management of the whole detecting elements. This implies a physical and software structure that is not depending on a particular link of the system.

Moreover, in spite of the arborescent structure of the treatments and controls, the multisensor fusion algorithms will have to ensure a compatibility with the upwards or downwards use of the data resulting from the various processing levels.

The work program is articulated around six phases. The four first phases of research concern the specialized processor integration with a specific task. In each case, the steps obey at the following diagram :

- Pre-standardization algorithms to operate with a spheric sensors,
- Data modeling algorithms,
- Estimations algorithms with KALMAN filters.
- Analysis of the channel of transmission and protocols formulation,

The four specialized functions are the following ones :

- odometer,
- artificial vision,
- localization,
- communications.

The four types of parallel functions being solved, the research moves towards the following stage while going up of a level in the system arborescence. The two last phases are the multisensors data modeling (with a method explained in chapter 2) and the "navigation - supervision" processors integration (with a methodological approach of the decision-making process based on the neural networks).

In conclusion, the interest of this program lies in the projection towards quasi optimal approaches relating to :

- the homogeneity of data processing architectures, control and diagnosis (possibly generalizable to other applications),
- modularity and flexibility of the system distribution,

* decision autonomy (removal of the umbilical cordon connecting the robot to a great information processing system).

All in all, we can consider that this research gives the philosophy of the mobile robots of the fourth generation.

4) OUR TECHNICAL 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 the perception and the multisensors fusion. 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 (THEMIS 923). 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 one, 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 reflection problems and also the diffraction of the reflected radiations.

* The absolute localization is more difficult. We used for this one the infrared buoys.

* The relative localization is done by odometry.

* Perception (research robot) is based on artificial vision (card TSVME 630 by THEMIS).Linear stereovision with this card and two cameras will also be tested.

* The axis control is made by a THEMIS 440 VME CARD and an electric engine for the first step. Finally, mobility is obtained with a gas engine and hydraulic power.

5) CONCLUSION

The ROBAT project, financed with the help of the French

State, is being done in the PRODUCTIQUE Department of the ECOLE DES MINES DE DOUAI with an active participation the companies NORPAC, CYBERG, and a factory which is specialized in small building vehicles. Its purpose is to build a mobile robot for the construction industry that involves very severe working conditions.

We have presented an efficient computational model for multisensor fusion, which consists in representing the data in a single and unified framework so that computation time can be significantly reduced and becomes compatible with a micro-computer.

A theoretical and technical foundation of multisensor fusion has also been established. The main idea is that we may integrate 3D spatial information derived from various images in the world model. This idea, in building industry, has other applications that the mobile robotics.

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

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