COMMISSARIAT A L'ENERGIE ATOMIQUE
CENTRE D'ETUDES DE SACLAY
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Service des Bases de Données Spécialisées
F91191 GIF SUR YVETTE CEDEX

CEA-CONF--10843

INTELLIGENT PERCEPTION CONTROL BASED ON A BLACKBOARD ARCHITECTURE

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Communication présentée à : International Conference on Industrial Engineering Applications of Artificial Intelligence and Expert Systems

Hawaii, HI (US)
2-5 Jun 1991

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EXTENDED ABSTRACT

IEA/AIE 91 - HAWAII

Area of submission : **Robotics.**

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KEYWORDS :

Blackboard - Sensor Planning - Sensor Fusion - Perception - Robotics - Artificial Intelligence.

INTRODUCTION

This paper presents a perception control system developed in the ongoing research CEA project SYROCO (COoperative RObots SYstem). The aim of this project is to integrate the different techniques required for the development of an autonomous mobile robot. This robot has to move around a nuclear plant which is not pre-equipped. In such hostile and dynamic environments, robots must be as reliable as possible after an incident and the better the robot can perceive its environment, the highest degree of efficiency it will reach. So, the perception system is the key of a reliable and safe execution of the robot mission.

In order to achieve all types of missions (navigation,inspection, intervention), the robot needs to set up the most adapted descriptions of the environment. As any sensor only provides incomplete information, the perception system must include a set of redundant and complementary sensors. It has also to include a wide set of algorithms which will allow a flexible control of the sensory data interpretation.

Each perceptual task may be performed using several perceptual resources and data processing. The choice and the parametrization of perceptual resources and data processing are done according to the current state of the environment and the constraints of the mission. So, an intelligent control is necessary to manage the complexity of the different alternatives :

- choice and command of the sensors,
- choice and parametrization of data processing,
- choice of the multisensory fusion method,
- choice of the perception strategies.

and its main characteristics are modularity, adaptability and configurability.

We have developed the GESPER ("GEStion de la PERception") system which achieves this control for an intervention mission in a nuclear power plant.

In this paper, we successively present the GESPER architecture, then the sensors and the data processing available on our robot and finally the implemented software architecture.

1. THE GESPER ARCHITECTURE

GESPER receives a perceptual mission and the trajectory the robot has to follow. The characteristics of the mission (perceptual goals, execution constraint : quickness or safety, ...) are given by an operator and the path is sent by the navigation module.

Two main processes are controlled by GESPER : the perception planning process and the data interpretation process.

According to the perception strategies , the perception planning module analyzes the perceptual goals of the mission and provides perception plans for the sensor activation description (which sensor has to be used, at what time and place and how must it be parametrized?), the parametrization of data processing and the choice of the way to fuse sensory data. In addition to the explicit perceptual goals of the mission, it generates and processes perceptual goals which are implicitly required for a safe navigation (for example : obstacle detection).

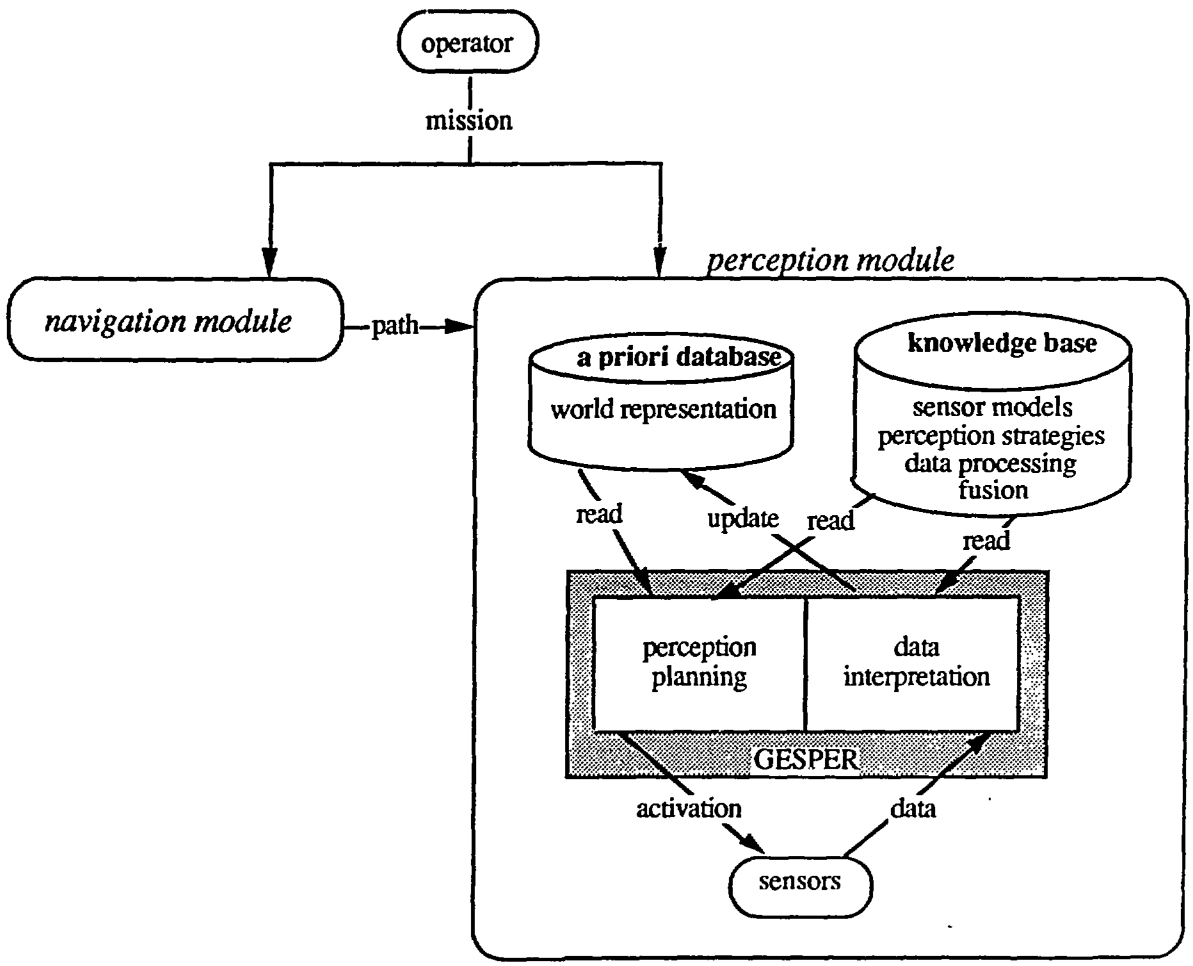
This perception planning module also carries out the execution control of the generated plans. It reacts dynamically to any unexpected change in the environment or in the robot (operator intervention, sensor failure...). It replans if possible or sends information to the navigator if not.

The perception actions are sent to the actuators and GESPER gets back raw data from sensors. The data interpretation process makes them interpreted by the relevant processing and selects the good fusion algorithm according to the perceptual goals.

The two processes communicate with an a priori database (read/update) and a knowledge base (read)

The a priori database records the structural knowledge of the environment (civil engineering knowledge for indoor environments). It is generated by a 3D modeller and uses an object oriented representation of the knowledge. It is updated thanks to the information extracted by the data interpretation module. It includes beacons and landmarks positions and models.

The knowledge base records all knowledge required for the choice and the parametrization of sensors and data processing. For example, sensor modelling consists in the description of characteristics such as orientation, field of view, ...Fusion and data processing algorithms are described in terms of : CPU time, type of information on which they can be applied, accuracy ... Perception strategies are also part of the knowledge base (best position to perceive landmarks for example)



The GESPER architecture.

2. PERCEPTUAL RESOURCES, DATA PROCESSING AND TASKS :

We present in this section the available resources (by now) on our testbed robot for this experimentation.

In order to achieve the perceptual tasks, we have identified two types of resources : perceptual resources and data processing .

A perceptual resource consists of one or several sensors.

GESPER has got three perceptual resources :

- a set of three wide field cameras,
- a time-of-flight range finder (2D scanning),
- a camera associated with a structured strip light (which can be oriented) .

It also takes into account odometer data to estimate the robot position.

The sensors stand on a turntable fixed on the robot. This gives an additional degree of freedom for the orientation of the sensors.

The data processing are related to the perceptual resources. Data processing are high level algorithms which chain pre-processing, primitives extraction, primitives interpretation... They have attributes such as : cost (vulnerability, cpu time, ...), usefulness (context use, error model, ...).

The data processing available are :

- stereo-vision algorithms for map building, localization and object recognition,
- localization algorithms based on landmarks recognition,
- obstacle/free space-detection algorithm,
- data processing associated with the odometer,
- data processing associated with the range finder.

Several data processing can be connected to one resource. For instance, two different stereo-vision algorithms are connected to the set of three cameras.

The perceptual tasks taken into account in GESPER are free-space detection, map building (2D and 3D), landmark recognition and localization. The localization task enables to determine the robot position in a reference frame. It corrects the drift of the odometer and can be performed by landmarks recognition and triangulation.

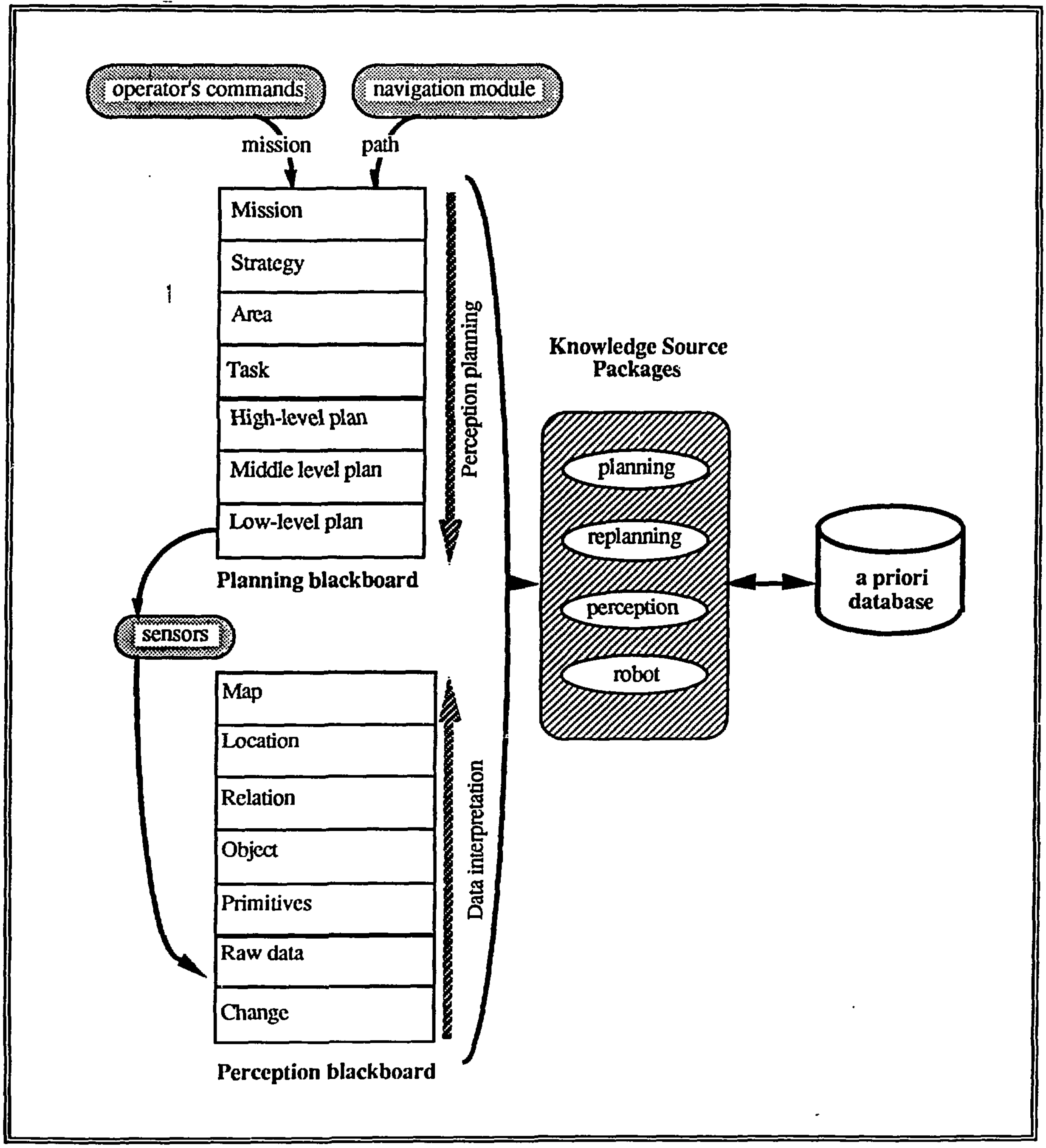
3. IMPLEMENTATION

We have implemented the GESPER system with TRAM, a blackboard tool developed in our laboratory.

The events deduced by GESPER are recorded on two blackboards corresponding to the two main processes : the planning blackboard for the planning process and the perception blackboard for the data interpretation process. The hierarchical structure of the blackboard is well suited to our problem : the planning blackboard is set up according to a top-down approach corresponding to successive refinements in the decomposition of the mission - from the global plan to the detailed one - , and the perception blackboard is set up according to a bottom-up interpretation approach - from the raw data (images, distance measurements ...) to the symbolic one (maps, robot position ...) -.

The blackboard architecture also fits our application because the knowledge base can be implemented as several cooperative knowledge sources, enhancing the system modularity.

The opportunistic resolution allows dynamic planning, replanning and interpretation depending on the evolution of the robot and of the environment.



GESPER is written in C language and runs on a SUN workstation.

3.1. Knowledge sources

The knowledge sources (KS) are split into packages : planning, replanning, perception and robot.

The "planning KS" carry out the real time perception planning. Two levels of planning are implemented : a global perception planning and a local one, this, to avoid to detail the plans too early.

The perception strategies are chosen according to the constraints of the mission. For example, a strategy based on a quickness criterion will use the competitive notion of sensors to select the best one.

A global planning splits the mission into work areas, which are successively treated by the local planning. So, the environment and the mission are locally analyzed in order to provide the final low level plan.A local planning is done on each work area:

- firstly, it determines the perceptual tasks and the location where they have to be performed (task blackboard level),
- secondly, it determines with which sensor, and which data processing will be concerned. (high level plan blackboard level),
- thirdly, it determines how those resources are parametrized (middle and low level plan blackboard level).

There is one knowledge source for each perceptual task. Each one has the knowledge about the execution conditions depending on the situation. And similarly, there is one knowledge source for each sensor. For example, the field of view of a camera is used to compute the robot location for landmark recognition, the error model of a sensor is used for data fusion ...

The low-level plan is sent to the sensor actuators. "Perception KS" (primitives extraction algorithms, object recognition algorithms, multisensor fusion algorithms...) are triggered to interpret the raw data sent back by the sensors. Those KS also query and update the a priori database and maintain its consistency.

The system takes into account changes in the environment : sensor failure, change in the lighting, detected obstacle... or an operator command. This activates "replanning KS" which analyzes if the problem belongs to GESPER competence. If it does, the replanning KS update the plan, if not, GESPER stops its resolution and sends a message to the operator or to the navigation module for path replanning.

During the planning and the execution steps, global knowledge related to the robot (kinematic model, robot dimensions, coordinate transformations, ...) is provided by "robot KS". For instance, the robot size has an effect on the space explored by GESPER.

3.2. The Planning and the perception blackboards.

The planning blackboard has seven levels :

The "mission" level records the specified mission.
The "strategy" level records the perception strategies which are determined according to the mission constraints.
The "area" level records the different planning work areas.
The "task" level records the set of tasks to be performed in terms of map building, landmark recognition,...
The "high-level plan" level records the scheduled plan of all the triplets "resource-data processing-task".
The "middle-level plan" level is a decomposition of the previous level. It takes into account the parametrization of the resources.
The "low-level plan" level is the set of controls which are sent to the sensors activators. It triggers data processing.

The perception blackboard has also seven levels :

The "change" level records all unexpected changes in the environment for a possible replanning.
The "raw data" level records sensory data (images, odometer data ...)
The "primitives" level records the results of the extraction algorithms.
The "object" level records all the recognition performed.
The "relation" level records topological relations between objects.
The "location" level records the location of the robot.
The "map" level records a 2D or 3D map of the environment.

4. CONCLUSION

In this paper, we have described the intelligent perception control system GESPER which is presently equipped with a set of three cameras, a telemeter and a camera associated with a structured strip light.

This system is of great interest for all our robotic applications as it is capable of autonomously planning, triggering acquisitions, integrating and interpreting multisensory data.

The GESPER architecture, based on the blackboard model, provides a generic development method for indoor and outdoor perception. The modularity and the independence of the knowledge sources make the software evolving easily without breaking down the architecture. New sensors and/or new data processing can be integrated by the addition of new knowledge sources that modelize them.

At present, first results are obtained in our testbed hall which simulates the nuclear plant as it gives similar experimental conditions. Our ongoing research concerns the improvement of fusion algorithms and the embedding of the whole system (hardware and software) on target robots and distributed architecture.

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