THE PANORAMA PROJECT APPROACH , FIRST RESULTS AND POTENTIAL APPLICATIONS.

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ABSTRACT

This paper presents the Panorama project , its objectives and technical approach, first results of autonomous motion with an experimental platform, and application scenarios.

The Panorama project aims to develop an advanced perception and navigation system for automated industrial vehicles dealing with partially structured and partially known environments (outdoors). Applications concern the automation of material transportation in building sites, forests, agriculture, open quarries, docks, warehouses and special-purpose machines, such as harvesters, rock drilling machines, building machines, cleaning machines for large areas.

1)PROJECT OVERVIEW

PANORAMA is an ESPRIT Project, funded by the European Commission and launched in March 1989, which is intended to prove the feasibility of an autonomous transporting system replacing a man controlled vehicle evolving outdoors in a partially structured environment such as in agriculture, construction sites, forest fields and open mines.

It is planned to construct two demonstrators available in 1993, one of these being an experimental platform derived from a forest forwarder machine supplied by RAUMA REPOLA, the other is dedicated to open mines experimentation and supplied by TAMROCK. These machines should evolve in a real environment as Finnish forest and open mines at the begining of 1994 and should demonstrate autonomous operation.

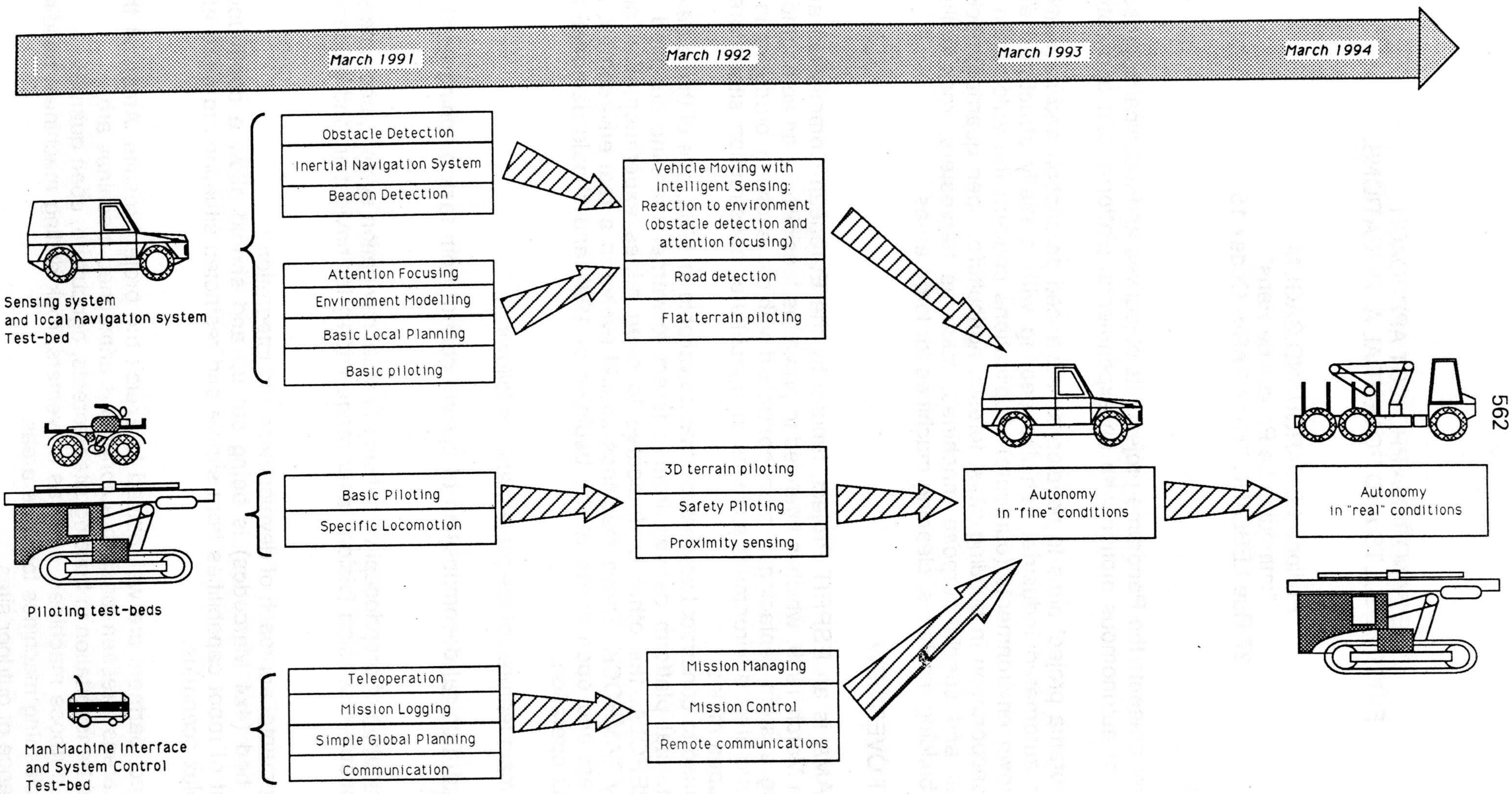
The main features of the project are the following :

- a hierarchical decomposition of system control from task planning level to action level.

- a combination of proprioceptive sensing (inertial navigation system, odometers) and exterioceptive sensing (vision, laser range finder) for navigation and guidance purposes.

- an incremental approach of development and integration :
a test - bed (4x4 Mercedes) is being set up and should allow a continuous assessment of robot capabilities from simple and restricted situations to more and more complex scenarios.

The project partners are well placed to exploit the project results. Amongst the application areas foreseen for such autonomous unmanned machines are :
- material transportation in building sites, forests, agriculture, open quarries.
- special-purpose machines, such as harvesters, rock drilling machines, building machines, cleaning machines for large areas.
- surveillance of outdoor sites.


March 1991
March 1992
March 1993
March 1994
Obstacle Detection
Inertial Navigation System
Beacon Detection
Attention Focusing
Environment Modelling
Basic Local Planning
Basic piloting
Sensing system
and local navigation system
Test-bed
Vehicle Moving with
Intelligent Sensing:
Reaction to environment
(obstacle detection and
attention focusing)
Road detection
Flat terrain piloting
Basic Piloting
Specific Locomotion
Piloting test-beds
3D terrain piloting
Safety Piloting
Proximity sensing
Teleoperation
Mission Logging
Simple Global Planning
Communication
Man Machine Interface
and System Control
Test-bed
Mission Managing
Mission Control
Remote communications
Autonomy
in "fine" conditions
Autonomy
in "real" conditions

2) PROBLEMS AND DIFFICULTIES AN AUTONOMOUS SYSTEM EVOLVING OUTDOORS HAS TO COPE WITH

2.1) Partially structured environment and occurence of unexpected events

- Geometric reasoning

The main task of an autonomous mobile robot is to plan collision free paths in a cluttered environment. Depending on situations, this environment may be completely known, partially structured or unstructured. This emphasizes the complexity of geometric reasoning which has to manage balancing between a priori knowledge and perceived data, for its geometric representation part, and balancing between optimal control and real time constraints for its motion planning part. In any case, an autonomous mobile robot will have to face this complexity, because it will be impossible for it to have all the a priori knowledge to perform optimal motion planning for, at least, two reasons : first, it is impossible to represent and to store in memory all the enough accurate data at the right level of resolution and, second, the mobile robot has to cope with a dynamic world that continuously modifies the constraints of the problem.

- Navigation :

It is clear that in a poorly structured environment modelling is quite impossible and , as such dead reckoning navigation is the only way to achieve navigation task with the complementary aid of additional perception of landmarks .

- Obstacle detection and characterization

The robot needs capability of a 3D perception.,in real time, of the scene in order to detect and evaluate an eventual obstacle with its dimensions and its distance to the vehicle.Only laser range finding techniques can perform such task today.

2.2) Untethered system

Major part of intelligence has to be embedded on board in order to deal with available radio communication bandwidths and to permit eventual communication interruptions with the control station.

2.3) Fine localization

Accurate positionning of the vehicle in area of work is necessary considering operations the robot may have to perform locally as trees collecting, harvesting, or maneuvring for docking...

2.4) 3D terrains

Unstability problems may occur and image acquisition can be badly disturbed according to the vehicle attitude. Hence attitude measurement facility is required and also a prediction of local terrain profile ahead the vehicle with 3D perception means .

2.5) Harsh environment

Vision algorithms have to be independent of various illumination and precipitation conditions.

In such sophisticated machines the computing system should be fault tolerant in order to insure actual safety and reliability.

3) PANORAMA APPROACH

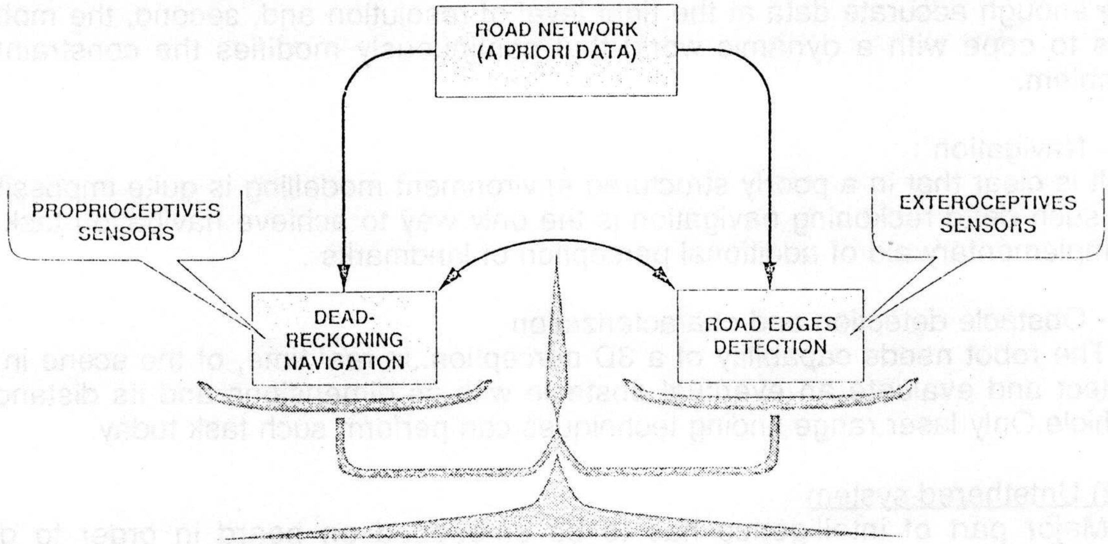
3.1) Navigation and guidance approach.

Considering partially known environments, navigation relies on a combination of proprioceptive information and visual information (as road/lane tracking, landmark detection).

The retained approach is to use an inertial navigation system (INS), a prepared data - base and a perception system (see figure below).

The idea is to monitor the vehicle trajectory (positions and attitudes) in order to pick - up in the data base therelevant information, to help vision. As a feedback, corrections are then possible, either in the data - base itself or for the navigation system.

In this way, the perception system is considered as a local help working with a prediction/verification strategy : the prediction is possible thanks to the combination of the INS and the data - base.



On the other side, the INS have one major technical drawback : their accuracy is altered with time. Here again the balance is helpfull since updatings of navigation drifts are possible, after detection of particularly well known beacons or landmarks.

The adjustement of the balance is a difficult and sensitive task which closely depends on the data - base contents and accuracy.

In order to update the navigation, it is clear that information with better accuracy than the navigation itself is required. As orders of magnitude, a typical INS that can be used for PANORAMA will have a drift of 10 meters after a 1 km mission: then the precision of the landmarks/beacons position must be better than 5 meters (typically one meter) to achieve efficient updatings. Such an accuracy is very difficult to obtain because the main existing geographical data - bases and maps do not guarantee such a precision.

3.2) Perception approach

Perception (composed of laser range finder, vision, ultrasound and infrared proximeters) is devoted to help the Navigation System based on proprioceptive sensing (inertial system, odometers, doppler radar). The Vision tasks are activated upon request of the Planner, thanks to an A Priori Data Base modelling the environment.

herefore, the three main Vision tasks are essentially "Goal - Driven" using a prediction - verification strategy :

- Beacon and Landmark detection,
In order to update the navigation drifts of the Inertial Unit, a recognition and localization of visual Beacons and Landmarks is performed when needed.

- Road Tracking,
Navigating in free fields is a suitable task for the Dead - Reckoning process, but the location drifts are not allowed when driving on a road. or a lane .The road tracking process intends to perform a visual servoing of the Robot on the road edges.

- Obstacle Detection,
The indispensable task to associate to Navigation is the obstacle avoidance. The obstacle detection is performed by a continuous scanning mode of the Laser range finder and then by the proximity sensors. Vision in this case will be an help, trying to identify the detected object which is not already mentioned in the A Priori Data Base.

In the beginning of the project experiments, Navigation will be mostly based upon dedicated and expensive Inertial sensors allowing fast and relevant results, but the balance should be stressed on Vision during the project course.

3.3) Localization approach

To obtain land vehicle position in a geographical coordinate system, there are two general solutions :

- absolute localization : the principle is typically to use certain known ground points (such as landmarks or beacons) or satellites (GPS, LORAN, ...) to compute the vehicle position with triangulation - like techniques. The system gives directly the absolute position, but the accuracy highly depends on the known reference points and on the distances or the angles measurements. The main drawback in the need of a specific and often heavy infrastucture,

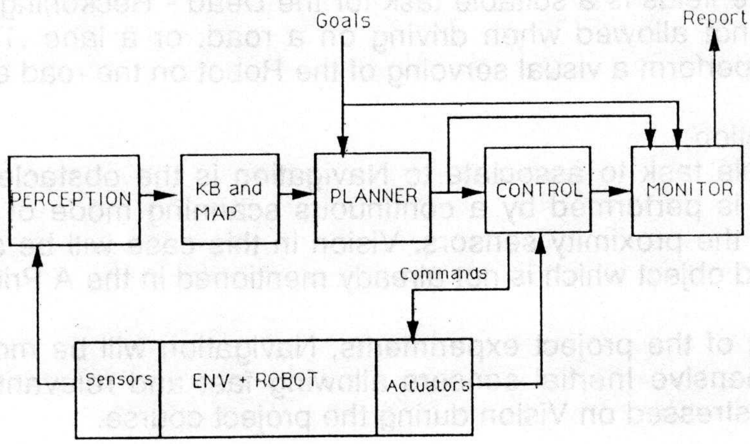
- dead - reckoning navigation : that is a method of calculating position with respect to an initial known position by integrating measurements of velocity (module and direction) to obtain position. The inertial navigation is the upper class of dead - reckoning navigation. The major drawback of this navigation process is that the uncertainty grows with the time or/and the travelled distance. Thus the navigation needs to be regularly updated by other means.

In the PANORAMA project, the approach is to use dead - reckoning based on gyroscopique heading and distance measurement (like odometers), and global positioning system (GPS - NAVSTAR) in differential mode (in open sites) and/or visual landmarks (in forest).

3.4) Planning and control approach

As the robot has to cope with unstructured environment, dynamic obstacles, constraints and insufficiently known model of systems, planning is not sufficient to complete the mission in an open loop approach. The robot has to be intelligent enough to replan its way in the largest range of circumstancies. To do this, it has to be able to plan and to control simultaneously in order to manage a closed loop with the world environment. This leads to the concept of a loop including planning which contains the basic characteristics of a control system :

1) a system to be controlled (robot + environment),
2) a desired objective,
3) a set of control commands,
4) a measure of the cost or effectiveness of control actions.



- Hierarchical approach

Two connected reasons lead us to have a hierarchical decomposition :

there are different levels of resolution of information,
there are different focus of attention for planner/controllers.

Four levels for the hierarchical planning and control system are considered :

1) the robot mission,
2) the global route,
3) the local path,
4) the reflexive pilot.

Level 2 and 3 belong to the navigation part of the planning and control system, and include the main functionalities of the geometric reasonning.
Each level includes :
a perception system (acquisition-reconstruction-updating),
an information system (maps),
a planning system (decision-making),
a controller system (feedback, monitoring, reports).

3.5) Route planning :

- Global route and local path

The global level is required to plan a global route in the total work space of the vehicule taking into account geometrical but also specific conditions such as weather or road traversability and mission constraints. The result of the route plan is a sequence of driving units which represent the basic tile of the tesselation at this level, which is mainly composed of a priori information.

The main purpose of the local planning is to cope with perceived environment and to produce a local safety path according to the route plan constraint and to the perceived free space and obstacles. It works in a space which is essentially a geometrical one. As it belongs to a rather low hierarchical level, it plans the path, the speed and the orientation of the vehicle in a very accurate way. We can envisage an accuracy of about 10cm for position, less than 5cm/sec for speed, and more or less 1 degree for orientation. In any case, this system belongs to a fast loop and so it has to perform "real - time tasks", let's say its frequency updating rate is equal or less than 1 s. Basically this rate will depend on the type of terrain and so on guidance law.

- Performances

It is targeted the system to achieve the capability of local planning in real time (free path computation within the field of perception) for vehicle speed of 10 to 20 km/h.

The time delays of decision making loops which are targeted are around the following :

1	--> 100 ms	for low level action control
0.1	--> 2 s	for local path level
2	--> 20 s	for global route
20	--> 200 s	for robot mission level

4) First results

The first concretization of that developments is the robotization of a commercial land vehicle which is now fully equipped with actuators, perception and navigation sensors and computing hardware. This vehicle is used as a project test-bed allowing continuous integration and tests of system functions, and it is expected the autonomy capabilities of the vehicle to upgrade continuously as software modules are integrated and refined.

Up to date the first version of the following functions have been successfully tested :

Visual beacons detection (SEPA and CEA), Attention focussing (LNETI), environment modelling (CRIF), Local path planning (CEA), localization(SAGEM), and piloting (VTT,CEA,SAGEM). The automated land vehicle features controlled actuation of steering, throttle and brakes and is able to navigate autonomously in a blind mode, outdoors in an industrial site .

The first integration of the on-board part of the Panorama system in the test-bed vehicle is planned by the end of this year(1991) and it is foreseen the vehicle to perform autonomy with environment interaction ability (i.e., obstacle avoidance) in a structured environment by beginning of 1992. In a second stage more and more complicated scenarios will be considered and eventually final system capabilities will be demonstrated within forest and open mine environments by the end of 1993.

Another important issue of the project is an original configuration of the computing hardware architecture which allies advantages of well-known VME based systems (for interfaces with sensors and actuators) and the high computing power potentialities of Transputer based architectures (parallelisation of high level processing for modelling,planning and decisionning processes), enabling an easy upgrading of system performances and large flexibility in development. This issue is owed to a close collaboration between workpackage leaders of the project (BAe,SAGEM,SEPA,CEA,VTT).

The application-oriented approach of the project made us to consider new solutions for navigation and localization of industrial vehicles. This led SAGEM to the definition and prototype realization of a low cost navigation system based on the hybridation of of an attitude measurement unit , GPS, and processing of cartographic data. As a main component of this navigation system, the issue of a prototype of an inertial strap-down vertical and azimuth reference unit "CARO"(Centrale d'Attitude Robotique), especially designed for robotics, is a relevant spin-off of Panorama and prepare future industrial developments/applications in vehicles automation.

5)PARTNERSHIP

Panorama is a collaborative project which gathers 7 major european industrial companies associated to 7 famous universities and research institutes , belonging to 6 countries of the European Community and to Finland as an EFTA country.

Participants	Country
SAGEM	F
BRITISH AEROSPACE PLC	UK
EASAMS LTD	UK
CEA - LETI	F
SEPA SPA	I
TAMPELLA LTD TAMROCK	SF
UNIVERSIDAD POLITECHNICA DE MADRID	E
RAUMA REPOLA	SF
LNETI	P
EID	P
CRIF/WTCM	B
TECHNICAL RESEARCH CENTRE OF FINLAND	SF
HELSINKI UNIVERSITY OF TECHNOLOGY	SF
UNIVERSITY OF SOUTHAMPTON	UK

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