DEVELOPMENT AND PRESENT STAGE OF CONTROL STRATEGIES COMPUTING ARCHITECTURES FOR A MOBILE ROBOT IN MINING PROCESSES

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ABSTRACT: In this domain more and more researches from all over the world, especially in universities, brings new proves of mobile robot's importance.
The paper present the most important aspects of control computing architectures of wheeled mobile robots and the possible applications in mining industry for exploration of dangerous zones, where people haven't access.

РАЗВИТИЕ И СЪВРЕМЕНЕН ЕТАП НА СТРАТЕГИИ ЗА УПРАВЛЕНИЕ АРХИТЕКТУРАТА НА ПОДВИЖЕН РОБОТ В МИННИТЕ ДЕЙНОСТИ
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РЕЗЮМЕ: В тази област се извършват все повече и повече научни изследвания по целия свят и особено в университетите, което е доказателство за значението на подвижния робот.
В статията са разгледани най-важните аспекти, свързани с компютърно управление на движещи се на колела, роботи, както и възможните негови приложения в минната индустрия при проучване на опасни, трудно достъпни за хората, зони.

1. GENERALITIES

Mobile robots represent an incited field because of the different parts involved: software, electronics and mechanics. The study presents some special models of computing control architectures for mobile robots, holding count about few requirements which the architecture have to satisfy: modularization, sustenance, adaptability and generalization. This means that it has to be compounded from some independent modules, capable to incorporate easily new characteristics. Because of these characteristics, the mobile robots necessitate special architectures, capable to convert the low level signals, generated of sensors in high level information, which is processing on her base making decision and executing specific actions.

In sense of definition, a mobile robot is an embedded real-time system which has sensors for the perception of environment, execution elements for the actions about environment and a control system for the perception in action. The perception, the action and application between them are most important aspects which define a robot mobile.

The most known type of mobile robot is Automated Guided Vehicle, being used by large scale in industry, even mining industry for material transports. Because such kind of mobile vehicle operate in pre-programated environments, its are inflexible and fragile in operating, any unforeseen modification of route being able to run at compromising of entire mission. Alternative represent the build of mobile robots with autonomy in movement. The autonomy means ability of mobile robot to move in environment for complete different tasks, ability to adapt to modifications of environment, ability to learn from experience and to change his behavior (the way to action). Also, autonomy means ability to built internal representations of environment able to be used for making decisions processes. These characteristics allow the use of these structures as applications for transport, supervision, orientation, evolution in heavy environments or hostile human operators like robots from mining industry.

2.THE STRUCTURE OF A MOBILE ROBOT

The structure of mobile robots correspond to general architecture of robots, having two parts:
- Mechanical structure which determine the technical performances.
- Electronical structure, (command and control) which conditions the qualitie of performances.

The mobile robot interaction with environment through by his mecanical structure, assuring the gripper movement, position and orientation. The mechanical structure contains:
- Locomotion system (with caterpillars or wheels)which assure the locomotion of robot on a working surface.
- Manipulation system which assure gripper position and orintation.

The locomotion system with caterpillars (fig.1) allow onwards and backwards movement, a rotation on horizontal plan and allow to robot to effect the left and right yaws.
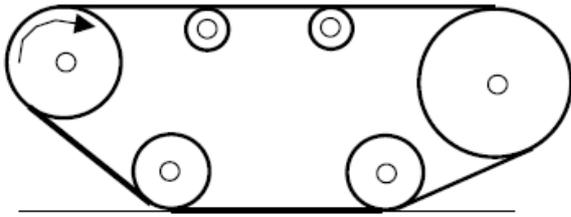
Fig.1.The locomotion system with caterpillar

The locomotion system with wheels allows the greater locomotion speed than the locomotion system with caterpillar,
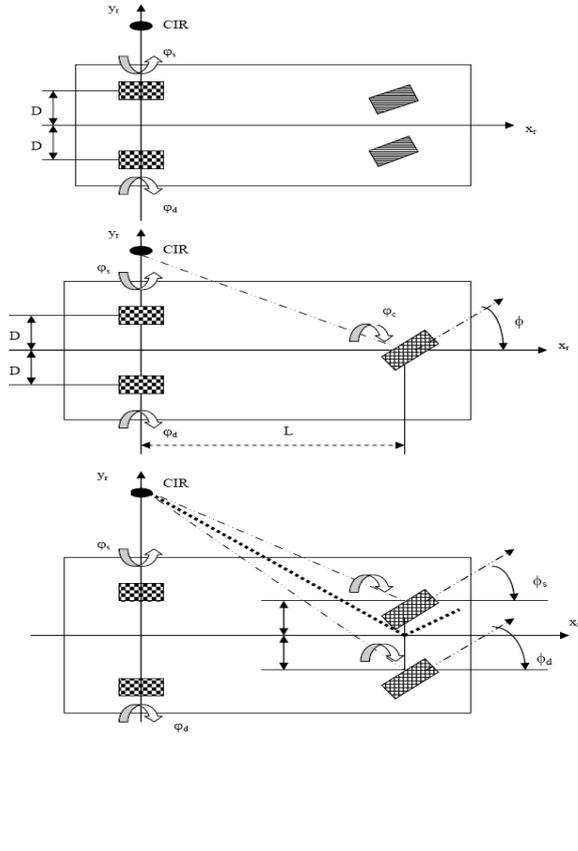

**Fig.2. Locomotion system with neorientable and orientable wheels.**

The selection of the most appropriate locomotion technique for a robot system was carried out by evaluating the most promising techniques by comparing certain criteria e.g. reliability, rough terrain performance, suitability for purpose, etc. Eight techniques were evaluated; Tracked, Purely wheeled, Articulated and Cartesian walking robot, Frame walker, Hybrid "legs with wheels", Flying (Fixed wing and rotary) and a Wheeled rover with High adaptive chassis. The initial selection was based on performance criteria derived from the user requirements, from this the most suitable concepts were under further review. The final contenders for the locomotion system were: Wheeled Rover with High Adaptive Chassis, Hybrid "leg with wheels" and Tracked Robot. These techniques have the potential to meet the requirements. Walking systems are, in fact, best suited for rough terrain but are too slow and difficult to control. Flying robots need complicated control systems and the high payload requirement to carry all the scientific instruments would make the flying robot solution very expensive.

having movement possibilities over smaller obstacle than the other case. Both of them are used in mining applications in function of demands and circumstances.

The kinematic of mobile robot is defined by the number, type and arranging wheels of mobile platform.
The mobile robots can have different type of wheels:
-conventional wheels, which can be ne-orientable,centrated orientable or orientable(fig.2).
-wheels with caterpillar;
-spherical wheels (Maxwheel wheels).
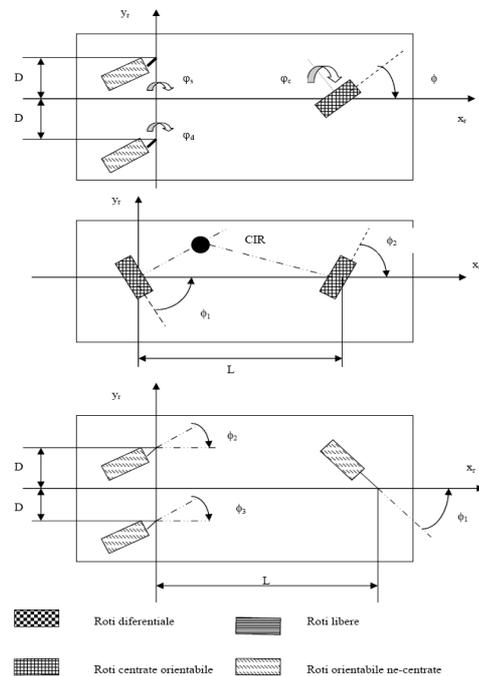
Hybrid systems are very promising, since they should have both the advantages of wheeled and legged machines. Though some successful results were obtained, in some situations the drawbacks of wheeled systems (low traction) and of walking systems (unstable and difficult to control) were apparent. The final selection of the most suitable concept was achieved by a qualitative assessment against key criteria. The criteria being that the solution be; able to achieve the user requirements and specifications; robust and reliable; easy to use and maintain; and have exploitation potential (cost effective). The favoured vehicle concept was a six wheeled chassis with a large range active or passive suspension. It is expected that differential steering will be adequate for the specified requirements and improve robustness and reliability.

3. BASE CONCEPT OF CONTROL AND DYNAMIC MODELLING OF ROBOTS MOBILE MOVEMENT

From functional point of view, classical control scheme of a mobile robot h3ave a appellation of „sense-think-act cycle", which the control system is decomposed in 5 functional blocs:
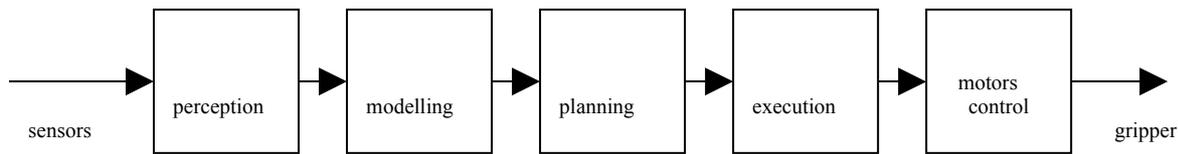
Fig.3. Control scheme of a mobile robot

Perception bloc is seeing about the dates processing from robot sensors, dates which are used for the implement some environment models where robot works (modelling bloc).Planning bloc uses the environment model for decide an action plan of robot in function of the robot tasks. The execution and control will execute the proposal actions.

For realise a model environment where robot works we have to find the matrix equation of the real-time robot control, which can be written in this way:

$$\overline{V}(t) = \overline{\Gamma}(t) = \overline{Q}(t) = \overline{X}(t)$$

Such a model can be applied to mobile robots which are to perform simple operations while the parameters which expresses the functional accuracy exhibits low values.

The real structure of a robot demans a severe analysis of the matriceal equations resulting from above, as it follows:

- $\overline{\Gamma}(t) = f(\overline{V}(t))$ - represents the dynamic matrix equation of the driving system;

- $\overline{Q}(t) = f(\overline{\Gamma}(t))$ - characterizes the dynamic matrix equation of transmission;

- $\overline{\theta}(t) = f(\overline{Q}(t))$ - the dynamic matrix equation of the robot mechanical structure.

- $\overline{X} = f(\overline{\theta})$ - represents the matrix equation defining the robot geometrical model, influenced by the elasticity and mass distribution corresponding to the mechanical structure links.
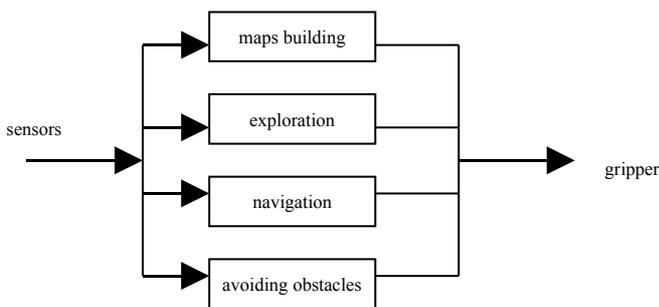

Fig.4.A behavior-based control architecture.

A control architecture completely different was proposed by Rodney Brooks and then Ronald Arkin. This architecture (behavior-based) (fig.4) proposes the usage of levels set, each level containing a control program able to work in speed which may produce changes in environment.

4.DEVELOPMENT OF CONTROL ARCHITECTURES FOR MOBILE ROBOTS.

The major purpose of fundamental research in elaboration of control architecture for a robot represent the development of a control for the command in real-time of robot's movement having the locomotion system compound from wheels actuated of electric motors, so that the robots to be capable to realize tasks of navigation in different type of working spaces, under the action of different control and operate modes: teleoperating, quasi-autonomous and autonomous.

For the realization of this objectives, will be scanning the following research stages:

1. Cinematic and dynamic modulation of mobile robots class having the locomotion system compound from combinations of wheels.
2. Specification of internal sensors and external multiple sensors with ultrasound and visual of type video camera and a method and algorithm of acquisition and purveyance of information.
3.Comparative studies of description method of working space, concordant of structure level and nature of obstacle (parking mobile), the choice and implementation of general normalization of unknown zone's description.
4. Elaboration the method and localization algorithm based on odometrics principle: the specification kind of map based on the breaking down in spatial cells, their maintenance and updating with information help from external sensors.
5.Formulating problem of desired purposes. The design of system in real-time, with the avoiding of dynamic obstacles and mainlining global cost functions.
6.The define of behavior classes of robot system:
    -principle;
    -security;

-preventive.

7. The choice of control architectures and elaboration of algorithm and implementation programs of elementary behavior modules.

A classification of control architectures may be done after following criterions:

1.Criterion "control system complexity": mobile robots by Alpha type (simple reflexive structure), Beta (with storage locomotion vector), Gama (with anticipation capacity).

2.Criterion "control philosophy" :hierarchical architectures, reactive architectures and hybrid architectures based on behaviors.

Among hierarchical architectures, the most representative is NASREM (NASA Standard Reference Model) suggested by James Albus for manipulator control from spatial stations. Reactive control architectures have affiliated the reflexive process concept, which means that a learnt trajectory may be executed in reflex mode, in similar conditions.

Control architectures based on behaviors appeared like solutions at problems by lack of precision. Its combine the qualities of two preceding structures: the classic hierarchical architectures precision and reaction capacity of reactive architectures, by deliberately judgment mechanisms.

Analyzing these two proposals of methodologies, it can finish a global proposal of design and implementation of one control architecture for a mobile robot:

- The defining of movement command problem and principal purpose: autonomous navigations with adaptation at environment dynamic (mobile obstacles, identification and interest objects localization).
- The specification of functional conditions and demands for control system.
- Analyze of command problem and method determination which it have to be solved by system by decomposition in elementary tasks and specifying necessary hardware and software mechanisms.
- Define software components in real-time of control system.

Base concepts for movement control of mobile robots chose methodology will be used for design a control software architecture for mobile robots which move in non-stationary environments.

The following figure presents the control system scheme, with user interface and mobile robot environment.
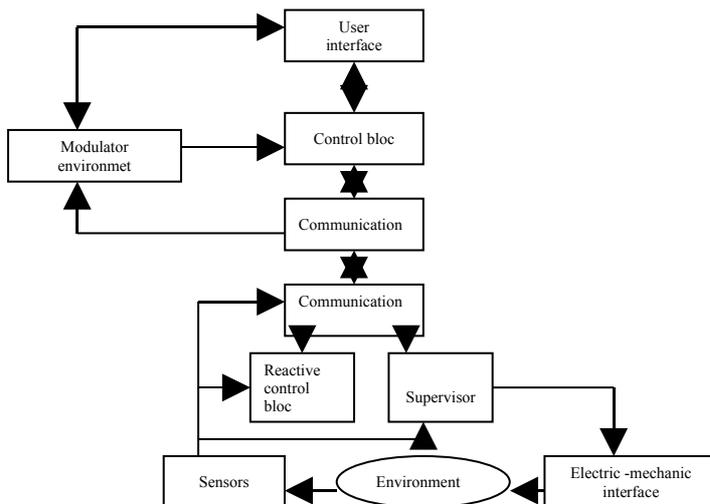

Fig.5.Control system scheme

The function of user interface consists in robot movement supervisor. In this purpose, interface have to receive and type following informations:

a). all previous parameters and confirmed by each task execution.

b). current translation and rotation speed, current position and orientation robot relating to reference system defined by user;

c). dates caused from sensors;

d). current stage of battery charge from mobile robot platform.

Control bloc will contain following specialized modules:

-environment modulator;
-control unit;
-communication modules;

-supervisor;
reactive control unit.

The advantage of dual reactive control scheme, in comparison to developed solutions means that exists situations which global system hasn't free necessary time for estimate in real time, on base of sensor's information, next command actions.

Such cases are determinate by situations of imminent crash danger, which for the immediate protection of robot is important in comparison to standard actions of navigation regime.

In return, if system is in a safe zone, control bloc will select and apply a determine action through by control unit.

Deliberate action base on environment knowledge, will help of one map which model it.

Modulator of environment: analyzing the different proposes for last years in present, in mobile robotics for modulation of environment (typology map and on-line methods) and will adopt in current researches, the quad trees environment map.
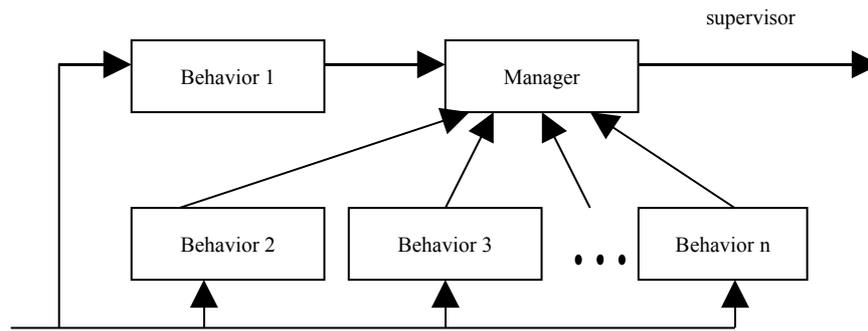

Fig.6.Reactive control architecture

In last years, in Robotics has appeared the concept "Behavioral Engineering" which major purpose is the ensemble of methodic and technical solutions for development adaptation and intelligence level of autonomous mobile robots.

Because of limitations in applications determined by established routes and the risk in dangerous spaces like a mine, dynamic mobile robots, these going to minor ameliorations of function autonomy. From these reasons the entire world researches have regarded creation some control and perception more efficient systems which give intelligence robot mobiles behavior, in their principal function navigation, with generation in real-time of self-routes.

One of the most important tasks of a mobile robot control system is the trajectory planning (fig.7). The main goal for such a control algorithm is a collision free trajectory that leads to the desired target point. In achieving this goal, the quality of the robot - environment interaction, especially the environment model accuracy is the key.
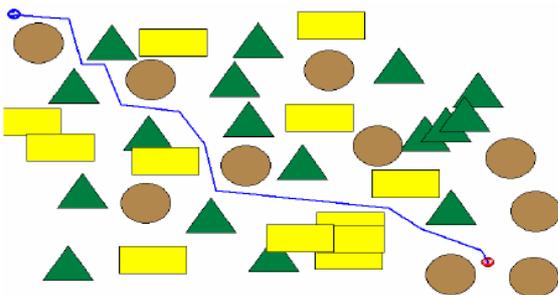

Fig.7.The determination of a mobile robot trajectory

For the obstacle avoidance behavior, a classification engine is to be created, one that can recognize either simple or more complex shapes. For this purpose a competitive neural network is chosen. Its output units are formally divided in classes. The first class comprises the simple competitive units that become active with one only neuron of the correlation layer active, meaning there is only one reflection source present in the investigated environment.

The surrounding environment features are strongly related to the brain activity patterns, and a correlation between this two can be created. In other words, it is possible to cluster the incoming sensorial patterns in classes, because there is a univocal relation between the fired class and the spatial position. Having in mind this biological example, the proposed structure for the *obstacle avoidance behavior* is distributed on three different levels.

The first level processes the ultrasonic sensorial information recorded by a biaural transducer system. The first level processor is a simple perceptron. It correlates the incoming ultrasonic field levels with known patterns stored as the perceptron weights. The perceptron neurons are spread over the inspected area, in front of the mobile robot. As already previously mentioned the second level achieves a clustering job. A simple competitive neural network is used to recognize the mobile robot spatial position based on the images generated by the first level. The last level, the third, decides the mobile robot azimuth correction as a function of the recognized situation and a set of empirical inferred rules.

From a historic perspective, the mobile robot control systems started with the hierarchical architecture, based on the *sense-plan-action* control cycle. Specialized literature provides several other names for this control paradigm: *high level control systems, coded behavior or analytical method*.

The most defining characteristic of these systems is the serial style processing cycle. First the robot acquires information from the environment and updates the internal environment model. Then the robot is reasoning about the necessary steps that should be taken in order to achieve the goal. And, in the last stage the robot executes one by one the tasks in the list resulted from the second phase.

The three steps described above form the *sense-plan-action cycle* which is repeated indefinitely, and is invoked each time the current action set stops matching the reality. Another main characteristic of the hierarchical control system is their *global environment* model. Unfortunately, such a model which should represent as many environmental details as possible, is very hard to conceive and maintain up to date. Even if ideally such a global model would be available, it is impossible to use an enormous data quantity for real time control.

These totally disappointing results moved the mobile robot field researchers to other new directions, to develop new and faster robot control algorithms. Thus, in the second half of the '80 the behavioral control theory is born.

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The one that first proposed the new idea was Brooks (1986) who proposed to assign a specific motor action to a specific stimulus for satisfying the present demand. In the new emerged theory the connection between stimulus and its action is called *behavior*. By means of using behaviors the robot is able to respond quickly to the environmental conditions, in a reflex manner. If multiple behavioral connection coexists, an apparent intelligent robot behavior may merge. In the new control approach the environment model is avoided by purpose. It is advocated the idea that the environment is the best model for itself .

The behavioral mobile robot control has gained a lot of interest in the last years. Nowadays, behavior such desire, intention and emotion are studied. The most important features of an efficient mobile robot control system are:
• Reliability;
• It should be easily adapted, or even better to adapt itself, to the environmental and sensorial system performances changes;
• It should be able to learn from it past experiences, and even to generalize from its already gained knowledge;
• It should react quickly in order to work in real time.

5.CONCLUSIONS

The control and command of a mobile robot in an incert and unknown environment like a mine represent a priorital orientation in robotics.First of all, using real mobile robot in mining experiments imply not only high expenses but also long experimenting time periods. In contrast, if a sufficiently reliable environment model could be conceived, then substantial amount of time and money can be saved with the simulations.

A mathematical model could be used to generate such data. Performing simulation in such cases could even contribute to a better understanding of the environment. In a real case some other features could be added to the robot action and behavior in order to obtain a more intelligent control system.

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