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**8th IARP Workshop**

**Robotics and Mechanical assistance in Humanitarian**

**De-mining And Similar risky interventions**

**HUDEM’2010**

**10, 12 May 2010**

**National Engineering School of Sousse**

**Tunisia**

**PROCEEDING**

**Background**

Robotics solutions properly sized with suitable modularized mechanized structure and well adapted to local conditions of dangerous unstructured areas can greatly improve the safety of personnel as well as the work efficiency, productivity and flexibility. Solving this problem presents challenges in robotic mechanics and mobility, sensors and sensor fusion, autonomous or semi autonomous navigation and machine intelligence.

The workshop will review and discuss the available technologies, their limitations, their adaptability to different environmental natural or artificial calamities (humanitarian demining (OTTAWA treaty, OSLO treaty including the detection of sub-munitions) but also Earthquake, fire, chemical pollution, natural disaster, CBRN-E threat, etc) and discusses the development efforts to automate tasks related to detection / interventions processes wherever possible through the use of Robotics Systems and other technologies.

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Mobility and stability of robots on rough and soft terrain: Modeling and control

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**Abstract**

On rough non-cohesive terrain, mobility or stability of a mobile robot could be critical. Then, control and planning processes must be based on relevant indexes which qualify system performances or the risk of immobility or instability.

Many models for characterization of locomotion systems exists, going from local approaches as the terramechanics to global approaches as used for biological systems. Terramechanics concerns mainly rolling systems and turned toward traction capacity evaluation as function of soil mechanical properties. It defines many mobility indexes based on a dimensional analysis of the traction on soft soil and a simple characterization using a penetration resistance measure called cone index. Terramechanics defines also a measure for traction efficiency which gives the optimal slippage ratio for a driven wheel on a loose ground and when the desired drawbar pull is important.

In opposite to terramechanics, biology and biomechanics propose global methods that analyze animal locomotion principles, and their extension to artificial locomotion systems such as wheels and tracks. Particularly, land locomotion modes, namely walking, running, peristaltic crawling, serpentine crawling and rolling, could be compared according different criteria, especially the mechanical cost of transport.

The paper deals with methods used for mobility and stability characterization of redundant articulated robots on natural irregular terrain. First, we give the structure of their mechanical models and their interaction models with natural soils. Basically, the two concepts of mobility and stability could be generalized by the one of force transmission between the contact, joint and task frames. Some methods directly inspired from manipulation or grasping applications will be used here for characterizing the obstacle clearance of articulated mobile robots or their stability on uneven ground surface Then we will analyze the velocity and force transmissions of locomotion system and proposes an extension of usual manipulation measures applied to the obstacle clearing evaluation of an articulated wheeled robot RobuRoc6. A kinematic decoupling-based analysis is proposed and applied to the hybrid wheeled and legged robot Hylos.

We will also develop through the terramechanics theory the relationship between mechanical properties of the ground material and the vehicle mobility, and show how these results can be used for trajectory tracking in the presence of skidding and slipping. In connection with that, the identification of ground properties and state parameters estimation such as ground velocity will be discussed.



About a New Design of Pneumatic

Walking Robot – (8LWR)

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**Abstract**

Autonomous robots are leaving the laboratories to master new outdoor applications, and walking robots in particular have already shown their potential advantages in these environments, especially on a natural terrain. The 8LWR is an eight legged, pneumatically powered walking robot. The pneumatic actuation system provides lightweight, powerful actuators. The robot's mechanical structure is a lightweight frame built from aluminum materials. This paper presents the development of a new design walking robot and turning gaits for octopod robots on a natural terrain characterized by containing uneven ground and forbidden zones. The gaits that offer the 8LWR have been fixed. It has height legs powered by compressed air at 5 bars.

The frame has been divided on tow parts relied with two DOF to offer the move on and the turner

The robot structure was composed of two moving parts ensuring its deviation. The relative movement of these two parts is ensured by 2 DOF. The action was given by two pneumatic cylinders.

The geometrical model of the 8LWR walking robot has been used for demining and inspection purposes. This robot has been built as a mobile platform for a sensory system to detect and locate antipersonnel landmines in humanitarian demining missions.

The walking platform robotic structure is composed of two parts dragging one on one with an alternative motion by two cylinders. Each part is supported by 4 legs of each which are commanded by a cylinder.

The two cylinders allow rotation to the right or left, two parts of the platform, combined with a movement of walking forward.

The particularity of this robot is its 360° rotation on itself without needing to move. This specificity allows both the reversing without resorting to a movement back and a vision on an angle of 360°.

**Keywords:** Walking; Robots; Legged robots.

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| **Fig.1 : Robot architecture** | **Fig.2 : 8LWR** |

A new concept of fast mobile rover with improved stability on rough terrain

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**Keywords:** *mobile robots, high speed obstacle clearing, wheel impact, active and reactive suspension design, dynamic modeling, stability control.*

**Summary**

Crisis conditions such as earthquake rescuing or de-mining operations require fast deployment and rapid analysis of broad areas of unstructured environment. In this context, a float of mobile, fast and inexpensive robots could be of great usefulness for extensive scanning of the area.

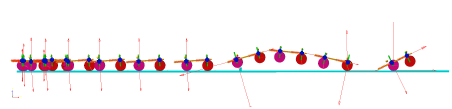
One important problem to address is mobility on irregular grounds at fast speed. The FAST program of the French National Agency of Research is dedicated to design an innovative mobile robot of about 1m and 150kg, capable to move at 10m/s on irregular grounds. Work is in progress on innovative mechanical architectures, as well as advanced control strategies. This paper focuses on straight line motion and pitch angle stability during dynamic crossing of steep obstacles at 10 m/s.

First, environment must be described and ground irregularities or obstacles must be categorized. Parameters such as obstacle height, wavelength and shape are defined. For this work, the rover is supposed to impact the obstacle with both front wheels at the same time, which allows to use a simplified 2D model in the sagittal plane with only pitch and no roll.

Although legged robots are known to be efficient on irregular grounds, fast motion of small robots is easier to achieve with wheeled or tracked architectures. Wheels were preferred to tracks because of low cost, energy efficiency and shock absorption properties of tires. In a second part, a simple model of a rolling heavy wheel with friction contact is presented. It allows to demonstrate the strong connection between the dimensions of the wheel and obstacle, the influence of engine torque and speed motion, and the importance of a parameter that is difficult to model: contact stiffness.

The main difference between irregular grounds and roads is the obstacle height and slope. The new rover should ensure fast crossing of steep obstacles as high as 80% of the wheel radius. This is similar to high frequency crashes on the wheels that have mostly a horizontal contact force component. From this remark, a new concept of suspension arises. To the classical vertical suspensions found on road vehicles, it also adds a longitudinal suspension, thus providing horizontal and vertical mobilities to each wheel with respect to the vehicle body. The third part of the paper presents a multibody model on Adams software that demonstrates the efficiency of this concept (Fig. 1). Virtual experiments allow to explore the design space of the robot and to find optimal values for the stiffness and damping coefficients of the vertical, horizontal, front and rear suspensions that maximize the pitch stability on a given obstacle.

Future work is traced to improve this original suspension, with is here shown in a passive version but may be transformed into an active suspension with additional control strategies.



***Figure 1.*** *Multibody modeling of obstacle clearing of a mobile*

*rover at 10 m/s with an innovative suspension.*

**Design of the W-AntNetSec Routing Protocol**

**for Robot WSN Platforms**

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**Abstract**

Recently, there has been renewed interest in using mobile robots as sensor-carrying platforms in order to perform hazardous tasks, such as searching for harmful biological and chemical agents, search and rescue in disaster areas, or environmental mapping and monitoring. Due to its high sensitivity, the data transferred on sensor networks should be secured, either user data or network protocol and management data. The unreliable communication channel and unattended operation make the WSN security defenses harder compared to the environments of conventional wired networks. Since sensor networks are known to be limited by severe resource constraints due to their lack of data storage and power, any security protocol should be mindful of this specific limitation. In this paper we present the work we carried to design a first implementation of the W-AntNetSec routing protocol using the ns-2 simulator. We focused on securing this protocol thus making it more efficient in sensor environments when used as Robot deployment platform.

**Keywords:** Sensor networks, Secure routing, AntNet, Simulation.

e-Training in RISE and HUDEM

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**Abstract**

The need of training of RISE and HUDEM systems’ operators is discussed in the article, and the way to satisfy this need by e-training is suggested. Experiences resulted from the project developed by the authors, with the aim to build computer platform enabling generation of trainers-simulators for e-training of operators of inspection-intervention mobile robots are presented.

Contemporary robots used in RISE and HUDEM field are of rather narrow autonomy and need to be driven by skilled operators. Furthermore, although RISE robots’ ability to autonomous operation will increase as control technology advances, and yet human operators have to interact with robots for covering tasks responding to altering needs of a mission. Thus, training of RISE and HUDEM robots operators is a necessity. Taking into account that the demand for skilled operators will increase because of increasing both number of robots and their applications, requirement for efficient and suitable for mass-use training methods appears. E-training methods will turn out to be very helpful in this situation. E-training is understood here as an extension of e-learning: e-learning consists in computer-network-based obtaining of knowledge, e-training has in view obtaining of operation skills. Similarly as in the case of e-learning, e-training systems will be able to serve large number of geographically dispersed learners, and self-paced courses accessed 24 hours a day, whenever they are needed, will be possible. As experiences of flight and driving schools show, the use of flight and driving simulators software, even installed on PCs, enables to cut costs of training even by half.

One can anticipate that diverse types of robots, differing by kind of traction, load capacity, range, manipulation ability, equipment with sensors will be applied in RISE and HUDEM missions. A need to train significant number of persons in operation of these robots, and obtaining high proficiency in operation, will come into being particularly for the sake of possible contact with explosives and toxic substances creating dangers for operator, population, and environment. Training tasks require many hours of exercises with different types of robots. Conducting of such training with use of real robots would be unprofitable, and probably unfeasible for the technical and organizational reasons – for difficulties of creation of all possible situations and coincidences with which an operator of robots has to cope. The use of trainers, simulating robots’ behavior in different situations and circumstances, will be a necessity. Such trainers, for different types and variants of robots, will have to be designed, manufactured, delivered to users and serviced, so establishing of an innovative enterprise of adequate profile will be justified. Computer platform being a subject of the project under consideration will be the basic “manufacturing appliance” of such enterprise.

About Evaluation of Electromagnetic Perturbations

Generated by Electronic Converters in Robotics

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**Abstract**

Electromagnetic compatibility / electromagnetic interferences (EMC/EMI) filters are widely used in robot sensors and actuators. These machines are usually electronically controlled. The sensitive electronics must be protected from EMC perturbations which can interfere with the process quality and the reliable functioning of the machinery.

The aim of this paper is to carry out an electromagnetic perturbation study of a power converter commutation cell in which perturbation measurement is ensured by means of an impedance stabilizer which is a device to create known impedance on power lines of electrical equipment during electromagnetic interference testing. It ensures two tasks: isolating the device under test from the net on which perturbations of both common and differential modes may occur, and allowing measurements in better conditions. Reduction of the undesirable phenomenon caused by the parasitic elements of electromagnetic perturbations needs to go into the commutation mechanism study of the most simple of power converter structures: a commutation cell. Results of this approach are very interesting and their analysis worth going into.

Keywords: Electromagnetic Compatibility, Power converter, switching cell, Parasitic Coupling, Electromagnetic perturbations, High frequency.

Logical solution for design, construction, production and deployment of automated technologies for environmentally friendly production of fruit and vegetables for fresh consumption in open and closed areas and Robotic Complexes for demining of mine fields

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**Abstract**

The material is a review of existing technical solutions and components ready for creation of complex-Robotic comprehensive solution for eco-friendly production of fruit and vegetables at outdoor and indoor areas for demining of minefields. Basis for establishing a transfer to be footed by the principle of printsishtat action of double acting pneumatic cylinder. Separation of each robotic harvester modules for a specific type of activity leads to minimize aggregation of the necessary energy.

Combines Production of robot-robot Complexes for production of organic fruits and vegetables in open areas are designed for a specific location for the operation, by type of fruit or vegetables and a variety of modules based on the actual liner removal from industrial robotics. To be effective in service to design and build additional manufacturing enterprises.

Organizational structure and working principle of the kind of Robotic Manufacturing harvester working with industrial robot type portal with amendments and additions to the basis for design and construction of complexes for Robotic Demining of environmental minefields. In adjacent and complementary technologies providing de-mining work of Robotic Robotic harvester creating complex environmental mining of minefields. Robotic mining to combine a radio controlled flying stredstvo a system for detecting the mine field and construction of the scheme itself elektornna field carrying electric cars full and empty containers for transfer to a mobile mini-inactivated or fixed utalizatsionen center.

The most recent economic resource areas cleaned of mines should be used for automated production of organic fruits and vegetables for fresh consumption.

Chemical Explosive Detection for Robotic

Demining Application

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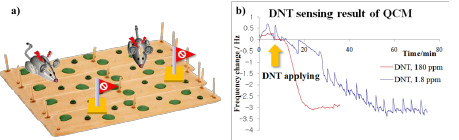
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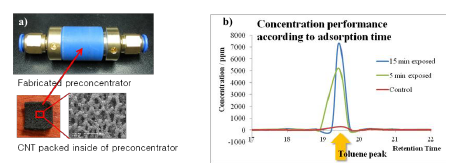
**Abstract**

This abstract reports an explosive detector system which consists of an anti-explosive sensor and a preconcentrator for detecting out extremely low chemical trace of trinitrotoluene (TNT) from anti-personnel mines. Unlike conventional mine detection methods such as metal detector and ground penetrating radar, our sensor directly recognizes the explosives on small robots deployed in a mine field (Fig. 1 a) [1]. A highly sensitive quartz crystal microbalance (QCM) is employed and functionalized with an explosive-specific capture molecule. Intriguingly, we adapt a biological peptide sequence screened out of peptide library using the phage display method, which resulted in a receptor specific to 2,4-dinitrotoluene (DNT) [2]. The DNT is a degraded form of TNT in atmosphere, thus represents the mine chemical. Cross-reactivity of sensor is verified by confirming that this sensor does not respond to analogues such as benzene, methanol, and ethanol, but reacts only with the DNT. Its reactivity is examined with wide range of concentrations, from 180 ppm to 1.8 ppm (Fig. 1. b)). Our sensor shows constant and repeatable responses to DNT exposure, up to 3 Hz of oscillation frequency change. Signal stability for an hour is less than 1 Hz at its nominal frequency, 5 MHz. The response time at 180 ppm DNT concentration is less than 10 minutes.



*Fig. 1. a) Concept of mine detection with deployed chemical sensors. b) DNT sensing result of QCM*

In order to detect the extremely low level of explosive molecule encountered in a real field, one needs to use a preconcentrator for a practical level of sensitivity. We use carbon nanotubes (CNTs) for absorbing and concentrating the analytes. High surface area of the CNT makes it a good adsorbent. The accumulated molecules on the large surface of the CNT is released at once and sent to the sensor by a heat pulse. The CNT itself can be used as a highly conductive Joule heating element in our system. The concentration performance is investigated with a gas chromatography (6890N, Agilent, USA). Despite its small adsorbent amount, 0.45 cc, the preconcentrator boosts up the concentration of a model molecule (toluene for present case) 19 times after absorption for five minutes and 27 times after 15 minutes (Fig. 2. b)).



*Fig. 2. a) Fabricated preconcentrator. b) Concentration performance according to adsorption time*

**Reference**

[1] Claudio Bruschini , et al., “Ground penetrating radar and imaging metal detector for antipersonnel mine detection” Journal of Applied Geophysics, Vol. 40, Issues 1-3, P. 59-71, 1998.

[2] Ellen R. Goldman et al., “Selection of phage displayed peptides for the detection of 2,4,6-trinitrotoluene in seawater” Analytiica Chimica Acta. Vol 457, p13-19

**New technologies to face CBRN-threats:**

**our vision**

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**Abstract**

The scenario of a terror attack using mass destruction and non conventional warheads is today a major concern of Europe. A device including CBRN-E (Chemical, Biological, Radiological, Nuclear agents and Explosives) agents may be found before its activation. It is widely accepted that such a scenario will be possible in the near future. In such a scenario it may happen that the device is not yet activated and Special Forces are required to give an immediate response. Most of these devices will contain only explosive warheads, but some chemical projectiles, which were left during and after WWI are still around in Middle Europe countries. The current technology of neutralization of munitions is based on remote manual operation, which is a very demanding and dangerous activity, since the human operator is assumed to remember technical details of thousands of possible treats. The innovative technologies should thus include a computer based device localization and identification, the development of an intelligent Command, Communication and Control station, where new sensors and human supervised autonomous control enables a distant intelligent robot to perform its task with maximum available knowledge; precise manipulation and world wide technical support in order to maximize the probabilities to successfully complete the task to neutralize a terrifying device. Some described activities are realized with the volunteered support of the Belgian relevant expert units (DOVO and DLD).



Design of robot's Adaptive Motors Controller

Based on Fuzzy Logic using Microcontroller

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**Abstract**

This paper combines two advanced technologies, microcontroller implementation and Fuzzy control, for the design of an adaptive multiple motor speed controller. The obtained solution compares favorably with classic methods in terms of design quality. The use of Fuzzy control allows implementing an original architecture which is faster and smaller then classical solution based on PID. The use of Microcontroller results in a drastic acceleration of the design process and increase design flexibility.

The robot controller acts between a "host machine" and a robot that makes use of 6 stepper motors. The controller is embedded in an on-board system. It interacts both with the robot's host machine and a group of motors. It adjusts the speed of each of the motors according to the distance to cover. A main computer computes the global motion of the robot and transforms it into specific elementary motions for each motor in the robot's coordinates. These elementary motions as well as some other motor characteristics are sanded to the memory of the microcontroller. For each motor, the controller system loads the remaining distance to cover. Then, using a fuzzy logic based algorithm, it computes the corresponding speed to smooth the motion of the robot and transmits it to the send module. The send module generates signals to supply the motor. The receive module memorizes the distance done by the motor in order to subtract it from the remaining motions in the memory.

With this architecture, this controller will compute concurrently all the motor speeds. The total execution time is obtained by multiplying one motor execution time by the number of motors. In this case we assume that we can have more then 6 motors to control at a comfortable reaction time. So, other motors can be installed on the robot in order to do some manipulations.

This paper presents the adaptive motor control application, the Fuzzy control approach and the results of the implementation using microcontroller.

Field Robot Teleoperation via Vibrotactile

User Interface

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**Abstract**

To prevent dangerous situations in the demining process, a heavy class mobile robot system should be controlled via teleoperation. A force-feedback joystick is often used for teleoperating a field robot to recognize environment’s obstacles and goal position with its resultant vector property. Since force-feedback joystick requires lots of electronics and heavy power to generate appropriate haptic feedback with large force, its size and required power are hard to be minimized. However, small size and

mobility are the key factors of a master controller in the field application. So many recent studies have explored the use of tactile cues, even they were confined to the unilateral display device.

Lots of bilateral haptic devices have been developed to provide a guiding force on an input handle, however, a vibrotactile stimulus has not been tried to present directional information on the handle.

This research introduces an attempt to combine a tactile display with an input device. A new 6DOF bilateral haptic device, which provides a spatial sensation on the handle using vibrotactile display, is proposed in this research. The sphere-shaped handle is specially designed to be covered with several pieces of vibrating panels. When a specific panel is activated, the user perceives the spatial location of the vibrotactile stimulus during an input operation. We introduce the design of the proposed device, including the selection guide of the dimension, location, and number of vibrotactile panels. The method for combination of vibrotactile stimulus and the way to achieve fine resolution with small number of tactors are discussed. Experimental results show that the users can reliably perceive the spatial information using the proposed device. A mobile robot that can be controlled by the developed haptic device was also simulated in the virtual environment. In this environment, the user easily follows the trajectory with guidance of vibrotactile cues, even in a dense fog. This application shows the practical effectiveness of the T-hive.

**A robot controlled remotely for area radioactivity topography**

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**Abstract**

We have realised a robot equipped with a mini camera based on a nuclear semiconductor detectors, Cadmium Telluride (CdTe) of elementary size of 2x2x2 mm3.¶ Two versions were designed one with 25 detectors and the other with 12 detectors.¶ Our objective is to propose a system controlled remotely to accomplish surface radioactivity topography.¶ This system can be also used as intra-operative camera in the medical field.¶

The originality of our approach consists on two points:¶

- The algorithm method to optimize the number of detectors per unit of detection area without losses of information.¶ A comparative experiment was done to verify the performances of our algorithm method using two different configurations in the number of detectors and in the geometry.¶

¶- The control and the data acquisition of the complete system are based on a connection remotely.

Multifunctional Surveillance Wallclimbing Machine.

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**Abstract**

The new type of multifunctional inspection robot is suggested that intended for environment surveillance by means of on-board inspection equipment. The structure of inspection equipment is interchangeable depends on solving tasks, such as nondestructive testing, detection of flame or fume, finding of mines. The sensors and information treatment system combine into inspection module.

The multifunctional inspection machine can move over horizontal, slope or vertical surfaces on the stepping mode operations. The structure of a robot is modular design. The paper presents description of main robot’s modules, including technological inspection, transport, control, information – measuring, supply. The technical parameters of the all machine are discussed.

The open modular design satisfies changing of the structure depends on inspection solving tasks. The information treatment system of the module produces representation and generalization of measuring data.

The base version of machine is supplied with the following testing equipment – thickness measuring device, structure material analyzer, video and photo for material testing of surfaces in real time. It is possible to use express diagnostics to provide video inspection in real time scale.

The sensory gauging and data processing includes several steps, such as measurement producing by means of necessary number of sensors, translation of the data to the processor unit, receiving information, is writing into data base and data base is open for man-operator reading.

The R&D was supported by Programs N15, N16 of OAMMPU, Russian Academy of Sciences.

**Key words:** multifunctional inspection robot, modular design, sensors, solving tasks, information measuring system, nondestructive testing.

Towards a human like voice command of robots

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**Abstract**

This ongoing research work aims to provide natural human language voice commands for robot control. We’re investigating segmentation and fuzzy formulation of human language in the context of complex command of robots. We start by training robot with simple fuzzy commands. Complex commands should then be expressed in terms of these basic commands to allow for smooth yet precise robot motion control. In this paper, we report results of the real time implementation of the voice identification part of the process.

Multi-robot collaboration and coordination

in a high-risk transportation scenario

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**Abstract**

This paper discusses a decentralized multi-robot coordination strategy which aims to control and guide a team of robotic agents safely through a hostile area. The "hostility" of the environment is due to the presence of enemy forces, seeking to intercept the robotic team. In order to avoid detection and ensure global team safety, the robotic agents must carefully plan their trajectory towards a list of goal locations, while holding a defensive formation.

The presented approach casts the multi-robot control problem as a behavior-based control problem. In the behavior-based spirit a complex control problem is divided into a set of simpler control problems that collectively solve the original complex control problem. This paper describes in detail how each behavior was designed and how the behavior fusion problem was solved. The behavior-based control paradigm was chosen, because it is inherently decentralized and because it thus provides a natural and elegant way to combine the different subtasks and capabilities of each individual robot and because - un- like more traditional sense-model-plan-act approaches - it scales very well when applied to a large number of robots.

An important aspect of the presented control architecture is that it is formulated in a decentralized context. This means that the individual robots have no knowledge of any global state parameters. As a result of this, the individual robots do not have a global map; hence they cannot rely on traditional global path planning algorithms for navigation. Instead, path planning is achieved through a behavior-based control paradigm, where multiple behaviors interact together. Each behavior considers one specific navigational task (e.g. avoiding obstacles, reaching a goal,...). Fusing all behaviors together leads to a complex global behavior, designating a path to be followed by the individual robots.

**Key words**: Multi-robot coordination, decentralized control, behavior-based control, formation control

Basic autonomous robot navigation

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**Abstract**

The evolution and democratization of different technologies of wireless communication, size and calculating power of computers, sensors capacities, image treatments, plug and play mechanical components with its electronic command during the last ten years, ease nowadays designing mobile robots.

This paper presents an overview of a project of designing a simple and universal command and control architecture dedicated to wheel driven autonomous and semi-autonomous robot. Mainly based on usual and economic hardware, the platform should be able to move while automatically avoiding obstacles. To accomplish tasks and navigate to the desired targets while reasoning intuitively thanks to the fusion of its sensors data, the robot could rely on a wireless human assistance with a mobile interface, when it’s necessary. Hazardous structured indoor and outdoor interventions are the main use of this robot. This project was divided into different subprojects and the obtained experimental results are reported.

**Keywords:** autonomous robot, robot design, autonomous navigation

An autonomous vehicle localizations system based on multisensor data fusion

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**Abstract**

Vehicle navigation systems perform three main tasks: positioning, routing, and guidance. In most navigation applications, the vehicle position is calculated from several information sources including on-board sensors, digital maps and the global positioning system (GPS).

This paper presents the conception of an autonomous vehicle navigation module which calculates the vehicle position and trajectory using only on-board sensors. The sensors used are: (i) an odometer which gives the distance information, (ii) a gyrometer which measures the angular rate of the vehicle and (iii) a magnetometer which provides the heading vehicle information.

Each sensor has measurement errors and cannot produce satisfactory results when used individually. The rate gyro yields bad results due to the temperature-dependent variation of its parameters such as zero-drift and sensitivity. On the other hand the magnetometer, sensitive to the earth’s magnetic field, can easily be disturbed by the magnetic environment variations such as local geomagnetic field variations, metallic structures, the vehicle’s own magnetic fields, etc...

In a first stage a study of the different errors of each sensor was done. Than appropriate models has been developed and applied to compensate certain of these errors.

Error sources of the gyrometer and those of the magnetometer are different, in a way that the two sensors are considered as complementary with regards to the heading information. In a second stage, in order to improve accuracy of the estimated vehicle heading, the rate gyro and magnetometer information is combined using a multi-sensor data fusion technique, based on the Kalman filtering.

The global system developed has been mounted in the vehicle in order to calculate its position and trajectory in real time. Test results and accuracy evaluations are presented.

**Modules for ROBOTICS Systems for Humanitarian De-mining: IARP WG HUDEM Contributions**

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**Abstract**

Several mobile remote controlled platforms for Humanitarian de-mining have been described (through IARP workshops), some ones illustrated by the figure 1.a to 1.i. The motion control needs to be highly sophisticated. General motion in difficult terrain needs advanced adaptive control. Closely controlled motion is required to deliver sensor packages to accurate positions when detection is in progress. The motion of the vehicle demands by far the highest power requirements. Whilst some scenarios allow the use of an umbilical, many need more autonomy so an on-board power supply is needed. Thus efficiency of motion is most important, requiring advanced control algorithms. On the other hand, speed is unlikely to be paramount since detection will take time and will probably limit forward motion. The modes of operation need to be specified. Most requirements have a man-in-the-loop operation and there is a direct line of sight operation at a safe distance. This safe distance has to be specified and as is the method of ensuring that the safety restraints are carried out correctly. Typically, current methods for remote control from close in up to 1-2 km distance use Tele-operation.

Examples of the advantages of Tele-operation are that the task can be carried out by a single operator and that camera positions are easily selectable using a microwave link or fibre-optic for a line of sight video transmission from the machine to the remote command station. To carry out complex tasks, the numbers of cameras needed and their positions have to be considered. It is likely that at least two fixed or one rotational camera need to be fitted to the vehicle to give all round viewing during operation and allow the modelling of the ground. Operator control units can be fitted to display single or multi-image options. The communication link might be a 1.4 GHz video link. Fibre optic links that offer high bandwidth can be used but the trailing of cables can be a problem over long distances. A communications link to carry control and sensor feedback signals is also required.

In summary, machines to carry out de-mining activities in place of human de-miners are generally likely to be wheeled or tracked. However, there is a possibility that in certain terrain, walkers will add value. Such machines are likely to be light in weight. The control and communications system is likely to be of a nature which will facilitate the addition of higher order functionality such as sensor fusion, HMI, navigation, etc.

The complete system will need to integrate the vehicle control and navigation systems with a data fusion system that will discriminate, to a high degree of confidence, between mine and ‘no-mine’ conditions.

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| fig5a |  | hunter2 |
| **Fig 1.a**. Gryphon-IV remote maneuvering experiment. The system can be remote-controlled in a range of about 150meters, Tokyo Institute of technology, JP [1] | **Fig 1.b**. Mine detection robot COMET-III – Chiba university, JP [2] | **Fig 1.c**. Mine detection robot Hunter Royal Military Academy, BE[3] |

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|  |  | fig5c |
| **Fig.1.d**. 16-wheeled (each tube tire able to support about 25 daN without explosion –most sensitive AP-mine is 0,064 bar) Sensing Vehicle, Tohoku University, JP [4] | **Fig.1.e**. AMRU-4, eight-legged electro-pneumatic sliding robot, RMA, BE [5] | **Fig.1.f.** Mine Hunter Vehicle, equipped with a teleoperated hydraulic manipulator, Chiba University, JP [2] |

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| AAAA0011 | Figure 8.2.2 DISARMADILLO new core powertiller.JPG |  |
| **Fig.1.g** Amaranta robot - PCP program (Colombia –COLCIENCIAS- and France), by the ECOS Nord project number COOM01 and by the Pontificia Universidad Javeriana.[6] | **Fig.1.h**. DISARMADILLA – PMAR laboratory of the Genova University [7] | **Fig.1.i** LADERO , a sliding robot equipped with MD, GPR and/or IR sensor [8] |

A new design for in-pipe inspection robot

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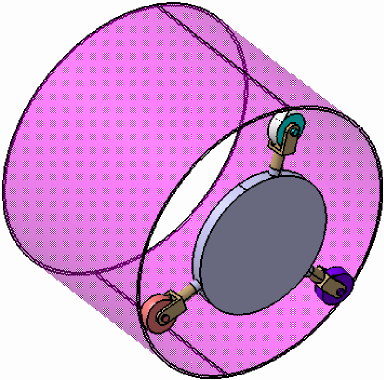
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**Abstract**

The paper presents a new design for in-pipe robot for inspection. Running based on the principle of screw. The robot consists of two parts articulated. One part is guided along the pipe by a set of wheels moving parallel to the axis of the pipe, while the other part is forced to follow an helical motion thanks to tilted wheels rotating about the axis of the pipe .The proposed new design has the capability of coping with curved pipes by performing a motion without any slippage. We show, in particular, that a variable inclination of the wheels is the key to avoid slippage when the pipe is curved. In the second part of the paper we present the different technological solutions study for command of the inclination.

Robot architecture: The figure presents the second part of the robot with tilted wheels.



*Figure1: Robot architecture*

To advance in curved pipes without sliding the tilting angle of wheels of the robot must be variable.

To have this variation, we opted for the solution eccentric wheels:

Wheel

Eccentric

Pipe

Direction module

*Figure2: Robot architecture with eccentric wheels*

We are to show in that case, that the strength of contact tends to adjust systematically the slope of the angle. We were able to show through a static study in rectilinear pipe that the strength of contact wheels-pipe tends to minimize the tilting angle as shows the following figure.

*Figure3: strength function titling angle*

Through a kinematic study we were able to show that the tilting angle of wheels is variable in the case of curved pipes as watch the following curve.

*Figure4: Titling angle*

We work at present on the validation of the eccentric solution through the determination of the relation between the strength and the tilting angle in the case of curved pipes.

This goes to allow us to establish a simulation which has for objective to verify if the movement of the robot with eccentric wheels in curved pipes this fact without sliding.

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