A
Seminar Report
On

APPLICATIONS OF MOBILE ROBOTIC SYSTEM AND CASE STUDY ON SURVELLIANCE OF INDOOR ENVIRONMENTS

Third Year
Mechanical Engineering

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Under the Guidance of
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CERTIFICATE

This is to certify that the seminar report entitled

"APPLICATIONS OF MOBILE ROBOTIC SYSTEM AND CASE STUDY ON SURVELLIANCE OF INDOOR ENVIRONMENTS"

SUBMITTED BY
ANUP SAHEBRAO BORSE

Examination No. - For partial fulfilment for the award of degree of B.E. (Mechanical Engineering) of university of Pune is approved.

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ACKNOWLEDGEMENT

It gives me an immense pleasure to submit this technical paper entitled **"APPLICATIONS OF MOBILE ROBOTIC SYSTEM AND CASE STUDY ON SURVELLIANCE OF INDOOR ENVIRONMENTS" .** I have tried my level best to represent this topic into compact and to the point framework.

I wish to express my sincere thanks with profound gratitude to my guide Prof. M. N. Pradhan for his valuable guidance and constant encouragement without which it would have been impossible for me to present and complete this seminar successfully.

I would like to extend my sincere and true thanks to my H.O.D. Prof. P. B. Joshi and all the staff members for impairing me the best of their knowledge and guidance.

Last but not the least; I thank all my friends and family for their assistance and help.

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Abstract

The following paper gives brief explanation on the mobile robots and its applications in the various purposes with great efficiency and precision in the fields of security, maintenance, modern agricultural techniques, terrain detection and sensing, usage of multirobot its docking and manipulating capabilities and heavy duty applications like automated assembly in aircraft bodies, etc.

The development of intelligent surveillance systems is an active research area. In this context, mobile and multi-functional robots are generally adopted as means to reduce the environment structuring and the number of devices needed to cover a given area. The feasibility of the approach is demonstrated through experimental tests using a multisensory platform equipped with a monocular camera, a laser scanner, and an RFID device. Real world applications of the proposed system include surveillance of wide areas (e.g. airports and museums) and buildings, and monitoring of safety equipment.

Secondly new version of the JL series reconfigurable multi-robot system called JL-2. By virtue of the docking manipulator composed of a parallel mechanism and a cam gripper, every mobile robot in the JL-2 system is able to not only perform tasks in parallel, e.g. moving and grasping, but also dock with each other even if there are large misalignments between two robots.

Long-range terrain perception has a high value in performing efficient autonomous navigation and risky intervention tasks for field robots, such as earlier recognition of hazards, better path planning, and higher speeds. However, Stereo-based navigation systems can only perceive near-field terrain due to the nearsightedness of stereo vision. Many near-to-far learning methods, based on regions’ appearance features, are proposed to predict the far-field terrain.

- ## Introduction to Mobile Robots:

Mobile robots are the objects which move around in their environment and are not fixed to one physical location. They consist of instrument panels like LASER scanners, monocular cameras and RFID devices for sensing the terrain.They can be controlled by Bluetooth, wireless network of pc, a wireless remote control microcontroller, etc. They are used for reasons like security, maintenance, industrial transports, in military, etc. Mobile robots are the focus of a great deal of current research and almost every major university has one or more labs that focus on mobile robot research. Mobile robots are also found in industry, military and security environments. They also appear as consumer products, for entertainment or to perform certain tasks like vacuum.

- ## Classification of Mobile Robots:

Mobile robots may be classified by:

- The environment in which they travel:
  - Land or home robots. They are most commonly wheeled, but also include legged robots with two or more legs (humanoid, or resembling animals or insects).
  - Aerial robots are usually referred to as Unmanned Arial Vehicle (UAVs)
  - Underwater robots are usually called Autonomous Underwater Vehicles.(AUVs)
- The device they use to move, mainly:
  - Legged robot: human-like legs (i.e. an android) or animal-like legs.
  - Wheeled robot.
  - Tracks.

Some of the robots are briefly described here.

1. **Automatically Guided Vehicles:**

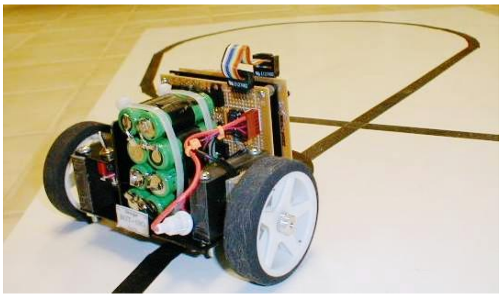
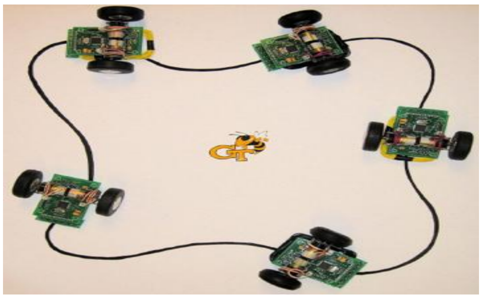
An **automated guided vehicle** or **automatic guided vehicle** (AGV) is a mobile robot that follows markers or wires in the floor, or uses vision or lasers. They are most often used in industrial applications to move materials around a manufacturing facility or a warehouse. Application of the automatic guided vehicle has broadened during the late 20th century and they are no longer restricted to industrial environments. Automated guided vehicles (AGVs) increase efficiency and reduce costs by helping to automate a manufacturing facility or warehouse objects behind them in trailers to which they can autonomously attach. The trailers can be used to move raw materials or finished product. The AGV can also store objects on a bed. The objects can be placed on a set of motorized rollers (conveyor) and then pushed off by reversing them. Some AGVs use forklifts to lift objects for storage. AGVs are employed in nearly every industry, including, pulp, paper, metals, newspaper, and general manufacturing. Transporting materials such as food, linen or medicine in hospitals is also done.


(A): Heavy Duty AGV

(B): Inertial Guidance AGV

2. **Line Following Robots:**

Some of the earliest Automated Guided Vehicles (AGVs) were line following mobile robots. They might follow a visual line painted or embedded in the floor or ceiling or an electrical wire in the floor. Most of these robots operated a simple "keep the line in the center sensor" algorithm. They could not circumnavigate obstacles; they just stopped and waited when something blocked their path. Many examples of such vehicles are still sold, by Transbotics, FMC, Egemin, HK Systems and many other companies.

3. **Autonomous Underwater Vehicles:**

An **autonomous underwater vehicle (AUV)** is a robot which travels underwater. In military applications, AUVs are also known as **unmanned undersea vehicles (UUVs)**. AUVs constitute part of a larger group of undersea systems known as unmanned underwater vehicles, a classification that includes non-autonomous remotely operated underwater vehicles (ROVs) – controlled and powered from the surface by an operator/pilot via an umbilical. Until relatively recently, AUVs have been used for a limited number of tasks dictated by the technology available. With the development of more advanced processing capabilities and high yield power supplies, AUVs are now being used for more and more tasks with roles and missions constantly evolving.

- **Applications of Mobile Robotic System:**

1. JL-2: A Mobile Multi-robot System with Docking and Manipulating Capabilities:

Self-reconfiguration technology is expected to be one of the key answers of how to combine flexibility, robustness, ability to self-repair and all-terrain navigation in one mobile robot system (Mondada, F.; et al., 2003), which will serve for applications like space explorations (Visentin, G.; et al., 2001), rescue (Casper, J.; Murphy, R.R., 2000) or civil exploration (Hirose, S.; Morishima, A., 1990). For a self-reconfigurable mobile robotic system, besides the communication among robots, an innovative cooperation is achieved by self-reconfiguration, that is, the capability to actively connect and disconnect, and to adjust the postures of the robots to enhance their locomotion abilities in the connected state. Furthermore, by dividing a mobile reconfigurable robot system into several smaller units, explorations in large areas can be performed in parallel to keep high efficiency.

System overview and design ideas

The new design of the JL-2 prototype is based on the following ideas:

1. *Combining the manipulation and a part of the docking and posture-adjusting functions to form a docking manipulator:*

One robot can take advantage of its manipulator to grasp and operate objects independently, as well as to connect with another robot in the system. Moreover, the joints of the manipulator also provide the DOF for the posture-adjusting and docking procedures.

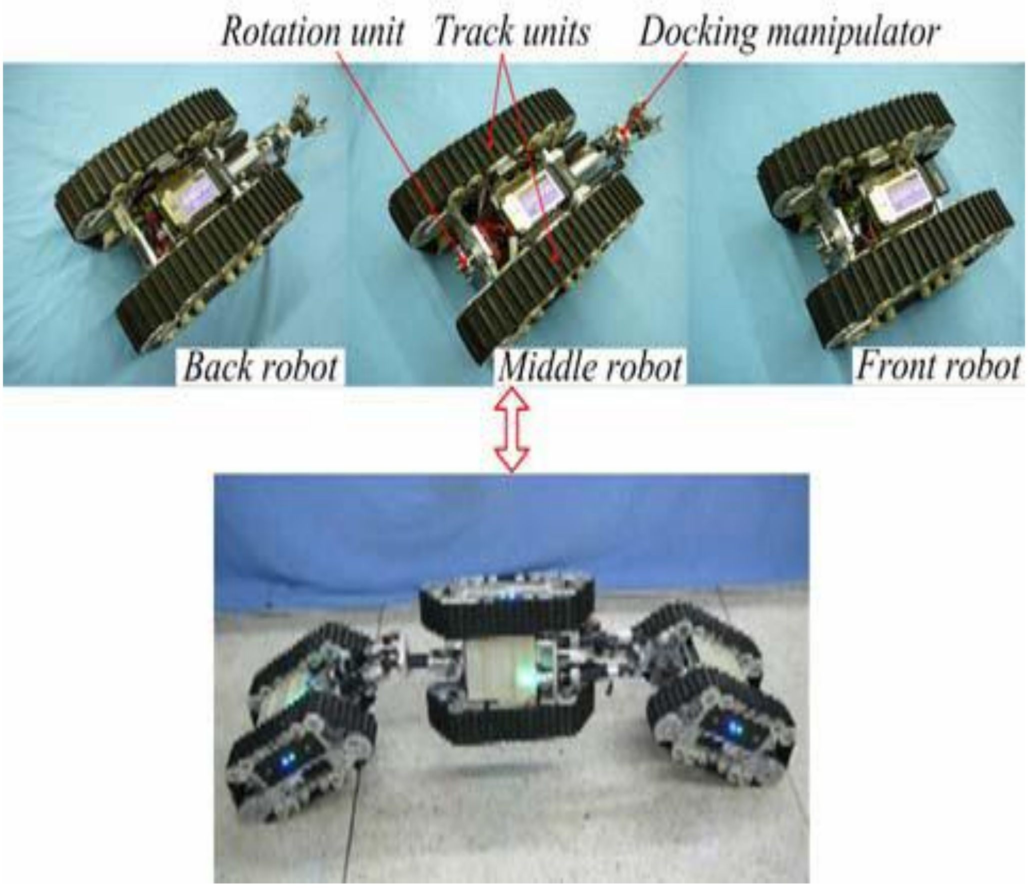
2. *Grasping-locking and gradual-alignment docking procedure:*

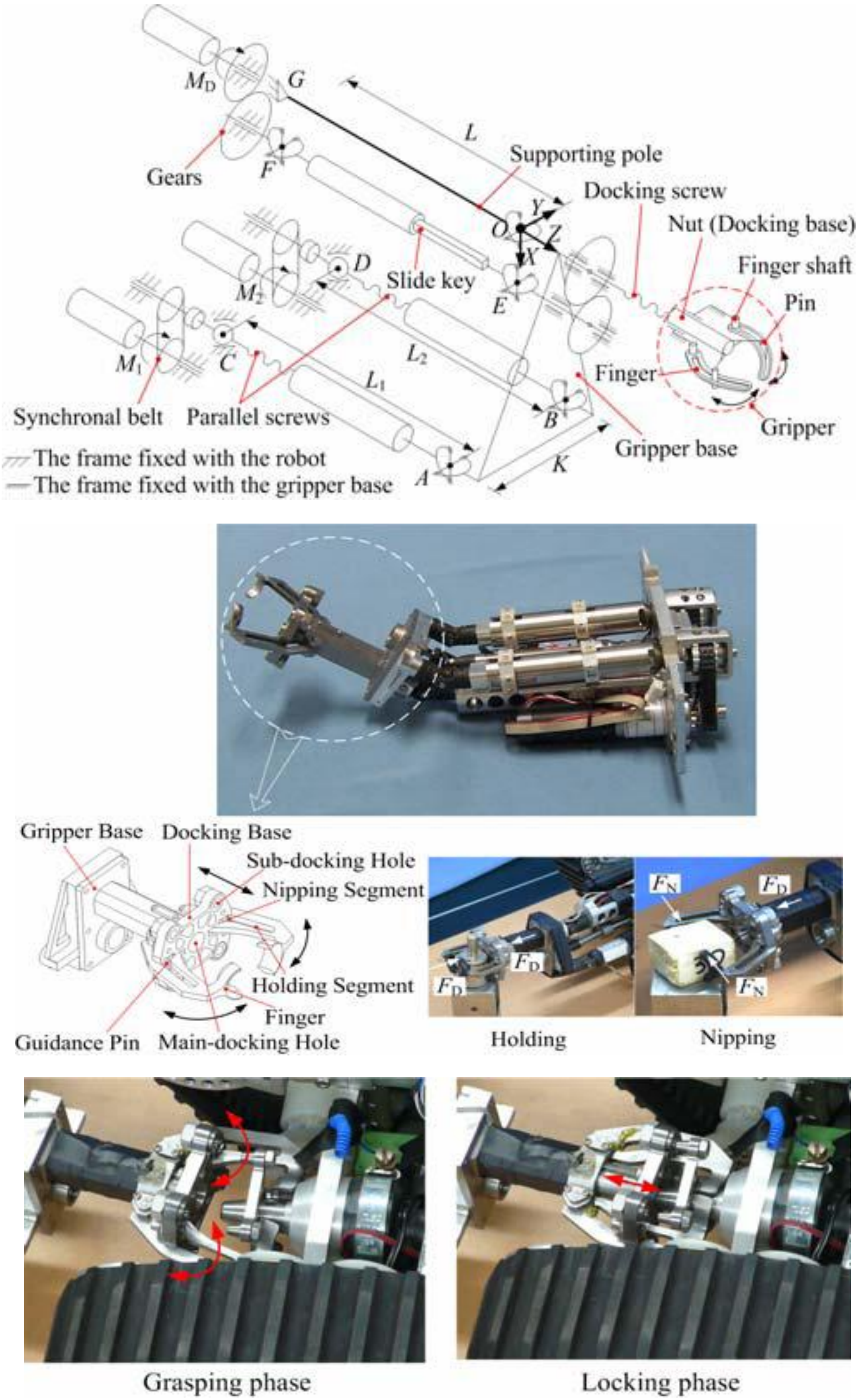
To simplify the structure of the docking mechanism, the docking procedure will be divided into different stages. At the beginning of docking, the gripper will surround and grasp the connector of another robot to prevent it from escaping from the docking area. In the following stages, only one or two misalignments will be diminished one by one.

3. *Self-assembling motorized spherical joint for posture adjusting mechanism:*

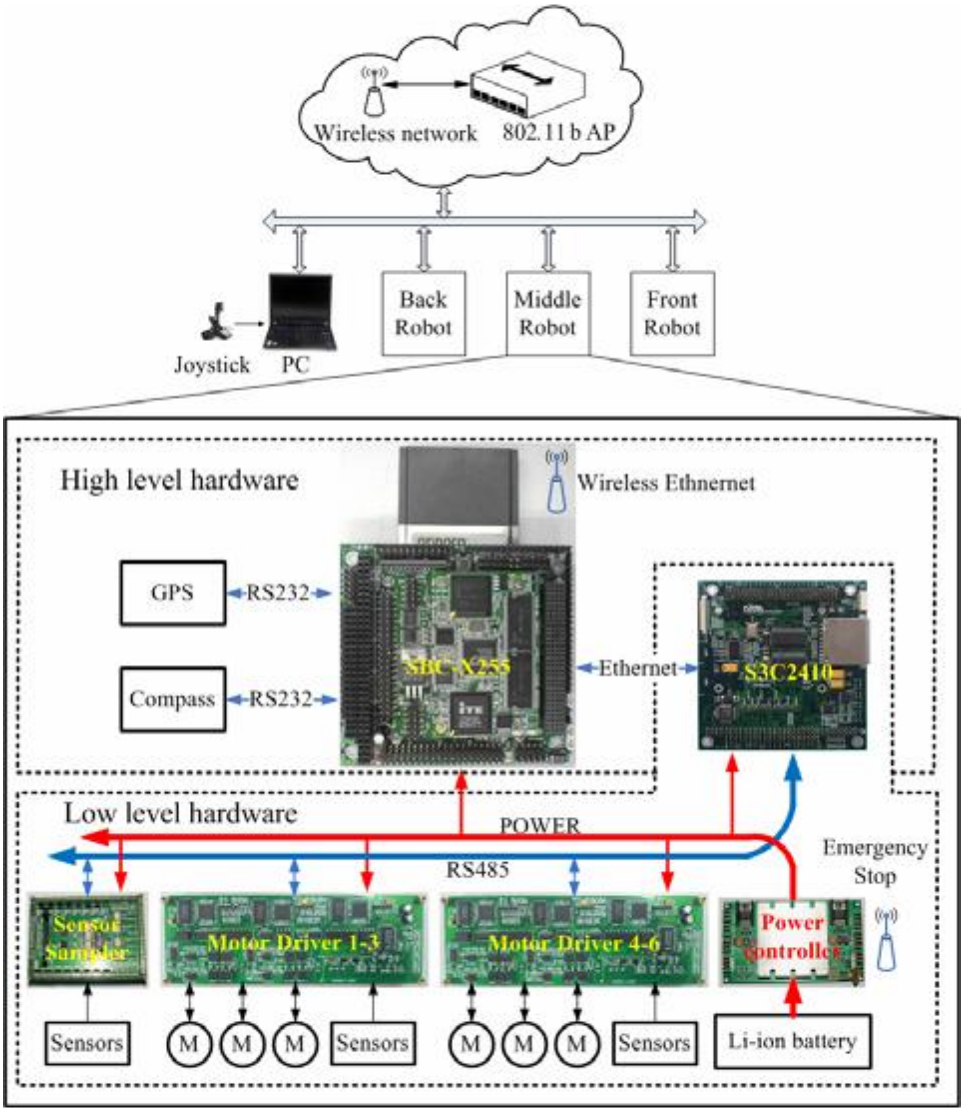
This design distributes the three DOF of the posture-adjusting mechanism to different robots. The joint is only fully functional when two robots are connected.

Based on the above ideas, the JL-2 prototype is designed, as shown in Fig. As same as JL-1, JL-2 is also composed of three independent robots with full navigation abilities in the field. They are called the back robot, the middle robot and the front robot respectively. If the robots connect, they will form a chain structure in which one robot is able to actively adjust the posture of the adjacent one in three dimensions by virtue of the two spherical joints between them.





M_D
G
L
Supporting pole
Gears
F
Docking screw
O
Y
Z
X
Nut (Docking base)
Finger shaft
Pin
D
Slide key
M_2
E
L_2
M_1
C
L_1
Finger
Synchronal belt
Parallel screws
B
Gripper
Gripper base
The frame fixed with the robot
The frame fixed with the gripper base
A
K
Gripper Base
Docking Base
Sub-docking Hole
Nipping Segment
Holding Segment
Finger
Guidance Pin
Main-docking Hole
F_D
F_N
Holding
Nipping
Grasping phase
Locking phase

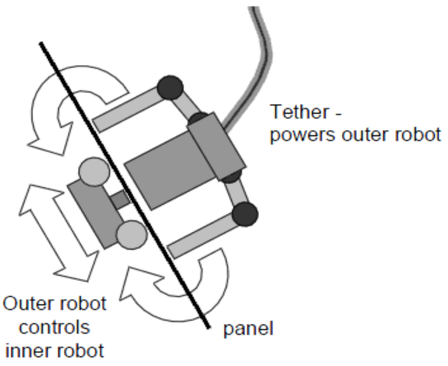


2. Design of a Semi-Passive Heavy-Duty Mobile Robotic System for Automated Assembly Inside an Aircraft Body:

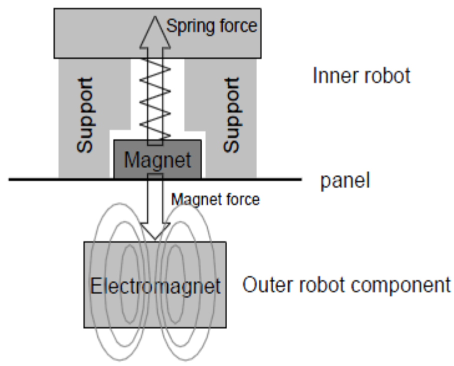
The aircraft industry faces unique manufacturing challenges when compared to processes such as automotive manufacturing. Airplanes are too large to carry along an assembly line, resulting in many repetitive tasks being performed by hand. This can be time consuming, expensive, dangerous, and ergonomically challenging for the worker. Obviously, the airline industry would like to automate these processes. We are interested in designing a mobile robotic system for this application. We believe the design concepts used in such procedures could provide valuable insights into automating other large scale processes such as ship building, plant construction, and building construction. We start with a specific manufacturing operation, fastener installation. Fasteners are used to attach thin sheets of material to one another; as an example, fasteners attach aluminium sheets to spars and strut flanges in the wing of the aircraft. There are generally hundreds of thousands of fasteners on an aircraft, and they are arranged in regular rows, making their installation an intuitive choice for an automation procedure.

Design Concept:

Our proposed solution to the problem of manipulating a robot on the interior of a wall panel is a robotic system that is comprised of two robots – one on the interior and one on the exterior of this panel. The exterior robot can easily be controlled and powered using tethers or possibly an external robotic arm. The interior robot, however, is controlled by the exterior robot. In order to allow these robots to operate at any orientation, we propose the usage of magnetic system to provide a holding force between the pair. By using strong electromagnets and permanent magnets, we can exploit the field that penetrates through the panel to hold the inner robot in place, as well as to manipulate it using the Lorenz force. That is, by running a current through a wire loop that is sitting within a magnetic field, we are able to induce a force on the robot *from across the panel*. Fig. 3 shows a possible location for a wire coil (powered by the outer robot) that could induce a force on the inner robot, much in the same way that a linear motor works.

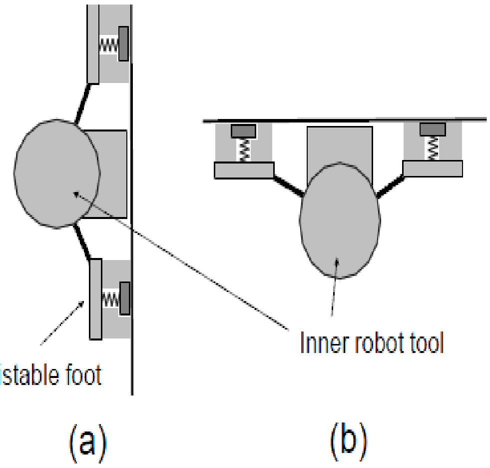


2 : Outer robot used to control inner robot

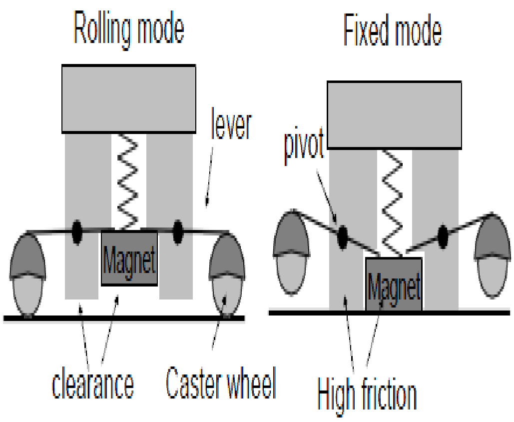


. 5 : Inner robot "foot" with outer robot electromagnet

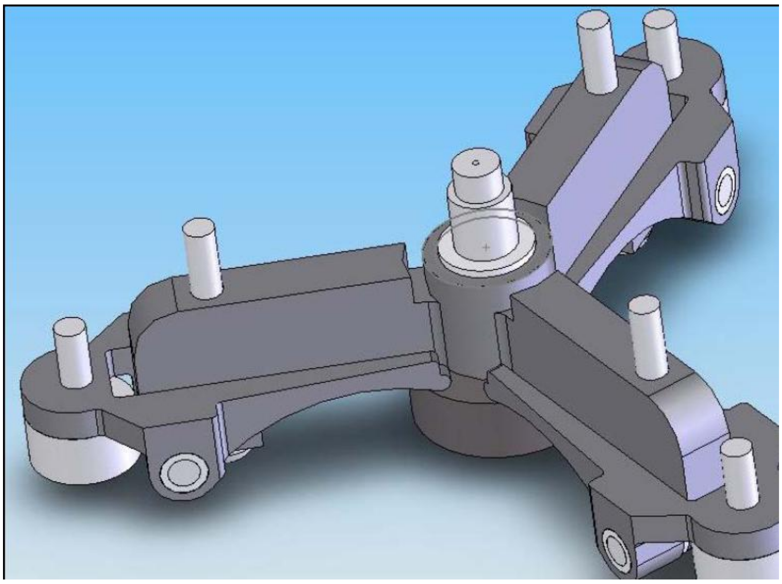
The feet of the inner robot are critical in the implementation of this design. The feet provide the magnetic holding force that causes the robot to stick to the surface. They must be able to move smoothly along with surface with little friction while the robot is traversing, but should also be able to adhere with high friction when the robot is holding. Finally, this change in frictional properties should be induced by a change in the magnetic field that the outer robot provides. The feet utilize off the shelf countersunk Neodymium Iron Boron permanent magnets as they are extremely powerful and resistant to demagnetization due to impact. In addition, their geometry makes them easy to mount and work with. These permanent magnets are spring loaded into a custom housing as shown in Fig. 5.



7 : Inner robot in two configurations



8 : High and low friction foot configurations



3. A Mobile Robotic System for Harvesting Greenhouse Products:

Integrated gripper and cutter is developed and tested on a robotic system for harvesting greenhouse products. The integrated end-effecter with gripper and cutter is small in size, light in weight, efficient in design, and low in cost. It is easy to use and can effectively perform the holding and cutting. The successful rate of harvesting is almost 100% if the robot can accurately move the integrated end- effecter to the work point on the fruit peduncle.

Robot harvesting operation can be divided into three tasks:

(i) fruit recognition is performed by a machine vision unit;

(ii) approach is performed by a manipulator control unit;

(iii) Picking is performed by an end-effector unit.

As part of the robotic system for harvesting vegetables in greenhouses, the development of an end-effector is very important. It should harvest vegetables like tomato in greenhouses, and easy to be mounted onto robot manipulators.

Design Principle:

The development of robot end-effectors for picking vegetables or fruits is based on their physical properties such as shape and size, structural properties such as cutting resistance and elasticity, and optical, sonic and electrical properties. In addition, chemical and biological properties are also considered when necessary. A harvesting end-effector usually is divided into 4 parts:

Sensors to detect the fruits, suction pads or gripper fingers to hold fruits for fixing and confirming the fruit position, a cutting device to cut the peduncle, and a control system to manage the action. It is difficult to design grippers to imitate farm workers, because

(i) It is difficult to hold the fruit by mechanical hands with force and size sensors to avoid fruit damage;

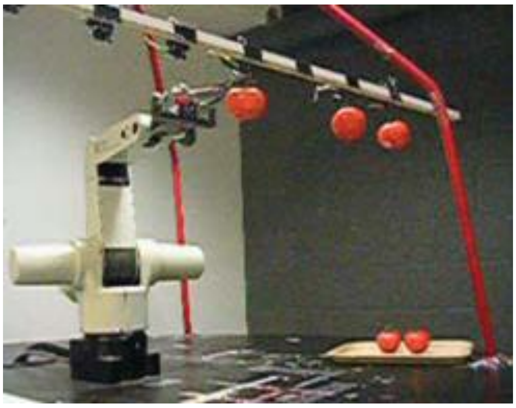
(ii) It is difficult to locate the peduncle position after confirming the fruit position and before cutting;

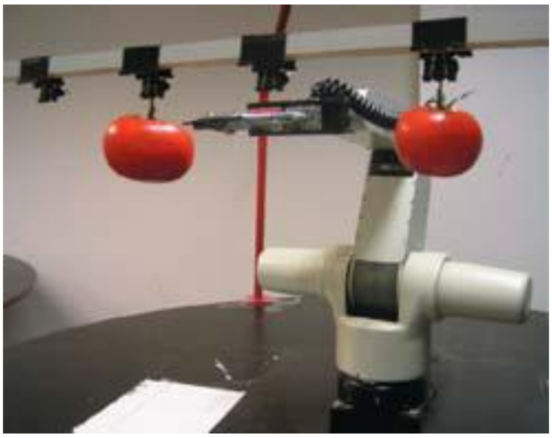
(iii) A big mobile platform with high cost is required to drive the complex device; and

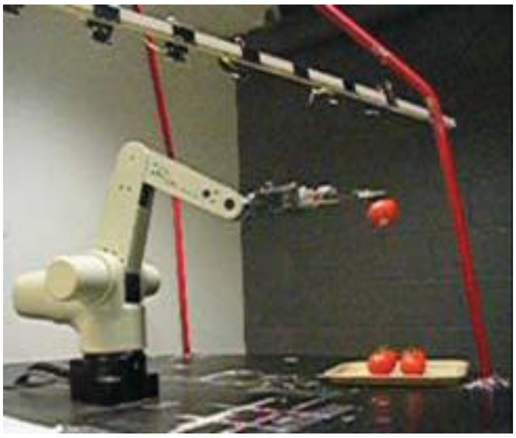
(iv) The design process is complex due to many uncertain elements in work environment.

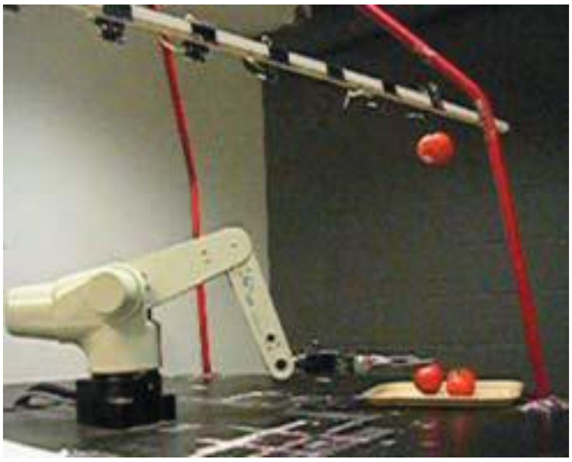
Actual Working Process:

The order of operation is shown in following pictures:









- **Case study on Surveillance of Indoor Environments using Mobile Robotic System:**

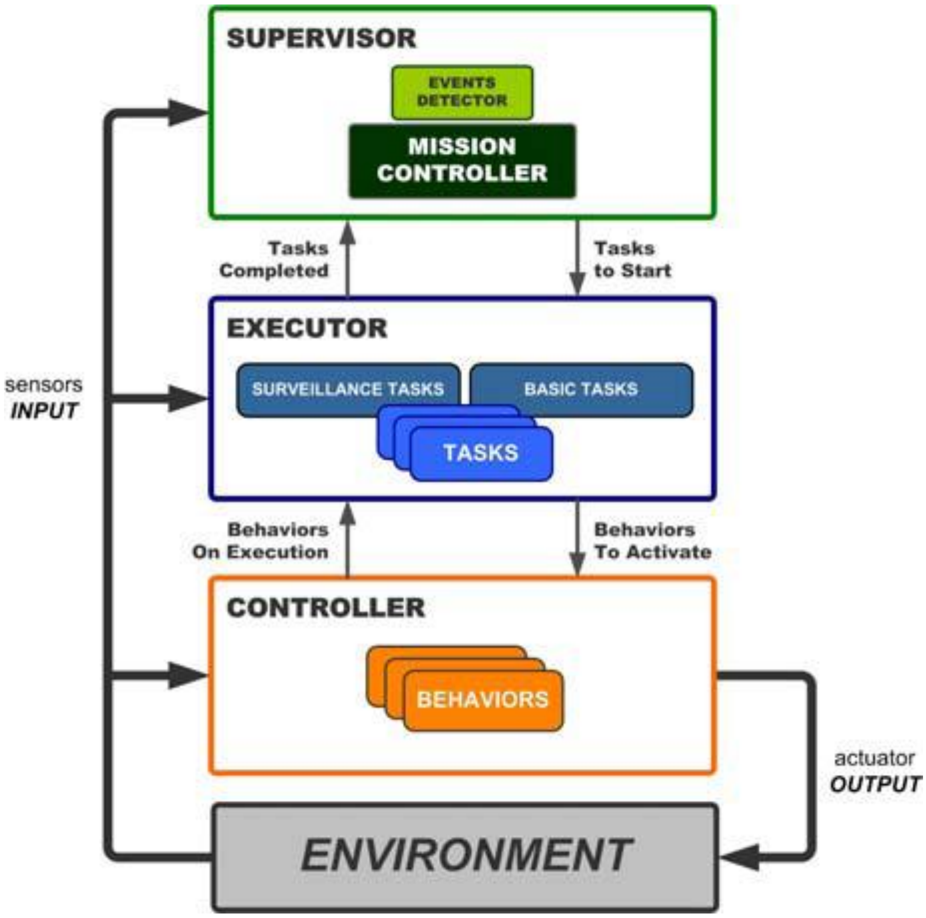
The increasing need for automated surveillance of indoor environments, such as airports, warehouses, production plants, etc. has stimulated the development of intelligent systems based on mobile sensors. Differently from traditional non-mobile surveillance devices, those based on mobile robots are still in their initial stage of development, and many issues are currently open for investigation. The use of robots significantly expands the potential of surveillance systems, which can evolve from the traditional passive role, in which the system can only detect events and trigger alarms, to active surveillance, in which a robot can be used to interact with the environment, with humans or with other robots for more complex cooperative actions.

Various Surveillance Robots:

1. Mobile Detection Assessment and Response System (MDARS): to inspect warehouses and storage sites, identifying anomalous situations, such as flooding and fire, detect intruders, and determine the status of inventoried objects using specialized RF transponders.
2. Airport Night Surveillance Expert Robot (ANSER): consists of an UGV (Unmanned Ground Vehicle) using non-differential GPS unit for night patrols in civilian airports.
3. Mobile Autonomous Robotic Vehicle for Indoor Navigation(MARVIN): to act as a security agent in indoor environments.

System Overview:

This section describes the three-layer architecture developed for the surveillance system. The component layout, depicted in Fig. 1, reveals the modular nature of the system. We propose a reconfigurable component based approach in which the three main components can be viewed as containers of dynamic libraries that can be configured for the particular scenario. More specifically we can select what primitive behaviours (e.g. avoid obstacles, wandering, go forward, etc.), complex tasks (e.g. robot localization with RFID and vision, detect removed or abandoned objects, detect people, etc.) and control algorithms (e.g. event detection, task sequencing, human operator interaction, etc.) have to start.



The **Controller** performs control functions at the behaviour level. This component contains all the behaviors needed to accomplish all possible tasks. Multiple behaviors can be executed at the same time, in case different tasks are active. Each behavior computes an output and when multiple behaviors are active at the same time, predefined behavior arbitration algorithm cooperative methods is used to obtain the final control signal.

The **Executor** handles the execution of the tasks as commanded by the upper level. Similarly to the Controller, this component is considered as a continuous state controller container. Each task can be viewed as a procedure to achieve a result. At the end of the task, the completion flag and the result is sent to the upper level. Two different classes of tasks are considered: Basic Tasks which are general purpose tasks (common for service robots) for environment mapping, safe navigation, global Localization and path planning; and Surveillance Tasks which are specific algorithms for scene analysis, in particular for object and people detection. For each class of tasks, the Executor sends the corresponding commands to the Controller.

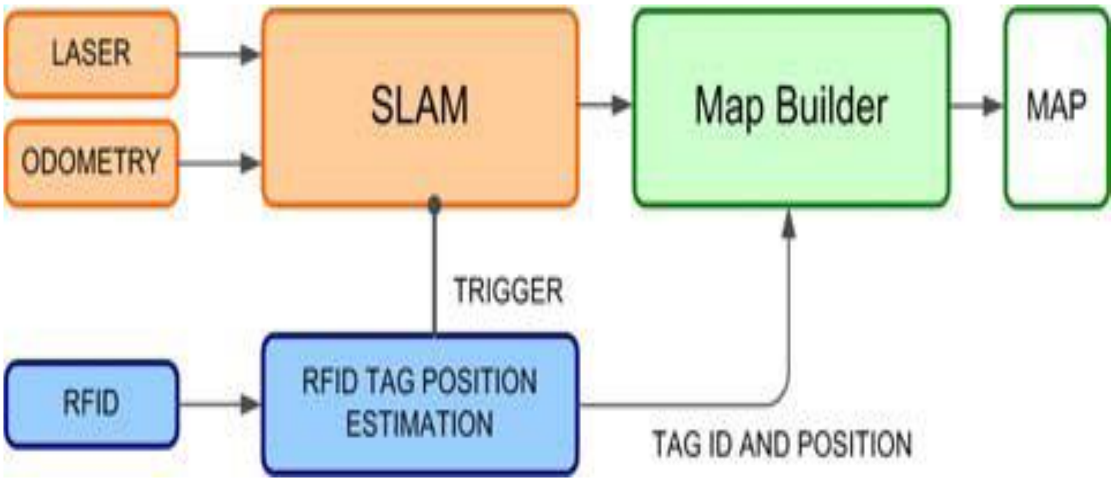
The **Supervisor** implements the high-level functionalities, monitoring the mission execution and generating events through the evaluation of sensory data. More specifically this module controls the execution of missions in progress (e.g. guaranteeing the satisfaction of precedence constraints), sends the configuration information about the tasks that must be started (Tasks to Start, in Fig. 1) to the Executor module and receives the information about the completed tasks.

Basic Tasks: Mapping and Localisation:

These tasks are implemented using a set of algorithms that allow the robot to autonomously build a map of the environment, self-localize and navigate safely, using laser, RFID and vision data.

- *RFID augmented mapping:*

1. During the procedure of Simultaneous Localization And Mapping (SLAM) based on laser and odometry data, the reader searches the tags.
2. When a tag is detected the SLAM procedure is interrupted and the tag localization algorithm is triggered.
3. After this phase, the tag ID and position are added to the map and then the SLAM procedure can continue.



- *Global localization: RFID and Vision:*

For a mobile robot, it is primary to know its global position, in the environment, at every time instant. To obtain this fundamental information, we propose a global localization method that combines RFID and visual input from an onboard monocular camera or global positioning system.

Surveillance Tasks: Object and People Detection:

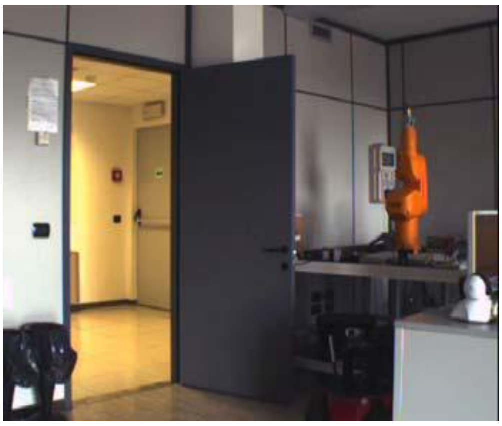
- *Abandoned and removed object detection:*

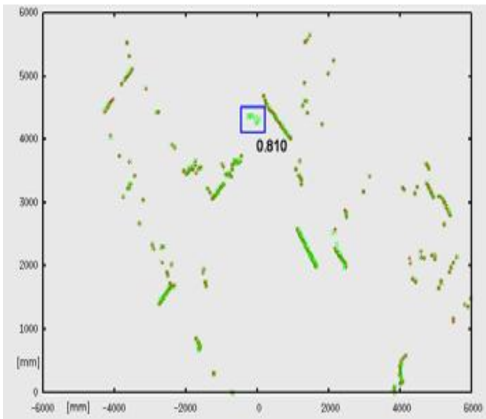
1. Once mapping is completed, the robot navigates throughout the environment to reach the goal-points. At each goal station, the robot stops and analyses the scene searching for abandoned or removed objects.
2. Visual information obtained from a monocular camera and input from a laser rangefinder is employed. Information is analyzed using various filtering, clustering and pre-processing algorithms. The outputs of the various algorithms are then passed to a logic component, which performs sensor fusion and decide if scene changes have occurred.

- *Laser-based people detection and following:*

The method for people detection and following consists of two main modules:

1. the Leg Detection and Tracking module: this module allows the robot to detect and track people using range data based on typical shape and motion characteristics of human legs.
2. the People-Following module: this module enables the mobile platform to navigate safely in a real indoor environment while following a human user. During the tour the robot can also acquire data for environment mapping tasks.



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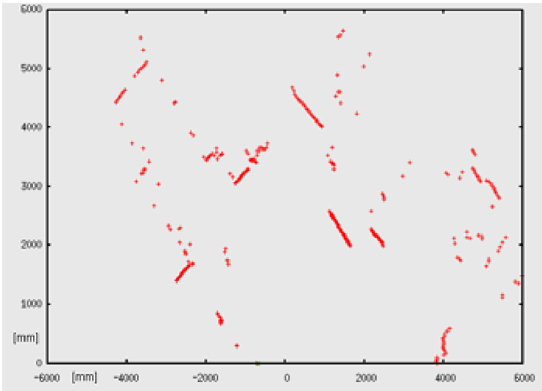
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6000

- **Conclusions:**

Integrating a simple gripper at the end of the parallel mechanism is a feasible solution to combine the grasping and docking function on reconfigurable mobile robots. The docking ability of JL-2 is enhanced by a 3 DOFs docking gripper and the high docking forces arising from a cam guidance mechanism. It is possible for JL- 2 to realize the docking action in rugged terrains in the future. Although the multi-point mating structure ensures a solid connection, it may introduce an over-constraints problem which results in a poor self-aligning ability around the rotation axis.

The design concept of these robots utilizes a pair of robots in which a primary, easily accessible robot is able to control an inner robot from across a thin panel. This control is performed using magnetic fields and a Lorenz force. The locomotion of the inner robot, even when it carries a heavy payload, can be accomplished through the thin panel by utilizing an energy accumulation strategy. A more detailed design of the feet (a critical component) of the inner robot has been demonstrated, and a functional prototype has been produced that can quickly switch between high frictional engagement and low friction rolling due to its bi-stable design. This property will allow for effective locomotion and reliable gripping as needed.

The integrated gripper and cutter is used to pick fruits such as tomatoes by holding their peduncle. It is a unique universal gripper which can pick up almost any fruit such as apples, grapes, crab apples, cherries, if the fruit peduncles are long enough. The gripper and cutter is small, light, efficient, and simple to operate. It is inexpensive and easy to control and manufacture. Because the gripper and cutter is so light, small robot payload is required. A small robot can be used to drive the gripper and cutter to harvest fruits and vegetables.

We described the architecture of the system based on a three-layer scheme that allows for modularity and flexibility, and may supervise a number of basic navigation tasks and specific surveillance tasks. The control system makes the robot able to execute autonomously multiple heterogeneous task sequences in dynamic environments, since it models the sequential constraints of the tasks, defines the priority among tasks and dynamically selects the most appropriate behaviours in any given circumstance. We also presented the localization and mapping modules that use vision, laser and RFID data. Then, the implemented modules for abandoned/removed object detection and people detection and following were introduced. Preliminary experimental results are promising and show the effectiveness of the overall system. The implemented tasks provide the first steps toward the development of a fully autonomous mobile surveillance robot.

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