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AUTONOMOUS CLEANING ROBOT FOR INTELLIGENT BUILDING

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Abstract: Intelligent buildings usually designed and built in unusual forms and shapes, the maintenance and cleaning of their outer surfaces is a real challenge. This case study demonstrates the way how an autonomous mobile robot was developed by M.Sc. mechatronics students of the American University of Sharjah. Mechatronics Design course is the culmination of engineering sciences studied by the students at lower levels. Through the design procedure of an autonomous mobile robot, the students could practice most of the techniques and skills they have acquired previously. The aim of this project was to develop an autonomous mobile robotic system for cleaning the outer surface of the Dubai International Airport new terminal building.

1. Introduction

Mechatronics Design is a compulsory subject at the American University of Sharjah, United Arab Emirates for M.Sc. mechatronics engineering students. They could form 3-4 members teams and select one of the available topics to develop a working prototype model of an autonomous mobile robot (for example to develop an unmanned aeronautical vehicle, under water vehicle, robot soccer, etc.). There were weekly plenary lectures and compulsory lab exercises, but the teams should develop their project independently. This case study demonstrates how an autonomous cleaning robot was developed by a 4 member student team. Advanced technology enables designers to construct comfortable and environment friendly buildings for their customers reducing energy consumption and operation manpower. These intelligent buildings need regular cleaning to ensure efficient heating/cooling, radiation absorption for photovoltaic glass surfaces etc. This student team task was to design and build a suitable robotic system for this purpose.

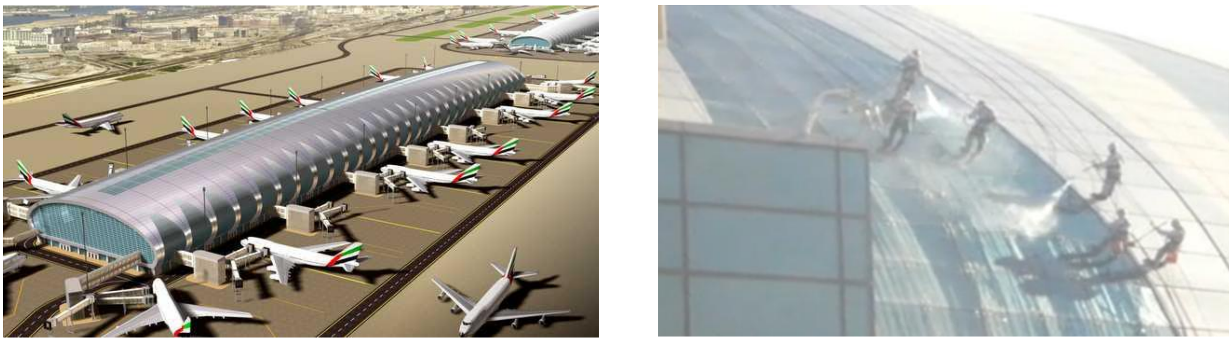

Figure 1 Manual cleaning of the airport terminal building;

2. Mechatronics Design Lectures

Mechatronics Design consists of classroom lectures followed by lab exercises, simultaneously each team should work on their particular project. These lectures covered a wide spectrum of topics, most of them were repetitions, reminders, extensions and summarizations of what they were taught on B.Sc. level or other subjects on M.Sc. level.

For example how to search literature, organize a work team, conduct meetings, write minutes of meeting, prepare presentations, about sensors and actuators, control theory, motor characteristics, system modeling, microcontroller programming, communication (wireless, CAN bus etc.), project feasibility and economical calculations, selecting parts and placing order; going on this list is not complete.

3. Design Process

Once the work groups were formed and each team has selected a suitable project the research and development has started.

3.1. Problem Statement

First step was the problem statement. In this example case, the project was supported by Dubai International Airport, which has got a new terminal building. The concourse of the building has ellipsoidal cross-section, the manual cleaning of it's surface was very dangerous and difficult, as it is shown on figure 1.

3.2. Literature Study and History

The second step was the literature study, to find out what is known about the theme, to find any similar example.

• "Multi-Limb locomotion: This mechanism is based on arms and grippers and can be used for complex surfaces. Legged structures with two to eight legs are predominant. More limbs typically provide redundant support and often increase load capacity and safety. These benefits are achieved at the cost of increased complexity, size and weight.

• Wheeled Locomotion: This approach is also used for surface-climbing applications. It is suitable for even-terrains like glass walls, concrete or brick walls and steel walls. However, the climbing action still needs the support of gravity-defying means such as vacuum pads combined with a lifting mechanism.

• Linkage Motion locomotion: This approach is a sliding frame construction where the main elements of the robot slide relative to one another. They need special control strategies, but such constructions are especially well suited for climbing applications."[1]

Figure 2. Previous model, with two robots are attached with cables and they move along the concourse.

There was a previous model (Figure 2.) built by previous year students, but instead of further developing that, they have decided to start to build a new, different robot model.

They have decided to develop a new 3 robot arrangement, the main robot can move along the concourse's keel, whilst the satellites are docked inside and at a suitable location discharge them for the next cleaning cycle.

3.3. Proposal presentation

Each team has prepared a proposal for the solution of their particular project and composed presentations for further discussion. Team members distributed individual tasks and responsibilities, prepared work breakdown, time and cost analysis.

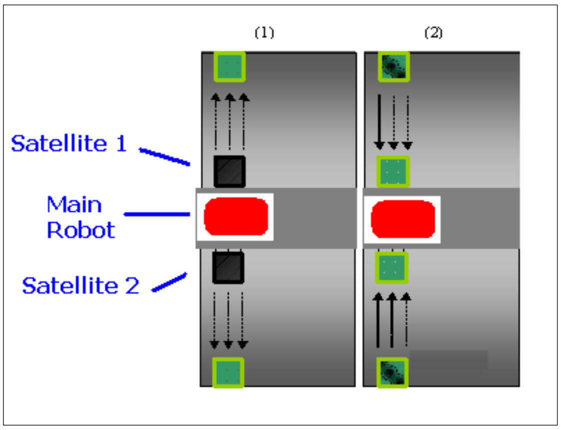

Figure 3. New 3 robots arrangement, one main robot and 2 satellites for cleaning action. (First concept model was made from plastic breadboards.)

3.4. Mechanical Design

3.4.1. Main Unit

"The main unit should be able to move independently/ or by following the operator's instructions on the top centerline of the building. Has to have the ability to follow a marking on the surface, to determine the distance covered by it's movement (to decide where to start the next cleaning cycle) and to observe when it reaches to the end of the building or to an object or obstacle."

3.4.2. Satellites

"The actual cleaning is performed by the satellite units. Practically there will be 2 of them, to accelerate (halve) the time required to complete the cleaning of the whole roof. The safety measures should be calculated according the scenario when there is only one satellite unit connected to the main unit. In case- normal case- when there are 2 of them, the geometrical arrangement of the 3 units will provide more safety against falling down from the roof.

The satellites are connected by a pair of ropes to the main, and they can ascend down by the help of powered wheels and wind up after cleaning by the ropes. In case of emergency- when one of the satellite units is not able to return to the main unit by itself, the operator is be able to retrieve the faulty unit by the help of the other satellite unit's winch. "

3.4.3. Realization

Figure 3 shows the concept and the first model, after the final shop drawings were approved; the working concept model was fabricated in the workshop. Used materials were aluminum and transparent polycarbonate.

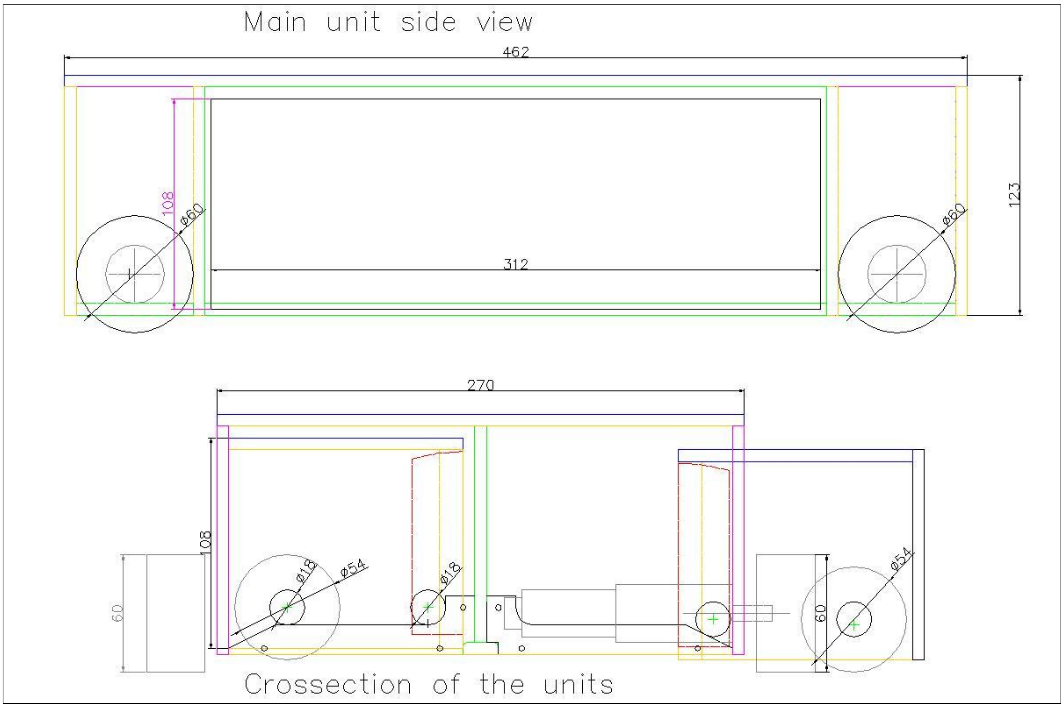

Figure 5. Part of the final shopdrawings, main unit side view and a crossection drawing, left side satelite show at racked in position, right side satelite shown in racked out position.

Figure 4. The assembled mechanical units, satellites are in racked in position.

3.4. Sensor fusion, Motor controller (PID by microcontroller)

This was the second team member's responsibility to select find suitable sensors for this robotic system. Sensors are needed for motion control and for helping the system in localization. For the first purpose incremental encoders, rope tension sensors and limit switches were used, electronic compass and tilt sensor for localization. They had to validate and calibrate each of them. Furthermore an optical sensing unit was developed for line tracking.

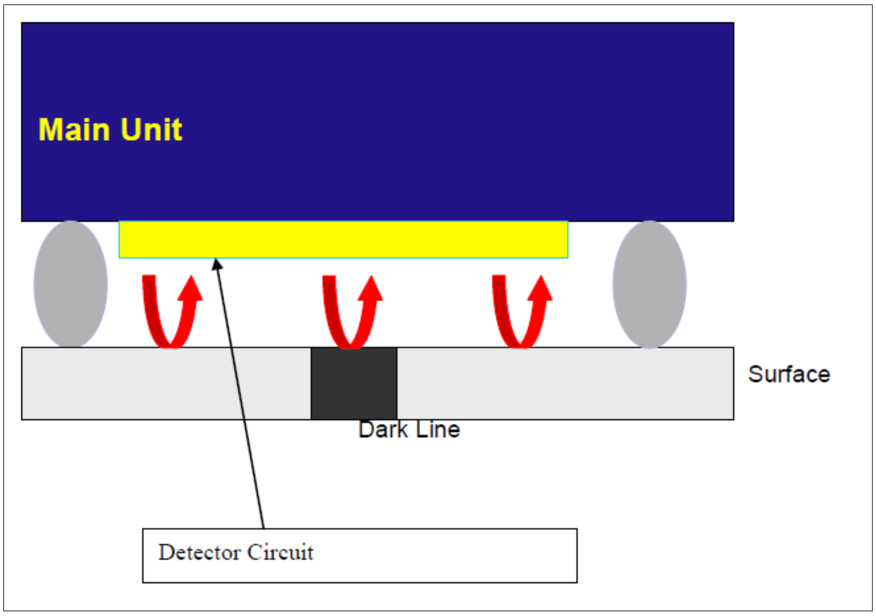

Figure 6. Line tracking system for the main unit.

3.5. Wireless communication

The 3 robot system used Smart Spread Spectrum Transceiver for RF wireless communication between the units.

3.6. Movement Control

Altogether there are 12 controlled motor in the system, 4 motors to drive the main robot's wheels, 2-2 motors in the satellites for the wheels and another 2-2 for the winches in the satellites. To adjust the PID controller properly, the students had to measure the motor parameters and validate the system. Their task was also to write microcontroller programs for encode reading, PID controller, communication.

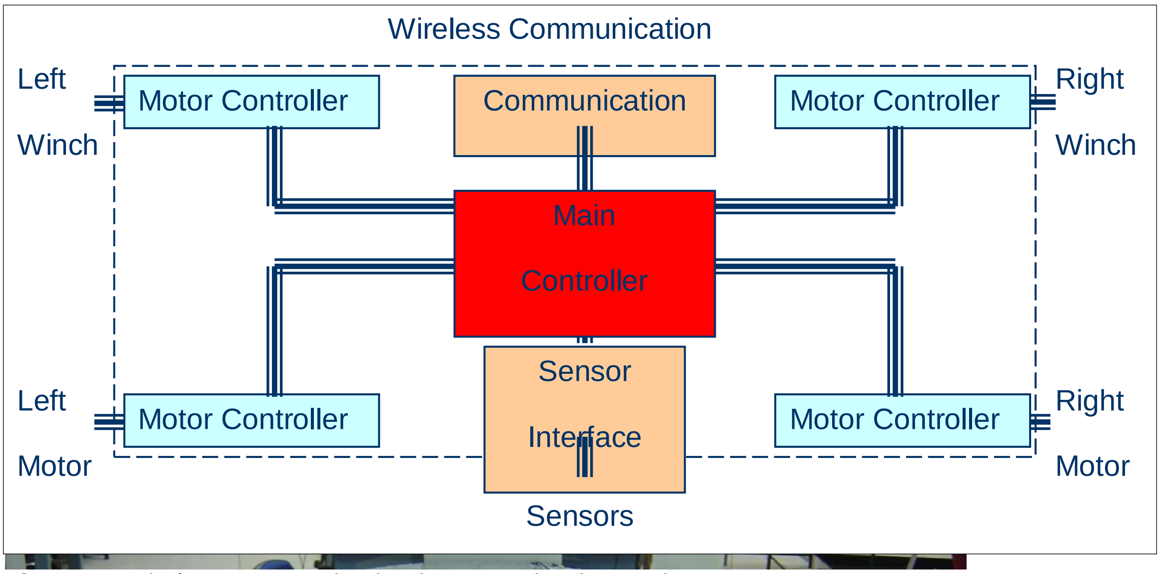

Figure 7. Wireless communication between the three robots.

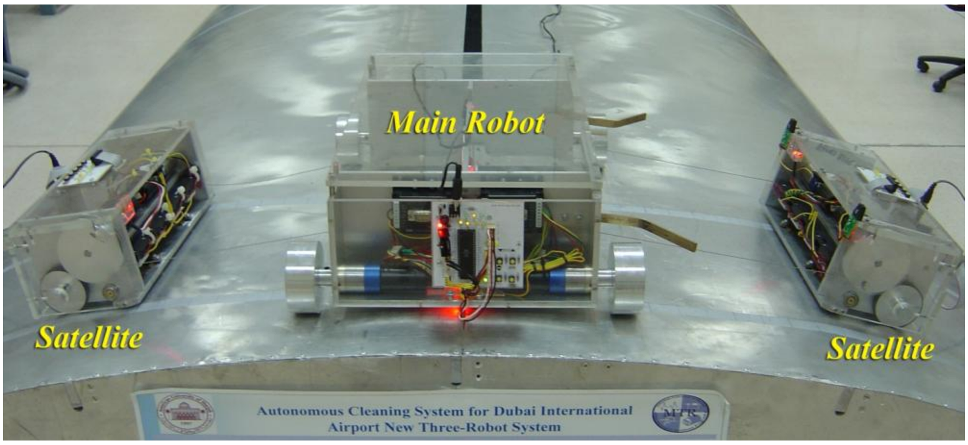

Figure 8. Cleaning in action. The main robot moves along the concourse following the black line, time to time stoped, the satelites are discharged and descend to perform a cleaning cycle.

4. Final presentation, final report,

At the end of the semester each team have prepared a final report and presented their work for a committee for approval.

5. Project's Afterlife,

The team members prepare a poster to be presented at the 3rd International Symposium on Mechatronics and its Applications (ISMA06) 2006 Sharjah, UAE and won the first prize of the conference poster competition. Localization method and software were developed by one of the team members Hossein Sadjadi, as his diploma design project and he has presented it on the next ISMA conference.

6. Acknowledgments

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