The 3rd International Conference on
″Computational Mechanics
and Virtual Engineering″
COMEC 2009
29 – 30 OCTOBER 2009, Brasov, Romania

STUDIES REGARDING OMNIDIRECTIONAL MOBILE ROBOTS

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Abstract: *The objective of this paper is to investigate the specific aspects concerning the autonomous omnidirectional mobile robots based on the development of applications using a specific omnidirectional platform named Robotino® omnidirectional mobile robot developed by Festo company. On the first part of the paper a short introduction in the mobile robots research domain is made, in the second and third part types of omnidirectional wheels and robot platforms are presented. In the last part of the paper Robotino® omnidirectional mobile robot is presented also with applications done so far by the authors.*
Keywords: *omnidirectional wheels, omnidirectional mobile robot, Robotino®, applications.*

1. INTRODUCTION

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 cleaning). A mobile robot needs locomotion mechanisms to make it enable to move through its environment. There are several mechanisms to accomplish this aim, for example one, two, four, and six legged locomotion and many configurations of wheeled locomotion. For smooth surface, wheeled-robots are always quicker than legged-robots. Wheeled-robots have no problem of stability or balance as always occurred in legged-robots.
The term omnidirectional is used to describe the ability of a system to move instantaneously in any direction from any configuration.
A large variety of omnidirectional robots are presented in specialized literature. These robots can be divided in two categories: robots with special wheels and robots with conventional wheels. Usually, an omnidirectional robot has three or more of these types of wheels.

2. TYPE OF OMNIDIRECTIONAL WHEELS

2.1 The standard wheels

The standard wheels are used because of their simplicity and because they are available in all sizes and shapes. In figure 1 a few standard wheels are presented.

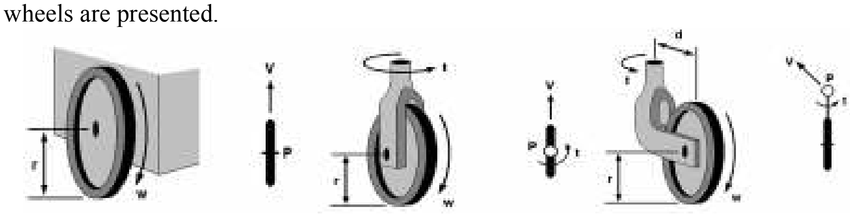


Figure 1: Standard wheels

2.2 Omnidirectional wheels

Omnidirectional wheels are wheels that enable the robot to perform movement in all directions without the necessary turning around the robot’s vertical axis [1]. An omnidirectional wheel is created by a hub, its perimeter being surrounded by rolling segments - spherical, cylindrical, conical or circular rollers. Wheels are divided according to the orientation of the rolling segments on the wheel hub.

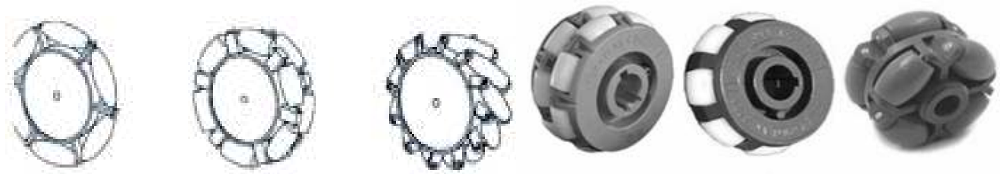
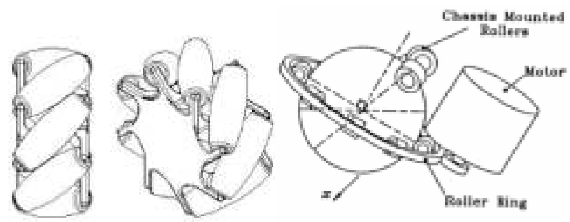


Figure 2: Omnidirectional wheels

Most special wheel designs are based on a concept that achieves traction in one direction and allow passive motion in another. The Mecanum wheel is an example of the special wheel design that has a number of small passive rollers mounted on the periphery of a normal wheel. The axes of the rollers are perpendicular to that of the wheel. Another special wheel design of note is the ball wheel mechanism. In the ball wheel design, power from a motor is transmitted through gears to an active roller ring and then to the ball via friction between the rollers and the ball (much like the action in a computer mouse).



a) b)

Figure 3: Special omnidirectional wheels: a) Mecanum Wheel, b) ball wheel design

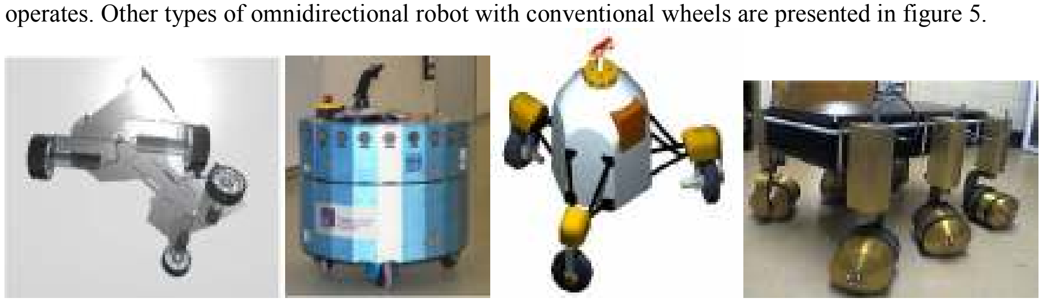
3. TYPE OF OMNIDIRECTIONAL ROBOTS

3.1 Omnidirectional robots with conventional wheel

The robot Azimut 2 is an ideal solution for operation over flat surfaces and uneven terrains. Each wheel contains a high efficiency brushless motor and gearbox packaged in a compact and lightweight manner. The robot can change the direction of these wheels over 180 degrees, making the robot capable of moving sideways without changing its heading [1].

Figure 4: The Omnidirectional Robot Azimut 2

Stability and compliance of the robot are enhanced by adding four independent vertical suspensions and using elastic actuators for the motorized directions of the robot's wheels. These elastic actuators make it possible to sense and control the torque at the actuator's end, improving mobility over uneven terrains by making the robot "feel" the surface on which it operates. Other types of omnidirectional robot with conventional wheels are presented in figure 5.



a) b) c) d)

Figure 5: Other type of omnidirectional robots with conventional wheels

Regarding the omnidirectional robots that use conventional wheels, a very often used principle is the synchronic drive principle. The three wheeled synchronic drive principle has some benefits with respect to other wheel configurations. The main benefits are:
-only two motors are necessary; one motor rotates all wheels together to produce motion, the other motor turns all wheels to change direction;
-no suspension needed; the three wheel configuration ensures the ground contact of each wheel;
-the mechanical guarantee of straight line motion;
-the robot can move to a certain position, and rotate in place to achieve a certain orientation;
- possibility of symmetric design.

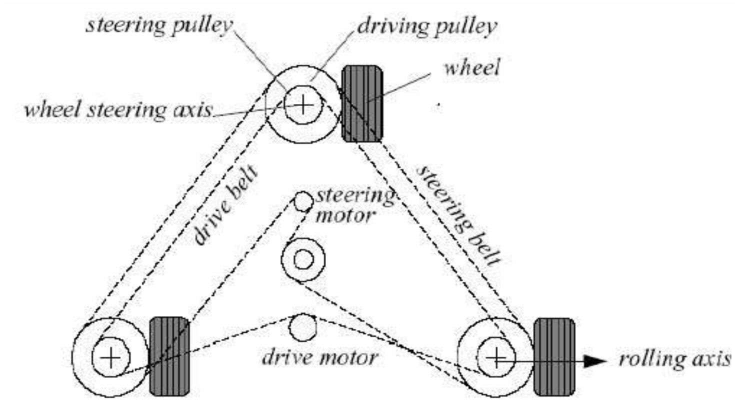


Figure 6: The three wheeled synchronic drive principle at omnidirectional mobile robots

The omnidirectional robot using this principle is presented in figure 7.

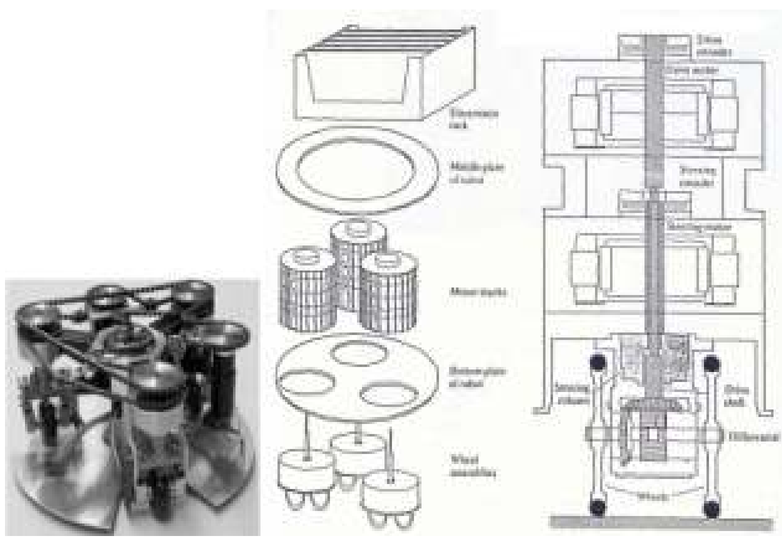


Figure 7: Omnidirectional robots with synchronic drive principle

3.2 Omnidirectional robot with omnidirectional wheel

Typical examples of omnidirectional robots with omnidirectional wheels have 2, 3, 4, 6 wheels. Segment rotation axis lies either in a plain perpendicular to rotation axis of the hub, or they contain a specific angle (Fig. 8, Fig. 9).

a) b) c)

Figure 8: Robots with three omnidirectional wheels

a) b) c)

Figure 9: Robots with four omnidirectional wheels

The Tribolo robot developed by Swiss Federal Institute of Technology, Lausanne, Switzerland is presented in figure 10.

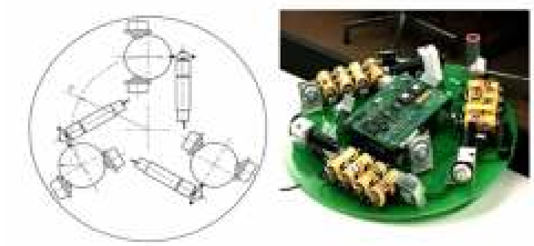


Figure 10: Omnidirectional robot with 3 spherical wheels

4. ROBOTINO® OMNIDIRECTIONAL ROBOT. APPLICATIONS

Robotino® is a mobile robot system with an omnidirectional drive, a learning system for basic and further training, and a research and development platform for universities and colleges, all in one system [3]. The three drive modules of the Robotino® are integrated in a sturdy, laser-welded stainless steel chassis. The chassis is protected against collision by means of a rubber protective guard with integrated switching sensor. Numerous additional components such as sensors, handling units or shooting devices can be mounted on the platform using prepared threaded holes.

Figure 11: Robotino® omnidirectional robot

Robot dimensions:
- Diameter: 370 mm
- Height including housing: 210 mm
- Overall weight: approximatively 11 kg

Three industrial DC Dunker motors with optical shaft encoders and gears with interchangeable pinions permit speeds of up to 10 km/h. The chassis contains nine infrared distance sensors. An analogue inductive and an optical sensor is also available by means of which the Robotino® can sense an aluminum strip or a colored line, for example. The Robotino® is supplied with a color webcam without jpeg compression and a second camera with jpeg compression. The compressed webcam image can be transmitted to the PC via the WLAN for image evaluation by Robotino® View or used as a live camera image. A powerful decompression module enables you to additionally use the images from the webcam for standalone control.

Power is supplied via two 12 V lead gel batteries which permit a running time of up to two hours.

The Robotino® features a high-performance embedded PC consisting of:
- PC 104 processor with real-time Linux kernel;
- 64 MB SDRAM;
- 256 MB Compact Flash card;
- Ethernet, 2 x USB, 2 x RS232, 1 x PS2, 1 x IDE, 1 parallel port and 1 VGA port;

- Wireless LAN in accordance with 802.11 g and 802.11 b;
- Expansion with additional firewire, CAN bus card or a PCMCIA adapter is possible.

Using Logitech Force 3D joystick the autonomous mobile robot was controlled [4]. The program was made using Robotino View® programming software and is presented in figure 12.

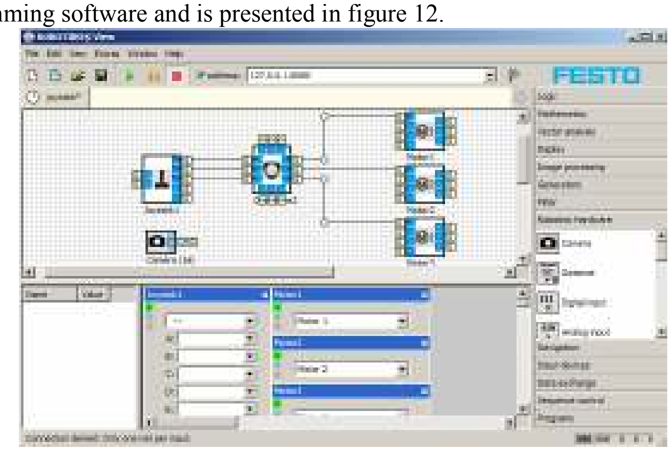


Figure 12 : Application made in Robotino View® programming software for the control of the robot using a joystick

First the joystick is conected via USB port to the laptop and then the axis and buttons of the joystick are set for the correct result. In figure 13 the test of the application and the way of connection are presented. The maximum distance at wich the robot can be controlled by wireless signal is 50 m. The images from the web camera are sent in real time so the user can easily guide the robot.

Figure 13 : Testing the behaivor of the autonomous mobile robot Robotino® using a joystick

In the next application, the omnidirectional movement module named *OmniDrive* of the robot is tested. In figure 14 the program made in Robotino View® is presented.

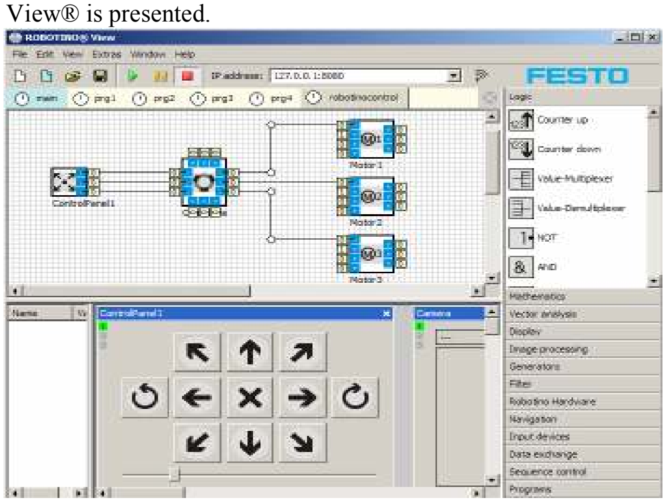


Figure 14 : Application using an control panel made in Robotino View® programming software

One of the most complex applications of the robot is when it is put in a labyrinth and he has to follow a black line until it will find a red colored ball positioned somewhere in the labyrinth.

In the figure 15 the program developed for the labirynth application using Robotino View® is presented.

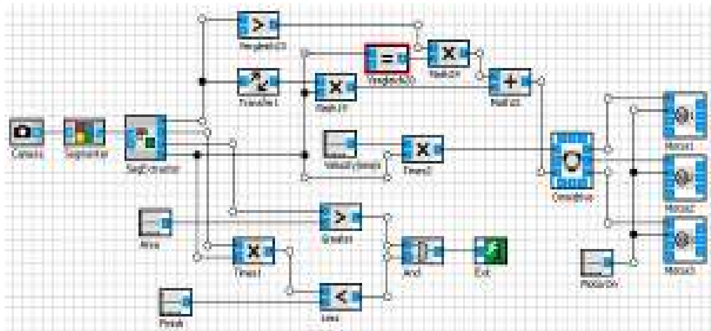
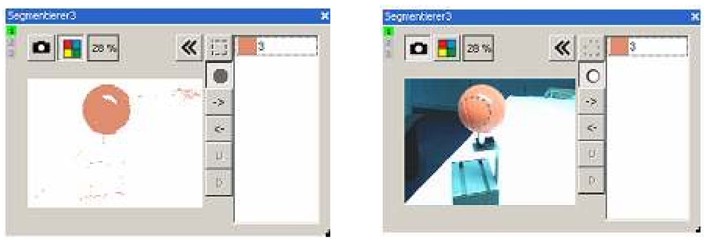


Figure 15 : Labirynth application made in Robotino View® programming software

The main component is the web camera that extracts images from the environment in which the robot is positioned. The image is transmitted to a image processing block named *Segmenter*. This block segments the image from the video camera and transmits it to the next block named *SegExtractor* wich gives the possibility of selection of the red color and the further process of it. In figure 16 the *Segmenter* block function is presented. The color selected (noted with 3) appears in the image with a 28% percentage after segmentation and it will be memorized, then the agent is put in the labirynth to find it.



a) b)

Figure 16 : *Segmenter* function block

In figure 17, the test of the labirynth program in wich Robotino® is following the black line and searches the red ball is presented.

Figure 17 : Testing Robotino® in labirynth application

3. CONCLUSIONS

Omnidirectional robotic platforms have vast advantages over a conventional design in terms of mobility in congested environments. They are capable of easily performing tasks in environments congested with static and dynamic obstacles and narrow aisles. These environments are easily found in factory workshops, offices, warehouses, hospitals and elderly care facilities. Robotino® mobile robot is a powerful research and educational robot with enormous capability to adapt to the environment in which it operates.

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