Solid State Phenomena Vol. 198 (2013) pp 132-137
Online: 2013-03-11
© (2013) Trans Tech Publications, Switzerland
doi:10.4028/www.scientific.net/SSP.198.132

Structures of the Omnidirectional Robots with Swedish Wheels

Mihai Olimpiu Tătar[1,a], Claudiu Cirebea[1,b], Dan Mândru[1,c]

[1]Technical University of Cluj-Napoca, Department of Mechatronics and Machine Dynamics, Muncii Blvd. 103-105, Cluj-Napoca, România

[a]olimpiut@yahoo.com, [b]claudyutzu_delu_18@yahoo.com, [c]mandrud@yahoo.com

Keywords: omnidirectional, mechanum, universal, swedish, wheels.

Abstract. In the first part of the paper, specific aspects concerning the omnidirecional Mecanum wheels are presented, while the second part is dedicated to the presentation of two prototypes of omnidirectional robots, equipped with omnidirectional Swedish wheels.

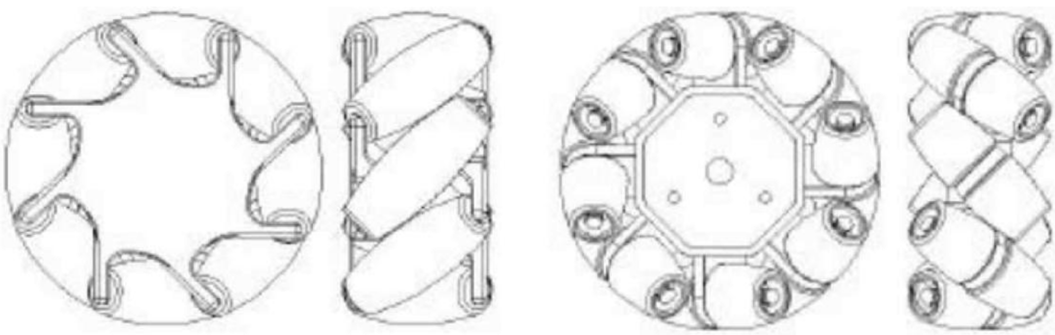
Introduction

Mobile robots can be used in many applications, such as carpet cleaning, search and rescue, exploration, assistive medicine, industrial conveyance. 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 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. These robots can be divided in two categories: robots with special wheels (omnidirectional wheels) and robots with conventional wheels. Usually, an omnidirectional robot has three or more of these types of wheels [1, 2, 3, 4, 5].

Omnidirectional wheels

The omnidirectional wheels enable the robot to perform movement in all directions without the necessity of turning around the robot's vertical axis. An omnidirectional wheel is made of a hub, its perimeter beings surrounded by rolling segments - spherical, cylindrical, conical or circular rollers. The wheels may be divided according to the orientation of the rolling segments on the wheel hub. Most special wheel designs are based on a concept that achieves traction in one direction and allow passive motion in another.

The Mecanum wheel was invented in 1973 by a Swedish engineer (Mecanum Company), named Ilon [6]. This is why it is called Mecanum or Swedish wheel. Using four of these wheels provides omnidirectional movement for a vehicle without needing a conventional steering system. The design in figure 1 a shows a traditional *Mecanum* wheel with the peripheral rollers held in place from the outside [7].

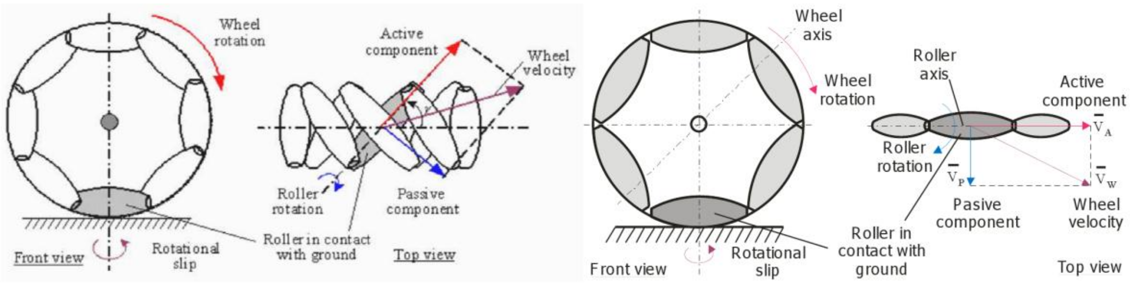


a) b)

Fig. 1. The *Mecanum* wheel based on *Ilon*' concept and the *Mecanum* wheel with centrally mounted rollers

The wheel is driven in a normal way, while the rollers allow for free motion in the perpendicular direction. This design, though has a good load carrying capacity, has the disadvantage that, when encountering an inclined or an uneven work surface, the rim of the wheel can make contact with the surface instead of the roller, thus preventing the wheel form operating correctly. A simple alternative design, also proposed by Ilon, which alleviates this problem, consists in having the rollers split in two and centrally mounted as is shown in figure 1 b. [7].

An omnidirectional wheel has 3 DOFs composed of wheel rotation, roller rotation, and rotational slip about the vertical axis passing through the point of contact. In most cases, the omnidirectional wheels are clasped relative to the robot body and do not rotate for steering, since steering can be performed by a combination of wheels velocities, in these types of mechanisms. Figure 3a shows a typical omnidirectional wheel in which the roller axes have an inclination angle γ with the wheel plane [8]. The wheel velocity can be divided into two components, one in the active direction and another in the passive direction. The active component is directed along the axis of the roller in contact with the ground, while the passive one is perpendicular to the roller axis. The wheel shown in the figure 3 a, b represents a general omnidirectional wheel and several different wheel mechanisms are available depending on roller types and inclination angles (e.g., Mecanum wheel with γ = 45° and universal wheel with γ = 0°), [8, 9].



a) b)

Fig. 3. The DOFs in a general omnidirectional wheel

In [7] two methods to improve the efficiency of the Mecanum wheel (Fig. 4, Fig. 5) were proposed. The first is a mechanically simple method (Fig. 4) of improving the energy losses when the robot is travelling in a straight line. The second method is mechanically more complex (Fig. 5), it proposes a model in which the peripheral rollers have the capability of having their angles dynamically adjusted to best suit the direction the platform is travelling in.

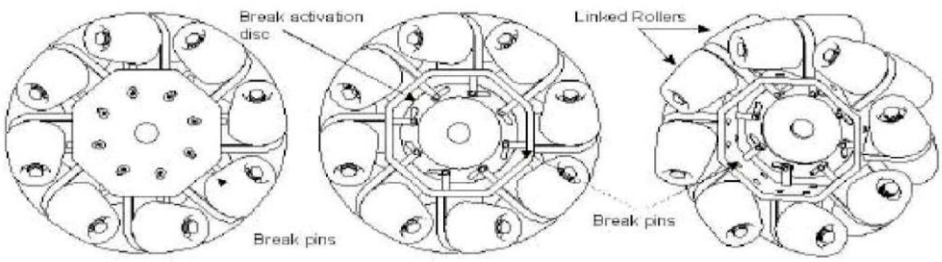
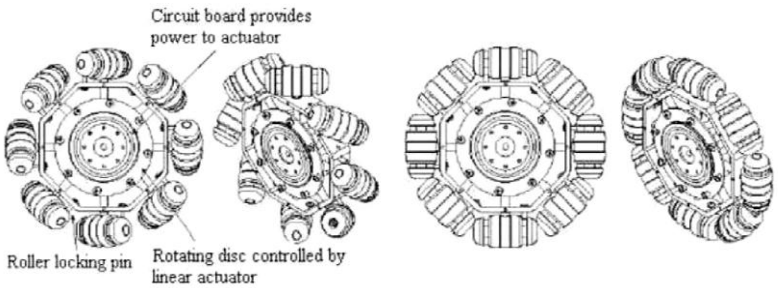


Fig. 4. The Mecanum wheel with lockable rollers



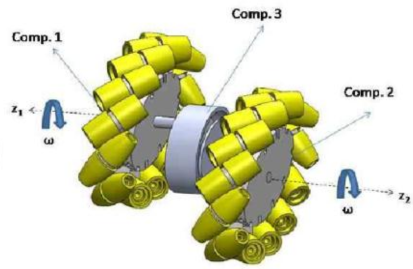


Fig. 5. Mecanum wheel with rotary rollers

Fig. 6. Elliptical Mecanum double wheel

In order to overcome the Mecanum wheel difficulties when moving on rough terrain, [10] has developed two new concepts of this type of wheel, using the principle of "steeping on obstacles". The first one is the concept of "elliptical Mecanum double wheel" (Fig. 6) and the second concept is the "semicircular Mecanum double wheel" [10].

Typical Mecanum wheel mobile robots are square or rectangular, attach with wheel with +45º roller and wheel with -45º roller on each side. The omnidirectional capabilities of the robots depend on each wheel contact firmly with the surface and some of the Mecanum wheel mobile robots are equipped with suspension systems.

The developed omnidirectional robots

The first omnidirectional robot presented in this paper (Fig. 7a) has a simple geometric shaped platform, at whose ends are attached two T-shaped elements. The robot is driven by four DC motors and the motor axis is connected with the hub of the Mecanum wheel. For each wheel the robot has attached a suspension system. The suspensions are connected to T- shaped elements and mobile element that is mounded on the motor-wheel ensemble. This design ensures that the rollers are always in contact with the work surface, thus allowing better performance on uneven surfaces. The developed robot is not energetically autonomous, being supplied from a voltage source. The 3D model of the robot is shown in figure 7a and the picture of the developed prototype is presented in figure 7b.

a)

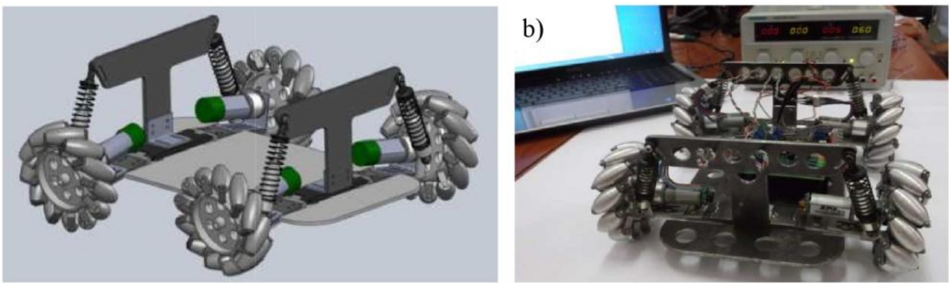


Fig. 7. The 3D model and the picture of the omnidirectional robot with Mecanum wheeles ($\gamma = 45°$)

The wheels design consists of a circular hub surrounded by the 12 rollers. The rollers are at 45 degrees to the axis of the hub and are fixed to the hub by a U shape element. At this type of wheels the hub is driven and the rollers idle. The 3D model and the picture of the wheel are shown in Fig. 8.

a)

Fig. 8. The 3D model and the picture of the Mecanum wheel

For the command and control of the omnidirectional robot, was designed and developed an electronic board using the following components: ATMega 644 microcontroller, 20 MHz extern oscillator, two L293D H-bridge drivers, TSOP34836 infrared sensor, LM7805 voltage stabilizer (Fig. 9). The control of the robot is possible in two ways: using infrared remote control or using a wireless PS2 joystick.

The structural scheme of the whole modular ensemble, including both mechanical and electronic components, is presented in figure 10. Achievement of the main movement directions is possible by changing the wheels rotation directions. For example the forward movement is possible when all four wheels are driven in the same direction.

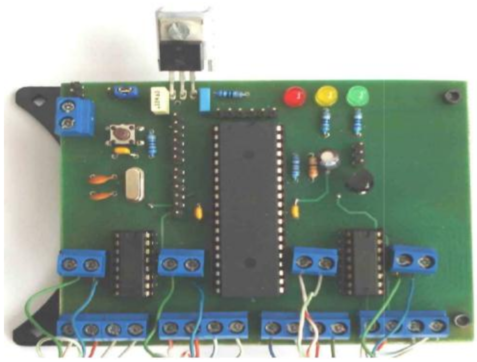


Fig. 9. The picture of the electronic board

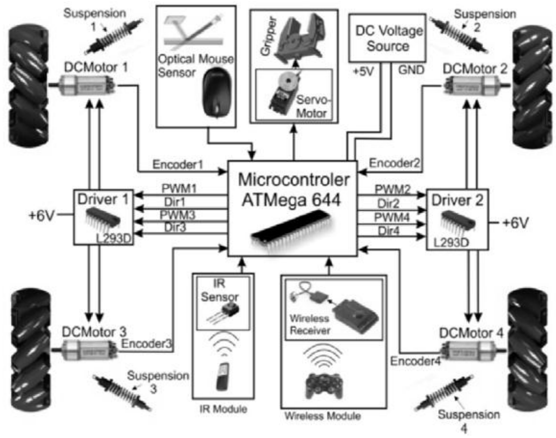


Fig. 10. The main modules of the omnidirectional robot

In figure 11 are specified the rotation direction for each wheel and the driving directions for each combination.

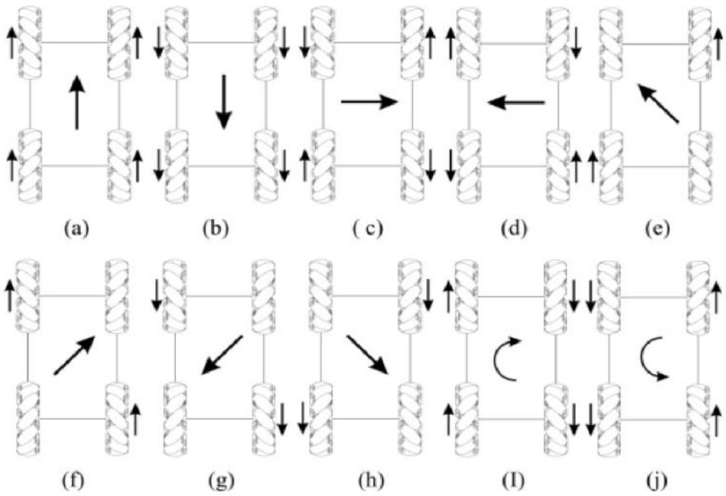


Fig. 11. Getting the robot's main directions of movement

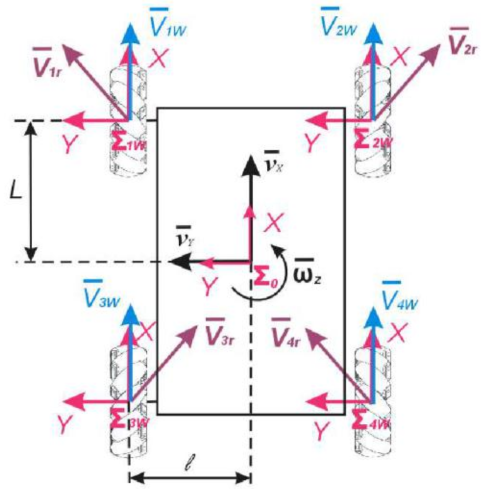


Fig. 12. Disposition of Mecanum wheels and frames [11]

In the figure 12 is presented the disposition of the wheels and the frames Σ_0, Σ_{iw} (i = 1,2,3,4), respectively. V_{iw} (i = 1,2,3,4) is the velocity vector corresponding to wheel revolutions, where $V_{iw} = \omega_{iw} R_w$, R_W, is the radius of wheel, ω_{iw} is the revolution velocity of the wheel, and V_{iw} (i = 1,2,3,4) is the tangential velocity vector of the free roller touching the floor. The velocity of the robot v_x, v_y and ω_z ar given by the relation [11]:

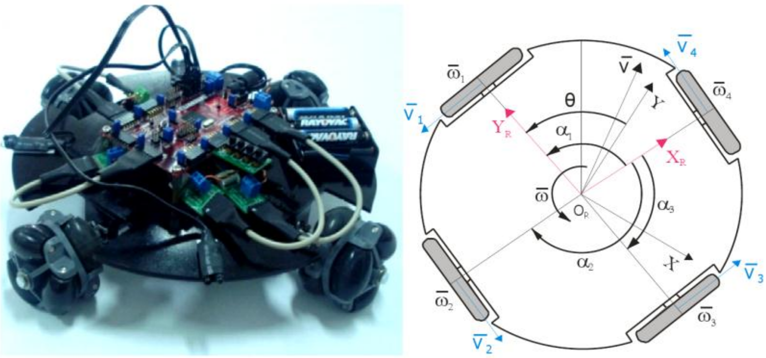
$$\begin{bmatrix} v_x(t) \\ v_y(t) \\ \omega_z(t) \end{bmatrix} = \frac{R_W}{4} \cdot \begin{bmatrix} 1 & 1 & 1 & 1 \\ -1 & 1 & 1 & -1 \\ -\frac{1}{L+l} & \frac{1}{L+l} & -\frac{1}{L+l} & \frac{1}{L+l} \end{bmatrix} \cdot \begin{bmatrix} \omega_1(t) \\ \omega_2(t) \\ \omega_3(t) \\ \omega_4(t) \end{bmatrix} \qquad (1)$$

The angular velocity of the wheel are given by the relation:

$$\begin{pmatrix} \omega_1(t) \\ \omega_2(t) \\ \omega_3(t) \\ \omega_4(t) \end{pmatrix} = \frac{1}{R_W} \cdot \begin{bmatrix} 1 & -1 & -(L+l)/2 \\ 1 & 1 & (L+l)/2 \\ 1 & 1 & -(L+l)/2 \\ 1 & -1 & (L+l)/2 \end{bmatrix} \cdot \begin{bmatrix} v_x(t) \\ v_y(t) \\ \omega(t) \end{bmatrix} \qquad (2)$$

Robot weight is about 2 [kg], has a height of 140 [mm], length of 290 [mm] and a width of 270 [mm]. This omnidirectional robot was tested in laboratory conditions and the obtained results were good.

The second omnidirectional robot (Fig. 13) presented in paper has four universal omnidirectional wheels arranged at 90^0 around a circular platform. Fig. 14 shows a commercial omnidirectional wheel used in our mobile robot design. This commercial wheel, called *Omniwheel* has six passive rollers on the periphery of the wheel, a trio on each side. The shafts of the rollers are perpendicular to the shaft of the wheel. An Omniwheel is driven in a normal fashion, while the rollers allow for a free motion in the perpendicular direction (sideways).

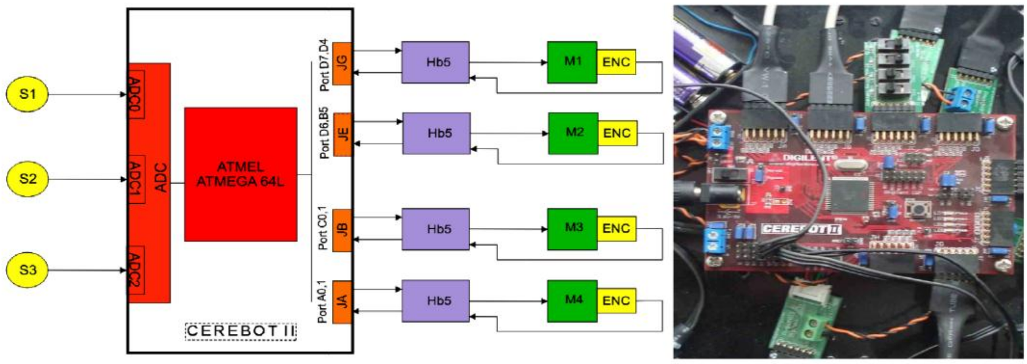


a) b)

Fig. 13. The omnidirectional robot with the four universal omnidirectional wheels

Fig. 14. The universal omnidirectional wheel

For its control, this robot is equipped with a Cerebot II circuit board [12]. The driving and control system architecture is presented in figure 15. Three optical distance sensors are mounted at 120^0 one from each other, on the main robot frame and connected to the ADC ports of the controller electronic board. Based on the received signal from the sensors the main electronic board sends command signals to the four DC motors connected at the ports JA, JB, JE and JG. Feedback signals are given by four rotary encoders, obtaining the position of the robot in the given space based on the kinematics of the robot.



a) b)

Fig. 15. The control system architecture for omnidirectional robot with four universal omnidirectional wheels

We consider the coordinate frame $X_RO_RY_R$ attached to the robot body and XOY the world coordinate (Fig. 13 b). The radius of the wheel and the radius of the robot body are denoted by r and L respectively. The angle between the axles of the wheels are denoted by α_i (i = 1,2,3,4). The angular velocity of the wheel is denoted by ω_i (i = 1,2,3,4) and the direction of the linear velocity of the centre of the wheel is indicated by v_i (i = 1,2,3,4) with respect to the coordinate $X_RO_RY_R$. The angle between the coordinates $X_RO_RY_R$ and XOY is denoted by θ. The linear and angular velocities of the robot are denoted by $v = [v_x, v_y]^T$ and ω [13].

The angular velocity of the wheel are given by the relation:

$$\begin{pmatrix} \omega_1(t) \\ \omega_2(t) \\ \omega_3(t) \\ \omega_4(t) \end{pmatrix} = \frac{1}{r} \cdot \begin{bmatrix} -\sin(\alpha_1) & \cos(\alpha_1) & L \\ -\sin(\alpha_2) & \cos(\alpha_2) & L \\ -\sin(\alpha_3) & \cos(\alpha_3) & L \\ 0 & 1 & L \end{bmatrix} \cdot \begin{bmatrix} v_x(t) \\ v_y(t) \\ \omega(t) \end{bmatrix} \quad (3)$$

The robot is energetically autonomous, has a diameter of 307 [mm] a height of 100 [mm] and a mass of 1,3 [kg].

Summary

The omnidirectional wheeled mobile robots have great potential in various applications, due to their ability to move toward any direction and rotate independently and instantaneously from any configuration. The robots which are proposed in this paper are omnidirectional robots equipped with four Swedish wheels (Mecanum and universal omnidirectional wheels), driven by DC motors and reducers. The developed prototypes were tested in laboratory conditions and the obtained results were good.

References

[1] T. Braunl, Embedded Robotics: Mobile Robot Design and Applications with Embedded Systems, First Edition. Springer-Verlag, Berlin, 2003.

[2] I. Doroftei, V. Grosu, V. Spinu, Omnidirectional Mobile Robot - Design and Implementation, Book-Chapter, Bioinspiration and Robotics - Climbing and Walking Robots, Editor Maki K. Habib, Published by Advanced Robotic Systems International (Vienna) and I-Tech, 2007, pp. 511-529.

[3] Y. Liu, J. J. Zhu, R. L. Williams, II, and J. Wu, Omni-directional mobile robot controller based on trajectory linearization, Robotics and Autonomous. Systems, 56 (2008) 461 - 479.

[4] G. Indiveri, Swedish Wheeled Omnidirectional Mobile Robots: Kinematics Analysis and Control, IEEE Transactions on Robotics, 25(1) (2009) 164 - 171.

[5] H. P. Oliveira, A. J. Sousa, A. P. Moreira and P. J. Costa, Modeling and assessing of omni-directional robots with three and four wheels, in: A. D. Rodi (Ed.), Challenges and Solutions, INTECH, 2009, pp. 207-229.

[6] B. E. Ilon, U.S. Patent 3,876,255. (1975).

[7] O. Diegel, A. Badve, G. Bright J. Potgieter S. Tlale, Improved Mecanum Wheel Design for Omnidirectional Robots, Proceedings of the Australasian Conference on Robotics and Automation, 27-29, 2002, pp. 117-122.

[8] J.B. Song, K.S. Byun, Design and Control of a Four-Wheeled Omnidirectional Mobile Robot with Steerable Omnidirectional Wheels, Journal of Robotic Systems, 21(4) (2004) 193-208.

[9] K.S. Byun, J.B. Song, Design and Construction of Continuous Alternate Wheels for an Omnidirectional Mobile Robot, Journal of Robotic Systems 20(9), (2003), 569–579.

[10] A. Ramirez-Serrano, R. Kuzyk, Modified Mecanum Wheels for Traversing Rough Terrains, Sixth International Conference on Autonomic and Autonomous Systems, ICAS 2010, Cancun, Mexico, 2010. pp. 97-103.

[11] P. Viboonchaicheep, A. Shimada, Y. Kosaka, Position Rectification Control for Mecanum Wheeled Omni-directional Vehicles, Proceedings the 29th Annual Conference of the IEEE Industrial Electronics Society, Roanoke, VA, USA, 2003, pp. 854-859.

[12] Information on www.digilentinc.com

[13] L. Huang, Y.S. Lim, D. Li, C.E.L Teoh, Design and Analysis of a four wheel omnidirectional mobile robot, The 2nd International Conference on Autonomus Robots and Agents, New Zealand, 2004, pp. 425-428.

Mechatronic Systems and Materials IV
10.4028/www.scientific.net/SSP.198

Structures of the Omnidirectional Robots with Swedish Wheels
10.4028/www.scientific.net/SSP.198.132