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Remote Controlled Omnidirectional Guided Vehicle

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ABSTRACT: Our research goal is to realize a robust navigation in indoor and outdoor environment for autonomous vehicle. An omnidirectional vehicle driven by four Mecanum wheels was chosen for our research platform. Mecanum wheel has 16 (depending on the dimension of the roller) tilted rollers (45 degrees against the direction of wheel rotation) around the wheel, so the vehicle moves omnidirectional by controlling these wheels independently. This project speaks on the omnidirectional vehicles that which dismisses the use of Ackerman steering or differential drive system. These vehicles can move sideways and turn on the spot. These vehicles are used to perform tasks in environments in static and dynamic obstacles.A variety of designs of mobile robot have been developed in recent years in order to improve their Omni-directional maneuver and practical applications. Omni-directional mobile robot has vast advantages over conventional design likes differential drive in term of mobility in congested environments. The main purpose of this research is to design, develop and implement an Omni-directional mobile robot with custom made mecanum wheel for autonomous navigation. Using these mecanum wheels, the mobile robot is provided with three degree of freedom (DOF) mobility. Attention also paid for the development of kinematics and dynamics model to analyze the mobile platform motion performances. Motor driver and robot controller were also developed. Experiments were performed to analyze the motion characteristic of the mobile robot motion in Y axis, X axis and differential drive capabilities. The developed mobile robot will provide a test bed for advanced path planning and navigation projects in the future.

I. INTRODUCTION

Each Mecanum wheel has three degrees of freedom of motion in a plane, so a mobile robot system consisting of three or more than three Mecanum wheels can achieve omnidirectional motion in a plane only through the coordination of direction and rotation speed of wheels without the assistance of an auxiliary steering mechanism. Because of the simple structure and good motion flexibility, omnidirectional mobile robots with Mecanum wheels are widely used in various fields. According to application needs in different fields, a variety of Mecanum wheel configurations can be designed to develop various omnidirectional mobile robots. Some service robots usually adopt three or four-Mecanum-wheel configurations. In the industrial field, an AGV (automated guided vehicle) with four Mecanum wheels, a kind of omnidirectional mobile robot, is also widely used. For transporting large-scale equipment or components, a robot platform with multiple Mecanum wheels or multiple-Mecanum-wheeled robot platforms are used cooperatively. In order to design an omnidirectional mobile robot, it is necessary to select a reasonable Mecanum wheel configuration for the robot. However, not all combinations of Macanum wheels can implement omnidirectional motion, and the arrangement of Mecanum wheels also influences the mobility performance of the robot. Therefore, designing a reasonable configuration of Mecanum wheels constitutes the most basic and important technology problem in the design of omnidirectional mobile robots. Firstly, these configurations must satisfy the conditions of realizing omnidirectional movement. Secondly, motion performance, controllability, and structural rationality of these configurations must be evaluated in order to select the optimal Macanum wheel configuration.Some researchers have paid attention to the study of Mecanum wheel configurations. The kinematics and dynamics of a Mecanum-wheeled mobile robot form the basic premise to judge the robot to achieve omnidirectional movement in theory. Introduced a methodology for the kinematic modeling of wheeled mobile robots, studied an omnidirectional wheeled mobile robot with four Mecanum wheels, and derived the kinematic model of roller angle dead reckoning robot position wheel slip. Angeles deduced a general kinematics model of the Mecanum-wheeled omnidirectional mobile system by vector method, and gave kinematics and dynamics equations of three-wheel and four-wheel robots, respectively. Campion used a matrix transformation method to study the mobility characteristics of the robot under constraints, gave a unified description of modeling of a wheeled mobile robot, and deduced the kinematics equation of the three-wheeled robot. Gracia and Tornero described the singular and heterogeneous types of mobile robots based on Mecanum wheels and Castor wheels using a descriptive geometry method, established the kinematics model of omnidirectional mobile robots under sliding conditions, and further established the Lagrange dynamics model. Zhang and Wang analyzed the steering motion of a Mecanum-wheeled omnidirectional mobile platform, and established a control system model and dynamic model in MATLAB and RecurDyn software, respectively. Using joint simulation, the anisotropic motion characteristics of a mobile platform with different slip rates were obtained. Wang and Chang analyzed the condition of omnidirectional motion of a Mecanum-wheeled mobile system and found that the Jacobian matrix of inverse kinematics velocity is a column full rank, discussed the possible singularities and solutions in motion, and showed six types of Mecanum wheels layouts and determined the four best Mecanum wheel layouts. Mishra et al. proposed 10 possible configurations of the omnidirectional mobile robot with four Mecanum wheels. Gao et al studied a type of three-Mecanum-wheel omnidirectional mobile robot with symmetrical and concentric layout structure, and the motion simulation of the three-Mecanum-wheeled platform is compared with that of the symmetrical four-Mecanum-wheeled mobile robot platform. Zhang et al. studied the three and four-Mecanum-wheeled concentric layouts and analyzed the influence of the angles between wheel axes for a centered layout. He et al. studied the two most used arrangement modes of Mecanum wheels, Type-X and Type-O, and used the inverse velocity Jacobian matrix of the arrangement to judge whether a vehicle can fulfill omnidirectional movement. The main contributions of these studies on wheel configuration include: (1) the method of establishing a kinematics equation of an omnidirectional mobile robot is proposed; (2) the method of judging omnidirectional mobility by rank of the Jacobian matrix of inverse kinematics is obtained; (3) the possible configuration of three or four Mecanum wheels is summarized and analyzed and compared. However, when using an inverse kinematics Jacobian matrix to analyze a multiple-Mecanum-wheeled mobile robot system, the calculation process is complex. Previous studies have not systematically summarized multiple-Mecanum-wheel (more than four wheels) configurations, and have not explicitly proposed a method to obtain the wheel configurations for omnidirectional mobile robots with more than four Mecanum wheels. This study explores a simple and efficient method to judge whether the wheel configurations possess omnidirectional mobility. On this basis, the common wheel configurations are judged and analyzed, the law of wheel configurations is explored, and the topological design methods of wheel configurations for an omnidirectional mobile robot are summarized and refined. This paper is organized as follows: In Section 2, on the basis of studying the kinematic constraints of a single Mecanum wheel in a mobile system, the kinematics model of an n-Mecanum-wheeled mobile robot is further deduced. In Section 3, the relationship between the intersections of bottom-rollers axles of any three Mecanum wheels and the column rank of the Jacobian matrix of inverse kinematics of the mobile robot is established, and a bottom-rollers axles intersections approach for judging the omnidirectional mobility of Mecanum wheel configurations is proposed and proved theoretically, which is a simple and efficient geometric method. In Section 4, the four-Mecanum-wheel configurations are judged by using a bottom-rollers axles intersections approach, and the optimal four-Mecanum-wheel configuration is selected through comprehensive analysis and theoretical verification. In Section 5: firstly, the above method is used to judge the omnidirectional motion of a combined configuration consisting of two four-Mecanum-wheel configurations, and then the sub-configuration judgment method, which can be extended to N sub-configuration combinations is obtained. Secondly, this judgment method is used to analyze the Mecanum wheel configurations and combination configurations for common omnidirectional mobile robots, and clarify the law determining wheel configuration. Finally, the topological design methods of the Mecanum wheel configurations are summarized and refined, including the basic configuration array method, multiple wheel replacement method and combination method. Furthermore, based on the symmetrical four-Mecanum-wheel configuration, the Mecanum wheel configurations are generated by using the topological design methods.

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II. METHODOLOGY

Robotic vehicles are often designed for planar motion, they operate on a warehouse floor, road, lake, table etc. In such a two dimensional (2D) space, a body has three degrees of freedom (3DOF). It is capable of translating in both directions (˙x, y˙) and rotate (˙θ) about its center of gravity. Most conventional vehicles however do not have the capability to control every degree of freedom independently. Conventional wheels are not capable of moving in a direction parallel to their axis. This so called non-holonomic constraint of the wheel prevents vehicles using skid-steering, like a car, from moving perpendicular to its drive direction. While it can generally reach every location and orientation in a 2D space, it can require complicated maneuvers and complex path planning to do so. This is the case for both human operated and robotic vehicles.

When a vehicle has no non-holonomic constraints, it can travel in every direction under any orientation. This capability is widely known as omnidirectional mobility. A variety of omnidirectional designs have been developed. They provide excellent mobility, especially in areas congested with static or dynamic obstacles, such as offices, workshops, warehouses and hospitals.

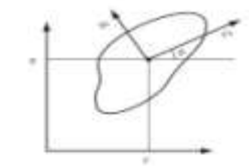

Figure 2.1: planar motion, 3 degrees of freedom

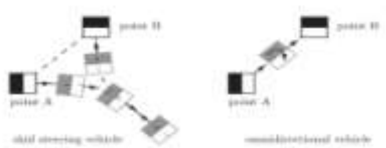

Figure 2.2: non-holonomic mobility versus omnidirectional mobility

At present, the mobile robot with four Mecanum wheels is the most popular configuration in both scientific research and industrial application. There are many possible wheel configurations for the four-Mecanum-wheel robot, some of them are illustrated in Figure 8. In Figure 8, the inclined line on the wheel in the figure represents the inclined direction of roller in contact with the ground. Figure 8a–j show 10 rectangular configurations of four wheels that are arranged at the corner and whose axles are parallel to the centerline of robot. Figure 8k–n show four possible centripetal configurations of four wheels. Figure 8o shows a centripetal circular array configuration of four Omni wheels. In the configurations (a), (f), and (k), any three roller axes are parallel to each other or coincide with each other. The number of intersection points of the three roller axles is 0 or 1 (the overlapping axles are considered to intersect at one point). The column ranks of the Jacobian matrix of these configurations are 2. These configurations obviously cannot achieve omnidirectional movement. In the wheel configurations (b)–(e), (g)–(j), and (l)–(n), the axles of the bottom-rollers of three wheels intersect at two points, so the Jacobian matrices of these wheel configurations are column full-rank matrices. In theory, these configurations can achieve omnidirectional movement in the plane. In practical applications, besides satisfying the conditions of the column full rank of the Jacobian matrix, the configuration also needs good operability and driving performance. Wheel configurations (b), (c), (d), (g), (h), (i), (l), and (m) can satisfy the conditions of omnidirectional motion, but the symmetry and the driving performance of the mobile system is poor. Considering the influence of dynamic factors, such as friction and moment of inertia, in actual operation, there will be a large deviation in the motion. Therefore, these configurations are generally not used. In addition, if the centers of four wheels in the configuration (j) form a square, the axles of the three bottom-rollers intersect at the one point, the column rank of Jacobian matrix in these configurations will change from 3 to 2, and it is no longer an omnidirectional mobile system. Configuration (n) has omnidirectional mobility, but the motion friction component of the configuration cannot offset itself in the course of movement, and there is a tendency to rotate in situ. Configuration (o) is the configuration (n) using orthogonal Mecanum wheels, mostly for small robotic mobile platforms. The symmetry of wheels configurations (e) and (j) is the best among these wheel configurations that can achieve omnidirectional motion. However, when rotating on the spot, the mobile robot system with the configuration (j) has a small driving torque and a weak driving effect. Therefore, the configuration (e) is the optimal configuration of a four-Mecanum-wheel system.Four-Mecanum-wheel configurations: (a)–(j) rectangular configurations of four wheels that are arranged at the corner and whose axles are parallel to the centerline of the robot; (k)–(n) centripetal

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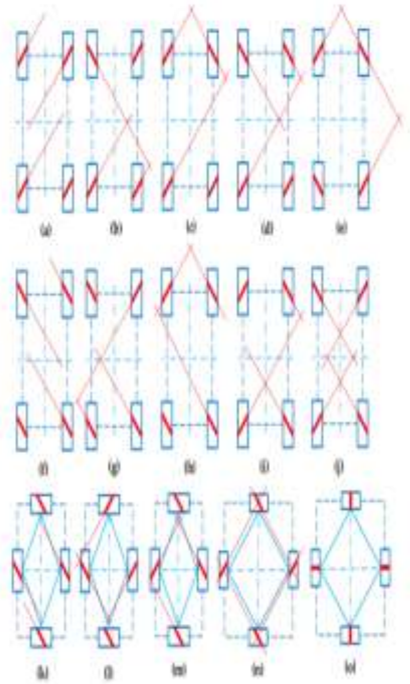
configurations of four Mecanum wheels; (o) centripetal circular array configurations of four orthogonal mecanum wheel.



2.1MATERIALS USED

2..1.1 MECANUM WHEEL

Mecanum wheel also known as ilon wheels It is a conventional wheel with a series of rollers attached to its circumference, these rollers having an axis of rotation at 45° to the plane of the wheel in a plane parallel to the axis of rotation of the wheel. Depending on each individual wheel direction and speed, the resulting combination of all these forces produce a total force vector in any desired direction thus allowing the platform to move freely in the direction of the resulting force vector, without changing of the wheels themselves.It is perfect for tight space.The Mecanum wheel is based on a tireless wheel, with a series of rubberized external rollers obliquely attached to the whole circumference of its rim. These rollers typically each have an axis of rotation at 45° to the wheel plane and at 45° to the axle line. Each Mecanum wheel is an independent non-steering drive wheel with its own powertrain, and when spinning generates a propelling force perpendicular to the roller axle, which can be vectored into longitudinal and a transverse component in relation to the vehicle.

2.1.2 DC MOTOR

The DC motor is very famous due to its unique properties and easy speed control as compared to AC motor. Starting torque for various DC motor is very high and can be useful in applications where load is very high and variable. Special DC motor can also be used for AC or DC supply. Some common household appliances like blenders and hair dryer uses DC motors. The Dc motor works on the principle of Lorentz force equation. It states that when a current carrying conductor is placed in a magnetic field, the conductor experiences a force. In the DC motor, the armature is the conductor and due its shape, it produces a torque, thereby rotating the shaft. This is also called as motoring action. If the direction of current is r eversed, the direction of forces also changes and motor starts to rotate in opposite direction. This direction of rotation is determined by Fleming's Left-Hand Rule.The DC motor is very famous due to its unique properties and easy speed control as compared to AC motor. Starting torque for various DC motor is very high and can be useful in applications where load is very high and variable. Special DC motor can also be used for AC or DC supply. Some common household appliances. like blenders and hair dryer uses DC motors. The Dc motor works on the principle of Lorentz force equation. It states that when a current carrying conductor is placed in a magnetic field, the conductor experiences a force. In the DC motor, the armature is the conductor and due its shape, it produces a torque, thereby rotating the shaft. This is also called as motoring action. If the direction of current is r eversed, the direction of forces also changes and motor starts to rotate in opposite direction. This direction of rotation is determined by Fleming's Left-Hand Rule.The DC motor is very famous due to its unique properties and easy speed control as

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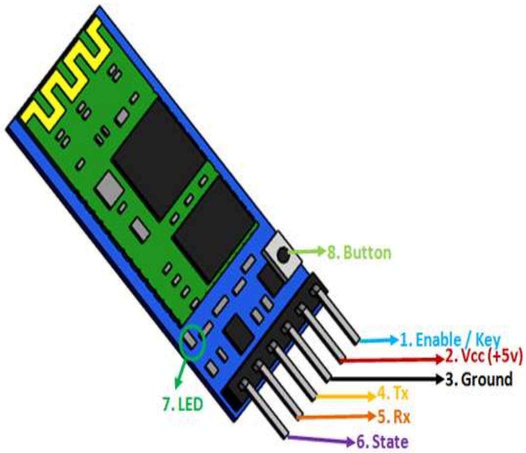
2.1.3 BLUETOOTH MODULE:

A Bluetooth module is usually a hardware component that provides. A wireless product to work with the computer; or in some cases, the. Bluetooth may be an accessory or peripheral, or a wireless headphone. Or other product (such as cellphones can use.) The Bluetooth technology manages the communication channel of the wireless part. The Bluetooth modules can transmit and receive the data wirelessly by using two devices. The Bluetooth module can receive and transmit data from a host system with the help of the host controller interface (HCI). 1 Select the proper wireless standard for the application, and decide whether the Bluetooth is the most suitable wireless technology for the product. 2 Select a Bluetooth chip or module suitable for your product. 3 Select the testing equipment or hire the RF design expert. He BT Bluetooth module is a stackable shield with serial ports based on the HC-06 module. The shield can be connected directly to the Arduino UART port for wireless communication. Without obstacles or other interference, the Bluetooth shield can communicate in a range of 10 meters.



2.1.4RELAY:

The 4 Channel Relay Breakout is an easy way to use your Arduino, Raspberry Pi, or other microcontroller to switch high voltages and high current loads. The board is both 3.3V and 5V logic compatible and uses 4 digital outputs to control 4 individual relays.Relays are electric switches that use electromagnetism to convert small electrical stimuli into larger currents. These conversions occur when electrical inputs activate electromagnets to either form or break existing circuits.

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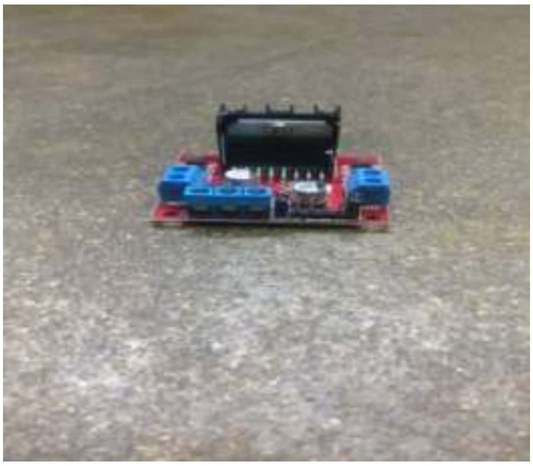
2.1.5MOTOR DRIVE:

Motor drive, or simply known as drive, describes equipment used to control the speed of machinery. Many industrial processes such as assembly lines must operate at different speeds for different products. Where process conditions demand adjustment of flow from a pump or fan, varying the speed of the drive may save energy compared with other techniques for flow control.

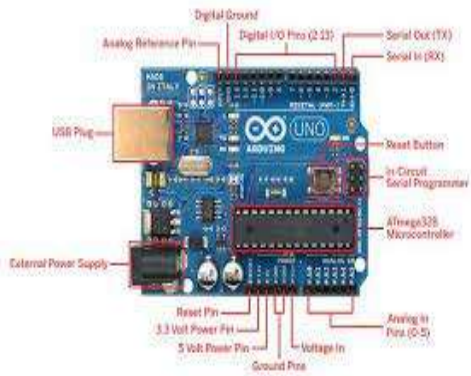
Where speeds may be selected from several different pre-set ranges, usually the drive is said to be adjustable speed. If the output speed can be changed without steps over a range, the drive is usually referred to as variable speed.

Motor drivers acts as an interface between the motors and the control circuits. Motor require high amount of current whereas the controller circuit works on low current signals. So the function of motor drivers is to take a low-current control signal and then turn it into a higher-current signal that can drive a motor.



2.1.6ARDUINO UNO:

The name Arduino comes from a bar in Ivrea, Italy, where some of the founders of the project used to meet. The bar was named after Arduino of Ivrea, who was the margrave of the March of Ivrea and King of Italy from 1002 to 1014. The Arduino Uno is a microcontroller board based on the ATmega328. It has 20 digital input/output pins (of which 6 can be used as PWM outputs and 6 can be used as analog inputs), a 16 MHz resonator, a USB connection, a power jack, an in-circuit system programming (ICSP) header, and a reset button. Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online. Arduino programs can be divided in three main parts: Structure, Values (variables and constants), and Functions.



2.1.7RACK AND PINION ARRANGMENT:

A rack and pinion is a type of linear actuator that comprises a circular gear (the pinion) engaging a linear gear (the rack), which operate to translate rotational motion into linear motion. This basic rack is the profile of the conjugate gear of infinite pitch radius. The rack and pinion gear set has two main functions: Conversion of the steering wheel's rotational motion into the linear motion needed for the vehicle's wheels to turn. Reduction of gears, which makes it easier for the steering wheel to turn the wheels. : A Rack and Pinion Lift is composed of two gears and a Rack and Pinion arrangement. The flat helical gear is the rack and the round helical gear is the pinion. The rack has teeth cut into it and they mesh the teeth of the pinion gear. The rack carries the full load of the actuator directly and so the driving pinion is usually small, so that reduces the torque required. This force, thus torque, may still be substantial and

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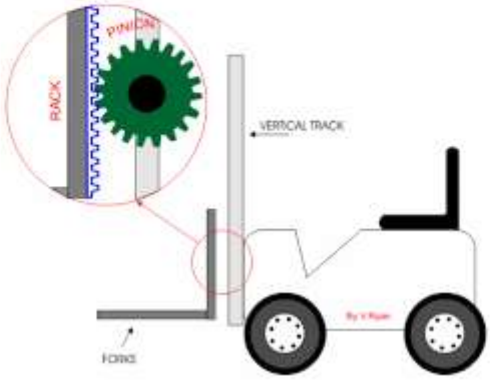
so it is common for there to be a reduction gear immediately before this by either a gear OR WORM GEAR reduction. Rack gears have a higher ratio, thus require a greater driving torque, than screw actuators.



These are the basic important accessories need for this project. Omni wheels or poly wheels, similar to Mecanum wheels, are wheels with small discs (called rollers) around the circumference which are perpendicular to the turning direction. The effect is that the wheel can be driven with full force, but will also slide laterally with great ease.

III. CONCLUSION

3.1 Conclusion

Wheeled mobile robots (WMRs) are increasingly present in industrial and service robotics, particularly when flexible motion capabilities are required on reasonably smooth ground and surface (Schraft et al., 1998). Several mobility configurations (wheel number and type, their location and actuation, single or multi-body structure) can be found in the applications (Jones et al., 1993), which can be lead to designing and implementing an asymmetric robot. This paper has presented a control model for a specific kind of asymmetric omnidirectional wheeled mobile robot. During initial modelling and experimental works, it was supposed that asymmetric feature could be a limitation for robot to meet the requirements. While this is true, it was however learned that if we derive proper control model for robot we can overcome this limitation to some extent. Since our objective was to model the control of a specific kind of an asymmetric omnidirectional wheeled mobile robot, this paper did not develop a method for a large variety of asymmetric robots. A control method that depends on the angles between robot wheels, and includes motion and velocity equations are supposed to be developed in the future studies as extension of this work.

REFERENCES

[1]. Borenstein, J.; Everett, H.R. & Feng, L. (1996). Navigating Mobile Robots: Sensors and Techniques. A K Peters, Ltd, MA, USA.

[2]. Bräunl, T. (1999). Eye-Bot: a family of autonomous mobile robots. In: Proceedings of 6thInternational Conference on Neural Information Processing, November, 1999, Perth, Australia. Dickerson, S.L. & Lapin, B.D. (1991). Control of an omni-directional robotic vehicle with Mecanum wheels. In: National Telesystems Conference Proceedings, March 26-27, 1991, Atlanta, USA.

[3]. Diegel, O.; Badve, A.; Bright, G.; Potgieter, J. &Tlatle, S. (2002). Improved Mecanum Wheel Design for Omni-directional Robots, Proc. 2002 Australian Conference on Robotics and Automation, Auckland, 27-29 Nov. 2002.

[4]. Dubowsky, S.; Genot, F.; Godding, S.; Kozono, H.; Skwersky, A.; Yu, H. & Yu, L. (2000). PAMM – A Robotic Aid to the Eldery for Mobility Assistance and Monitoring: A Helping-Hand for the Elderly, IEEE International Conference on Robotics and Automation, 2000.

[5]. Everett, H.R. (1995). Sensors for Mobile Robots: Theory and Application. A K Peters, Ltd, MA, USA.

[6]. Giachetti, A.; Campani, M. & Torre, V. (1998). The use of optical flow for road navigation. IEEE Transactions on Robotics and Automation. Vol.,14.

[7]. Ilon, B. E. (1975). Wheels for a Course Stable Selfpropelling Vehicle Movable in any Desired Direction on the Ground or Some Other Base. U.S. Patent. U.S.A.

[8]. Koestler, A. &Bräunl, Th. (2004). Mobile Robot Simulation with Realistic Error Models, 2nd International Conference on Autonomous Robots and Agents, December 13-15, 2004 Palmerston North, New Zealand.

[9]. Muir, P. F. & C. P. Neuman (1987). Kinematic Modeling for Feedback Control of an Omnidirection Wheeled Mobile Robot. IEEE Intenational Conference on Robotics and Automation.Muir, P. F. & C. P. Neuman (1987). Kinematic Modeling of Wheeled Mobile Robots. Journal of Robotic Systems, No. 4(2).

[10]. Muir, P.F. & Neumann, C.P. (1990). Kinematic modeling for feedback control of an omnidirectional wheeled mobile robot.

In: Autonomous Robot Vehicles, Editors I.J. Coxy and G.T. Wilfong, Springer-Verlag, Berlin. Nagatani, K.; Tachibana, S.; Sofne, M. & Tanaka, Y. (2000). Improvement of odometry for omnidirectional vehicle using optical flow information. IEEE/RSJ International Conference on Intelligent Robots and Systems.Salih, J.E.M.; Rizon, M.; Yaacob, S.; Adom, A.H. &Mamat, M.R. (2006).

[11]. Designing Omni-Directional Mobile Robot with Mecanum Wheel, American Journal of Applied Sciences3 (5). Siegwart, R. &Nourbakash, I.R. (2004). Intro to Autonomous Mobile Systems, MIT Press 2004.

[12]. Song, J.B. & Byun, K.S.. (2004). Design and Control of a Four-Wheeled Omnidirectional Mobile Robot with Steerable Omnidirectional Wheels, Journal of Robotic Systems,21(4), 2004, pp. Yu, H.; Dubowsky, S. & Skwersky, A. (2000). Omni-directional Mobility Using Active Split Offset Castors, Proceedings ASME Design Engineering Technical Conferences, Baltimore, September 2000

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