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# Intelligent wheeled mobile robot navigation


### Abstract

The paper deals with the wireless sensor-based remote control of mobile robots motion in an unknown environment with obstacles using the Sun SPOT technology and gives the fuzzy velocity control of a mobile robot motion in an unknown environment with obstacles. When the vehicle is moving towards the target and the sensors detect an obstacle, an avoiding strategy and velocity control are necessary. We proposed the wireless sensor-based remote control of mobile robots motion in an unknown environment with obstacles using the Sun SPOT technology and a fuzzy reactive navigation strategy of collision-free motion and velocity control in an unknown environment with obstacles. The simulation results show the effectiveness and the validity of the obstacle avoidance behavior in an unknown environment. The proposed method have been implemented on the miniature mobile robot Khepera® that is equipped with sensors.


### 1. Introduction

The paper deals with the wireless sensor-based remote control of mobile robots motion in an unknown environment with obstacles using the Sun SPOT technology and gives the fuzzy velocity control of a wheeled mobile robot motion in an unknown environment with obstacles. The simulation results show the effectiveness and the validity of the obstacle avoidance behavior in an unknown environment. Finally, the proposed method have been implemented on the miniature mobile robot Khepera® that is equipped with sensors and the free range Spot from the Sun Spot technology.

The paper is organized as follows: Section 1: Introduction. In Section 2 modeling of the wheeled mobile robots is illustrated. In Section 3 strategy of autonomous wheeled mobile robot motion in an unknown environment with obstacles is proposed. In Section 4 the simulation results are illustrated. In Section 5 Sun SPOT based remote control of mobile robots is proposed. Conclusions are given in Section 6.

### 2. Modeling of the wheeled mobile robots

The position of the mobile robot in the plane with obstacle and target position is shown in *Fig. 1.* Where: p – the obstacle distances, $\theta_1$ – the obstacle orientation, 1 – the target distances, $\theta_2$ – the target orientation.

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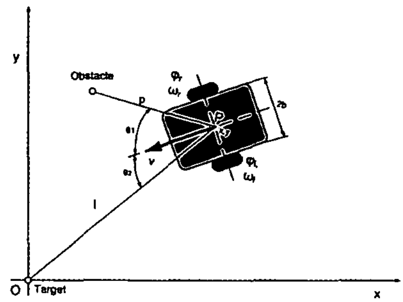


***Figure 1.* Position of mobile robot in plane**
(*Source:* Author)

A mobile robot involving two actuator wheels is considered as a system subject to non-holonomic constraints. The inertial-based frame (Oxy) is fixed in the plane of motion and the moving frame is attached to the mobile robot. The contact between the wheel of the mobile robots and the non-deformable horizontal plane supposes both the conditions of pure rolling and non-slipping during the motion. This means that the velocity of the contact point between each wheel and the horizontal plane is equal to zero. The rotation angle of the wheel about its horizontal axle is denoted by $\varphi(t)$ and the radius of the wheel by R. Hence, the position of the wheel is characterized by two constants b and R and its motion by a time-varying angle: $\varphi_r(t)$ – the rotation angle of the right wheel and: $\varphi_l(t)$ – the rotation angle of the left wheel. The configuration of the mobile robot can be described by 5 generalized coordinates such as:

$$q = [x, \ y, \ \theta, \ \varphi_r, \ \varphi_l]^T \tag{1}$$

Where: x and y are the two coordinates of the origin P of the moving frame (the geometric center of the mobile robot), $\theta$ is the orientation angle of the mobile robot (of the moving frame). The kinematics model of the vehicle velocity v and the angular velocity $\dot{\theta}$ of the mobile robot can be represented by the matrix as follows (Gyula Mester 2006):

$$\begin{bmatrix} v \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} R/2 & R/2 \\ R/2b & -R/2b \end{bmatrix} \begin{bmatrix} \omega_r \\ \omega_l \end{bmatrix} \tag{2}$$

## *3. Strategy of autonomous wheeled mobile robot motion in an unknown environment with obstacles*

Currently many researches in robotics are dealing with different problems of motion of wheeled mobile robots. Let us consider the autonomous motion of wheeled mobile robots in an unknown environment. The mobile robot must be capable of sensing its environment. Conventionally, mobile robots are equipped by ultrasonic sensors and a stereo-vision system.

The role of cameras is to identify the relative position and direction of motion of mobile robot in unknown environment. The accurate distance of the obstacle can be obtained from the ultrasonic sensors. In moving towards the target and avoiding obstacles, the mobile robot changes its orientation and velocity. In this section fuzzy control is applied to the navigation of the autonomous mobile robot in an unknown environment with obstacles (Gyula Mester

2006, W. L. Xu, S. K. Tso, Y. H. Fung 1998, Jian Wanga et al. 2006). We supposed that: the autonomous mobile robot has two wheels driven independently and groups of ultrasonic sensors to detect obstacles in the front, to the right and to the left of the vehicle. When the vehicle is moving towards the target and the sensors detect an obstacle, an avoiding strategy is necessary. With obstacles present in the unknown environment, the mobile robot reacts based on both the sensed information of the obstacles and the relative position of the target (Jian Wanga et al. 2006). In moving towards the target and avoiding obstacles, the mobile robot changes its orientation and velocity. When the obstacle in an unknown environment is very close, the mobile robot slows down and rapidly changes its orientation. The navigation strategy is to come as near to the target position as possible while avoiding collision with the obstacles in an unknown environment. The intelligent mobile robot reactive behavior is formulated in fuzzy rules. Inputs to the fuzzy controller are: the obstacle distances p, the obstacle orientation θ1, the target distances l, the target orientation θ2. Outputs of the fuzzy controller are: the angular speed difference between the left and right wheels (wheel angular speed correction) of the vehicle: $\Delta\omega = \omega r - \omega l$ and the vehicle velocity V. The obstacle orientation θ1 and the target orientation θ2 are determined by the obstacle/target position and the robot position in a world coordinate system.

For the proposed fuzzy controller the input variables for the obstacle distances p are simply expressed using two linguistic labels *near* and *far* (p Є [0, 3 m]). *Fig. 2.* shows the suitable Gaussian membership functions.

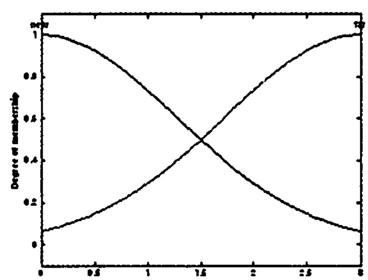

***Figure 2.* Membership functions of p**
**Source: Author**

The input variables for the obstacle orientation $\theta_1$ *(Fig. 3)* are expressed using two linguistic labels *left* and *right* ($\theta_1$Є[-π,π rad]).

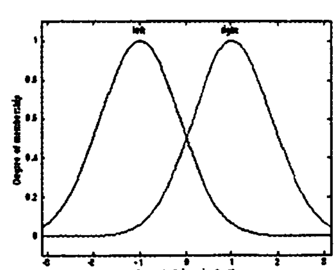

***Figure 3.* Membership functions of $\theta_1$**
(*Source:* Author)

The input variables for the target distances l *(Fig. 4)* are expressed using two linguistic labels *near* and *far*: l ∈ [0, 3 m]).

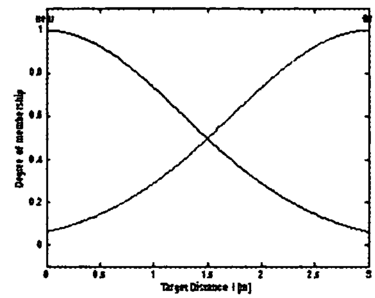

***Figure 4.*** **Membership functions of l**
(*Source:* Author)

The input variables for the target orientation $\theta_2$ are simply expressed using three linguistic labels *(Fig. 5) left*, *target-direction* and *right*: $\theta_2$ ∈ [-3.14, 3.14 rad].

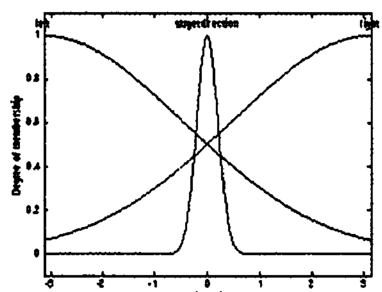

***Figure 5.*** **Membership functions of $\theta_2$**
(*Source:* Author)

The output variables the wheel angular speed correction are shown in *Fig. 6*.

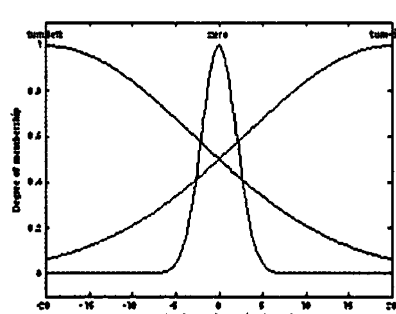

***Figure 6.*** **Membership functions of the $\Delta\omega$**
(*Source:* Author)

The other output variable *(Fig. 7)* of the fuzzy controller the vehicle velocity are normalized between: V € [-10, 20 m/s].

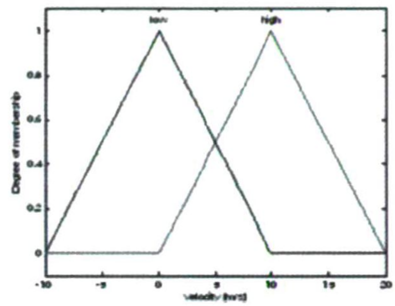

***Figure 7.* Membership functions of the V**
(*Source:* Author)

The rule-base for mobile robot fuzzy control are: **R1**: If $\theta_2$ is right then $\Delta\omega$ is turn-right. **R2**: If $\theta_2$ is left then $\Delta\omega$ is turn-left. **R3**: If p is near and l is far and $\theta_1$ is left then $\Delta\omega$ is turn-right. **R4**: If p is near and l is far and $\theta_1$ is right then $\Delta\omega$ is turn-left. **R5**: If $\theta_2$ is target-direction then $\Delta\omega$ is zero. **R6**: If p is far and $\theta_2$ is targetdirection then $\Delta\omega$ is zero. **R7**: If p is near and l is far then velocity is low. **R8**: If p is far and l is far then velocity is high. **R9**: If p is far and l is near then velocity is low.

## *4. Simulation result*

Now, we applied the proposed fuzzy controller to the mobile robot moving in an unknown environment with obstacle.

The results of the simulation are shown in *Fig. 8.*

*Fig. 8.* shows the goal seeking and the obstacle avoidance mobile robot paths of the right.

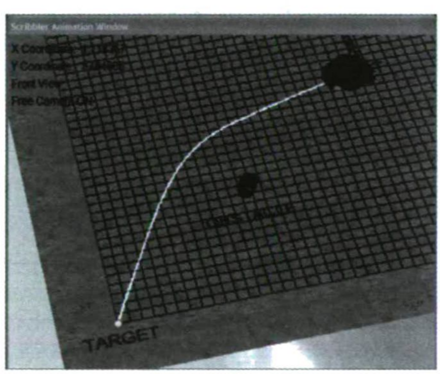


***Figure 8.* Obstacle avoidance trajectory of mobile robot**
(*Source:* Author)

### *5. Sun spot based remote control of mobile robots*

In this paper we have used: SunSPOT-s (Small Programmable Object Technology) to achieve remote control over a Khepera® mobile robot. For this task we have used 2 SunSPOT-s from the development kit (Sun Microsystems, Inc. 2007). Sun SPOT's wireless protocol is ZigBee, standard: IEEE 802.15.4. Sun SPOTS are small, battery operated wireles sensors. It contains: 32-bit ARM920T CPU, 512KB RAM, with 4 Mb Flash memory. Wireless networking is based on ChipCon CC2420 following the 802.15.4 standard with integrated antenna and operates in the 2.4GHz to 2.4835GHz ISM unlicensed bands. The Sun SPOT is designed to be a flexible development platform, capable of hosting widely differing application modules. We used the SunSPOT base station to read a file from the controlling computer and send its contents to the second free range SPOT. The second SunSPOT when receiving the data in turn opens up its outputs depending on what it received. These outputs control the speed of the wheels individually. The Sun SPOT base station will send data to Sun SPOT on mobile robot which will drive the controller to DC. The microcontroller will drive the Motors which will run the Khepera mobile robot. The Sun SPOT connection strategy is presented in *Fig. 9.*

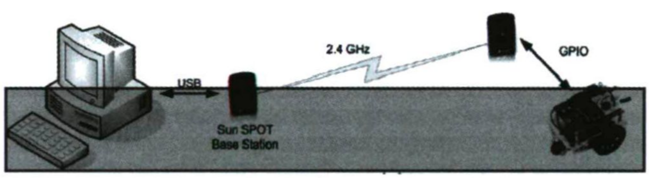


***Figure 9.* The Sun SPOT connection strategy**
(*Source:* Sun Microsystems)

We used the SunSPOT base station to read a file from the controlling computer and send its contents to the second free range SPOT. The second SunSPOT when receiving the data in turn opens up its outputs depending on what it received. These outputs control the speed of the wheels individually. The Hardware basically centers around Sun SPOTs and DC Motors. The Sun SPOT base station will send data to Sun SPOT on mobile robot which will drive the Basic Stamp controller to DC IO pins. The microcontroller will drive the Motors which will run the Khepera mobile robot. The user can start control experiment of mobile robots in Sun SPOT environment *(Fig. 10).*

***Figure 10.* Control of Khepera mobile robot motion in Sun Spot environment**
(*Source:* Picture – Szépe Tamás)

Sun SPOTs are programmed in a Java programming language, with the Java VM run on the hardware itself. Because of its Java implementation, programming the Sun SPOT is easy. The Software consists of two parts: first from the program used on the base station and from the program implemented on the free range SPOT .

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## 6. Conclusions

The paper deals with the wireless sensor-based remote control of mobile robots motion in an unknown environment with obstacles using the Sun SPOT technology and gives the fuzzy velocity control of a mobile robot motion in an unknown environment with obstacles. We proposed the wireless sensor-based remote control of mobile robots motion in an unknown environment with obstacles using the Sun SPOT technology. The simulation results show the effectiveness and the validity of the obstacle avoidance behavior in an unknown environment and velocity control of the proposed fuzzy control strategy. The proposed method have been implemented on the miniature mobile robot Khepera® that is equipped with sensors.

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