Mobile robot Khepera III. Programming for MATLAB/Simulink environment

Maciej Garbacz
Department of Automatics
AGH- University of Science and Technology
Kraków, Poland
mgarbacz@agh.edu.pl

Mieczysław Zaczyk
Department of Automatics
AGH- University of Science and Technology
Kraków, Poland
mza@ia.agh.edu.pl

Abstract. **This paper presents mobile robot Khepera III and its programming environment. The laboratory stand and some results of made experiments was presented. The application is based on MATLAB/Simulink system. The proximity sensors and ultrasonic sensors are used to detect obstacles in robot's workspace.**

Keywords. mobile robot; path planning; obstacle avoidance;proximity sensors;ultasonic sensors

I. Introduction

This paper describes the new laboratory stand, built in Laboratory of Automatics, Robotics and Fotovoltaics Systems. This stand is based on mobile robot Khepera III- product of swiss company k-Team. Khepera III is new, improved version of Khepera II [1]. The Khepera III is supplied by swapable battery pack composed of two Li-Ion Polymer elements. It is possible to work with robot continuously because there are extra battery packs and charger in laboratory. The communication between PC and Khepera is based on Bluetooth technology. In connection with the above there is no troublesome cable connection. Khepera III is equiped with proximity sensors and ultrasonic sensors to gather information about the workspace.

II. Khepera III Robot

The Khepera III has got a modular construcion. The robot has got a round shape to minimize result of collision with another robot. Robot is driven by two symmetrically placed wheels. Each wheel is moved by a DC motor coupled with the wheel through a reduction. The possible speed are between 14 mm/s to 298 mm/s. Each DC motor is equipped with incremental encoder. It gives information about the current position of robot. Some extra information about workspace give proximity and ultrasonic sensors. Robot is presented on fig. 1. The sensors visible at the top of the robot are ultrasonic sensors. Robot is equipped with 5 ultrasonic sensors type 400ST100/400SR100 of Midas company. These sensors consist of transmitter 400ST100 and receiver 400SR100. The carried out experiments shows, that ultrasonic sensors work better for greater distances. For smaller distances the proximity sensors are better. Khepera III has got 9 proximity sensors around robot and two extra under the robot to detect edge of table. In Khepera there are proximity sensors type TCRT5000 of Vishay Telefunken company. The sensors are placed around the robot as shown on fig. 2. Examples of characteristics of sensors are presented in next chapters. It is important that the more distance is, the smaller value of measure is. The value of measurements depends on condition of illumination, on material used to obstacles.

Figure 1. Mobile robot Khepera III

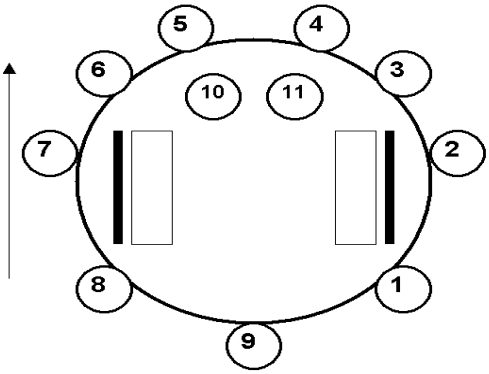

Figure 2. Position of the IR sensors

III. Programming for Matlab/Simulink

To make communication with Khepera easy there is constructed special library including ready-use command in MATLAB environment. Communication is based on serial line and it is possible in various environments. But the MATLAB is the most popular in our Department. In our application the RS232 protocol is used. PC is a master and Khepera is a slave.

The PC always initializes connection. Communication is realised by sending ASCII string. Each single connections consists of two parts:

- Command sending by PC: this command starts from capital letter, than there are numerical parameters (if necessary) separated by comma
- Answer send from robot to PC. The answer starts from small letter (the same like in command), afterwords there are numerical parameters separated by comma (for example measurements of sensors)

The commands can be classified into two groups:

- command concerned with configuration of robot (set parameters of serial protocol, set parameters of regulator, set sensor parameters)
- command concerned with control of robot (set position, set speed, read measurements of sensors)

Below the set of function for simply programming in MATLAB environment is mentioned:

- kopen ('COMx')- where 'x' is number of port; opens serial port COMx for communitacion with a robot and sets protocol parameters: 115299bps, 8 Data bits, 1 stop bit, no parity, no hardware control. Using of "*ref* = kopen ('COM5')" causes open communication by port COM5 and assign this communication to variable *ref.*
- kclose(*ref*)- function, which closes communication

Functions used to set the configuration of the robot:

- kConfSensor (*ref,n_sens*)- set number of active sonars (default set is only a central one)
- kConfSensEcho(*ref,n_echo*)- set number of sensor echos
- kInitMotors(*ref*)- initialize and reset of DC motors
- kBatteryState(*ref,index*)- get battery state; index- choose the voltage, the current, the absolute remaining capacity, the temperature or relative remaining capacity

Functions used to control robot:

- kAmbient(*ref*)- function returns 11-element vector of measurements from light sensors
- kProximity(*ref*)- function returns 11-element vector of measurements from proximity sensors
- kGetMeasure(*ref,us_numb*)- read distance in [cm] from chosen ultrasonic sensor
- kReadPos(*ref*)- read position from incremental encoders from left and right wheel
- kReadSpeed(*ref*)- read speed from both wheels
- kSetPos(*ref,left,right*)- set counters of position encoders
- kSetSpeed(*ref,left,righ*)- set speed for left and right wheel (control set value by PID controller)
- kSetSpeedProfile(*ref,max_speed,acceleration*)- set the speed and the acceleration for the trapezoidal speed shape of the position controller
- kSetTargetPos(*ref,left,right*)- set the position counter of the two motors. The position is in the pulse, each one corresponds to 0,047 mm
- kSetTargerProfile(*ref,left,right*)- set a positon to be reached. The move will be performed with three phase, a acceleration to reach the maximum speed and a deceleration phase before the finish position
- kSetPWM(*ref,left,right*)-set speed for motors, without speed controller
- kStop(*ref*)- stop robot
- kSetPosPID(*ref,kp,ki,kd*)- set kp,ki,kd parameters for position controller
- kSetSpeedPID(*ref,kp,ki,kd*)- set kp,ki,kd parameters for speed controller

Exemplary commands: kopen and kSetTargetPos in MATLAB is shown below:

```
function [ref]=kopen(p)
if p==1
ref=serial('COM5','BaudRate',115200,'DataBits',8,'Sto
pBits',1,'FlowControl','none');
else p==2
ref=serial('COM6','BaudRate',115200,'DataBits',8,'Sto
pBits',1,'FlowControl','none');
end
fopen(ref);

function r=kSetTargetPos(ref,left,right)
cmd=strcat('P',',','l',num2str(left),',','l',num2str(
right));
fprintf(ref,cmd);
v = fscanf(ref);
value = sscanf(v,' %s');
if value == 'p'
      r = 0;
else
      r = -1;
end
```

The crux of communication between PC and robot is sending property ASCII string. Written command in MATLAB make this communication easy for beginning students. Our library enable easy implementing and testing various path planning algorithm for mobile robots. It is possible generate any workspace using movable obstacles in our laboratory. So as, students can easily test own path planning algorithms. Written software was also used to test repeatability measurements from proximity and ultrasonic sensors. Fig. 3 describes measurement from 5 sonars for non-moving robot. The obstacles are in 25 cm distance from robot. Fig. 4 describes the same situation, but distance between robot and obstacles is 50cm. The experiments show good repeatability measurements. Fig. 5 describes measurements of distance (by central sonar) during motion of robot with constant speed. On the diagram measurement of the cental sonar was shown. Initial

distance between robot and obstacle was 130cm, the stop condition was 20cm. Fig. 6 shows relation between measurement and distance for proximity sensors. These sensors return measurement as a 12-bit value. The greatest value is near the obstacle.

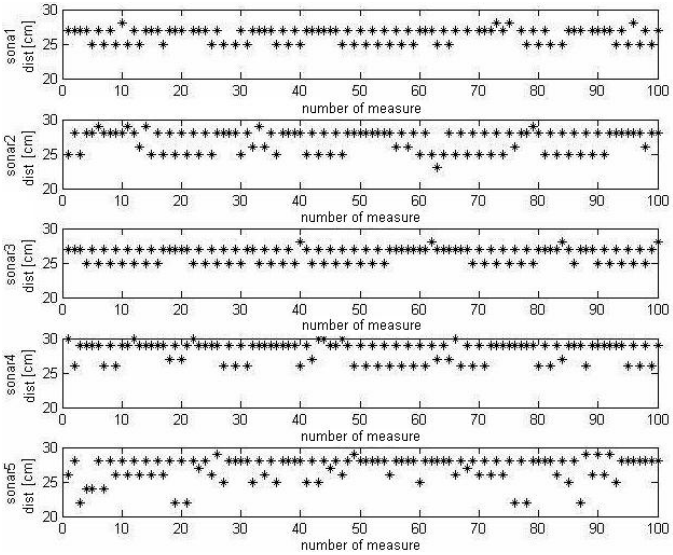

Figure 3. Value of measurements for each sonar; obstacle in distance 25cm

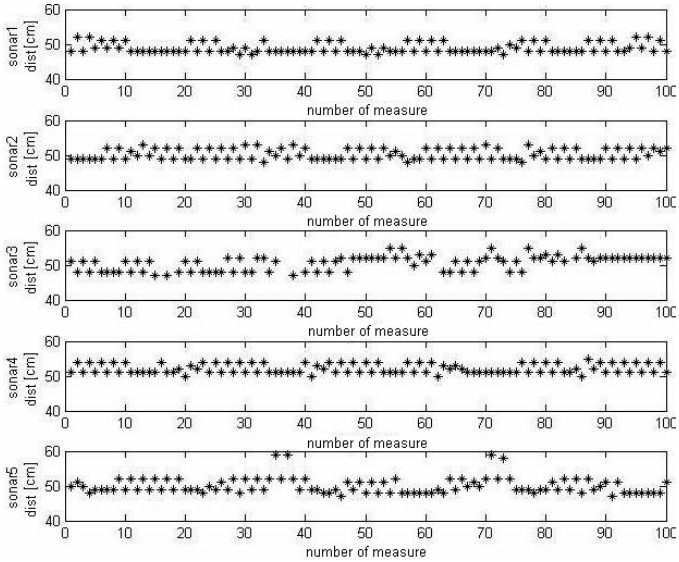

Figure 4. Value of measurements for each sonar; obstacle in distance 50cm

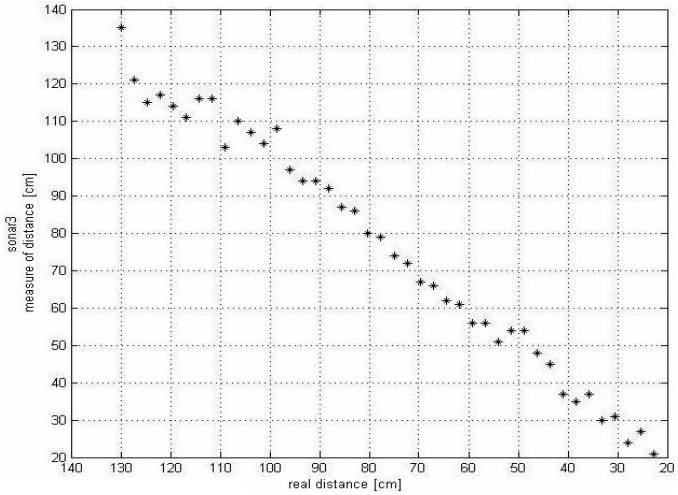

Figure 5. Value of measurement for central sonar during motion with constant speed

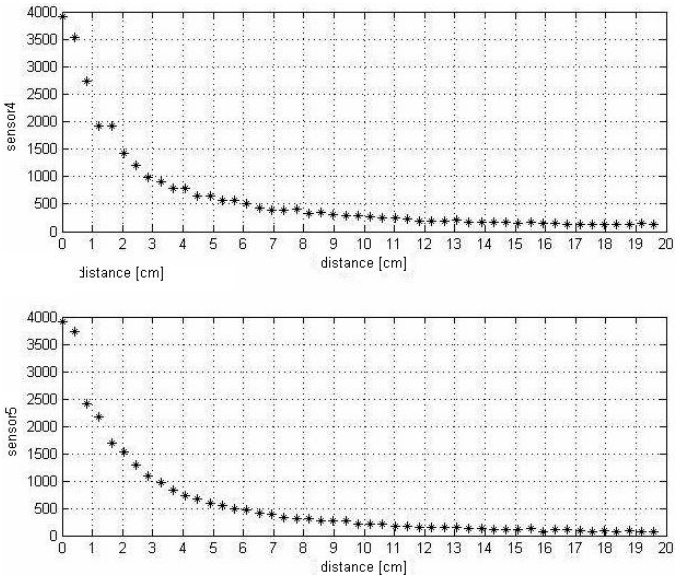

Figure 6. Value of measurement of proximity sensors for smaller distance between robot and obstacle

IV. Summary

In this paper special library of function to communication with Khepera III robot was presented. This library enable easy writing m-file for Khepera. Commands for communication and control robot are very intuitive. Because of good knowledge of MATLAB environment among our students this library is very helpful. Students can concentrate on path planning algorithms and do not waste time on difficult problem with communication by serial port with robot.

References

[1] Garbacz M., Laboratoryjny robot mobilny Khepera II. Automatyki (polrocznik AGH) t.9, z.3, 2005, 393-400.

[2] Midas Components Ltd.- Air Ultrasonic Ceramic Transducers 400ST/R100

[3] Vishay- Reflective Optical Sensor with Transistor Output TCRT5000(L)

[4] Khepera III, User Manual, K-Team S.A, 2007