AUTONOMOUS ROBOT "PHOENIX-3"

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I. INTRODUCTION

This report concerns of the technical aspects of student research project Phoenix-3. This robot is a test facility for research in the field of "control system learning " (sometimes used the term "teaching by showing") approach for multi channel control system on base of neuron net, started with project Phoenix-1 [1].

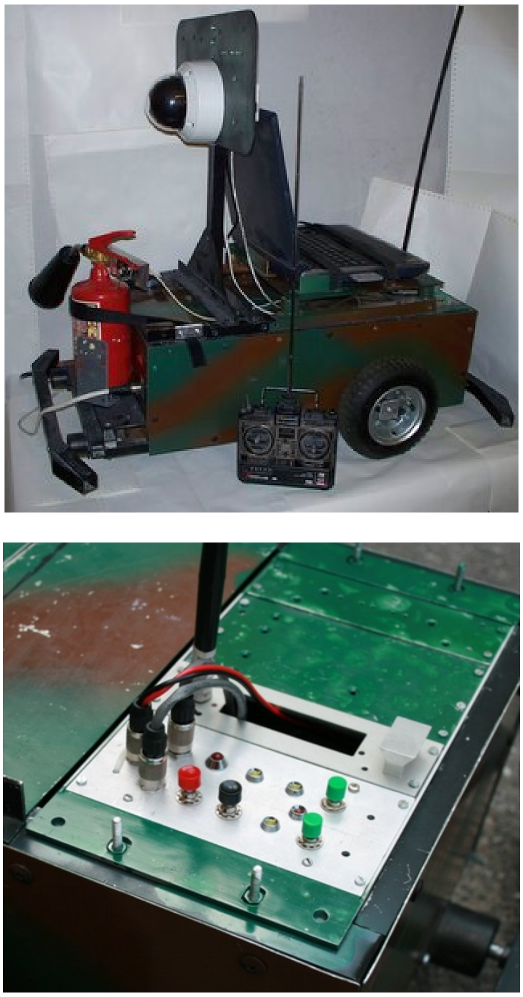


Fig. 1. General view of the robot Phoenix-3

Autonomic robot Phoenix-3 is designing to be able to patrol the determined area with the purpose of detection the centers of the flame. In case of the flame detection the robot should come nearer and use the on board fire extinguisher to eliminate flaming. For orientation in environment the video shock-proof camera with the rotary mechanism and a zoom lens is supposed to be used.

View of the robot is presented in fig. 1 and general view of the controller is presented in right corner of fig. 1.

In the paper presented most important and developed by the author during 2008–2009.

II. CONTROL SYSTEM STRUCTURE

For Phoenix-3 project the new control system architecture was developed. The developed structure corresponds for complex function of robot facility and reflects new level of understanding of problems, established during Phoenix-2 project and related with scientific goals of whole field of the research.

There are several steps in neural system synthesis using "teaching by showing" methodology. On the 1st step robot's movement are controlled by a traditional control system or by operator. During this procedure robot's sensors information and control commands are written. This data is used on the 2nd step for neural regulator coefficients determination.

It means that the control system has to have at least two basic modes of operations: operator control mode and autonomous operation. Operator control mode is used during the learning phase. The architecture of the robot control system is different for these two modes and is presented in fig. 2 and fig. 4.

Phoenix-3 Control system includes a lot of the subsystems: two channel RF-remote control, two channel video, multi channel ultrasonic orientation, on board power supply and so on. For more simple and flexible interconnection of the robot control system units there are two types of network interfaces are used: CANbus and Ethernet. CANbus was used to connect ultrasonic sensor modules to the main controller, but potentially can be used to interconnect many other units. Also, original CANbus controller P3 and high level protocol were developed. Ultrasonic module on base of controller P3 is presented in fig. 3.

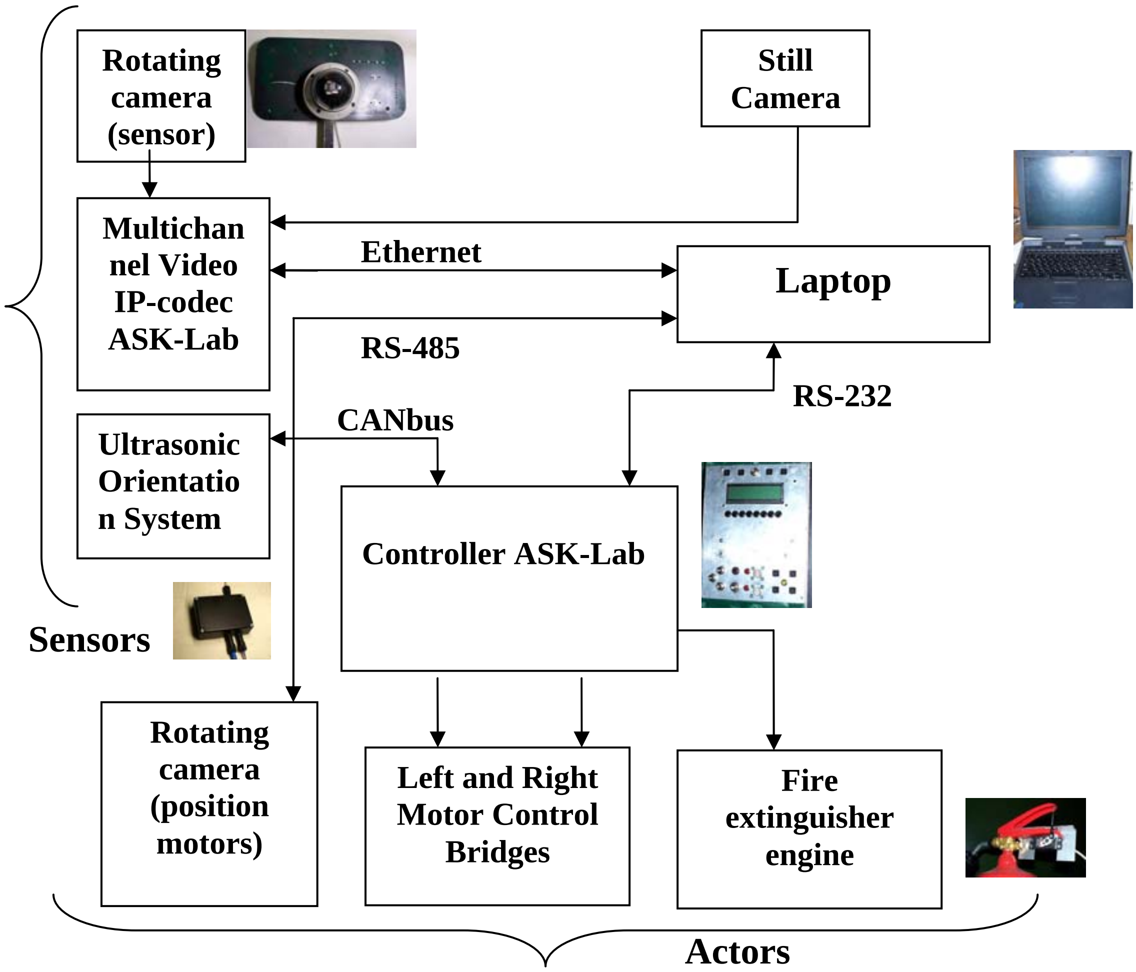


Fig. 2. Structure of the robot "Phoenix-3" during autonomous operation

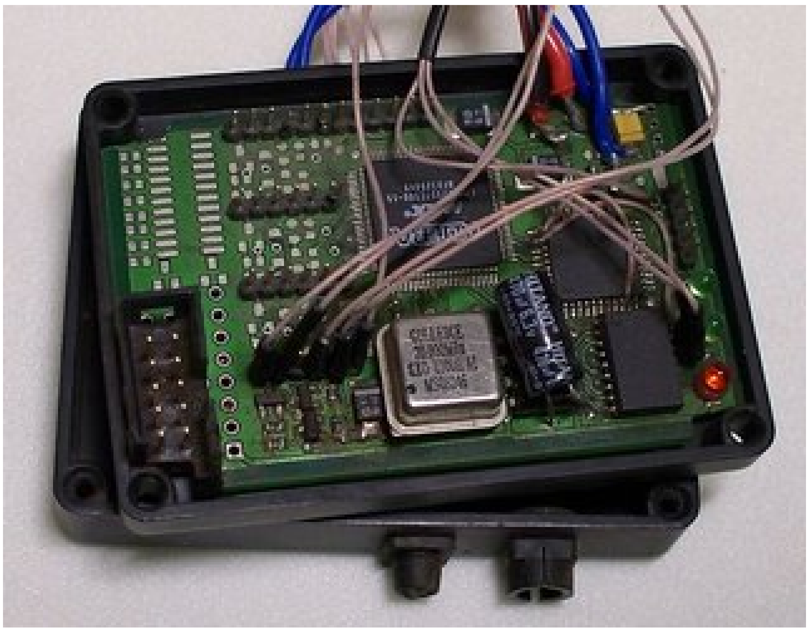


Fig. 3. Sensor/actor CAN controller P-3

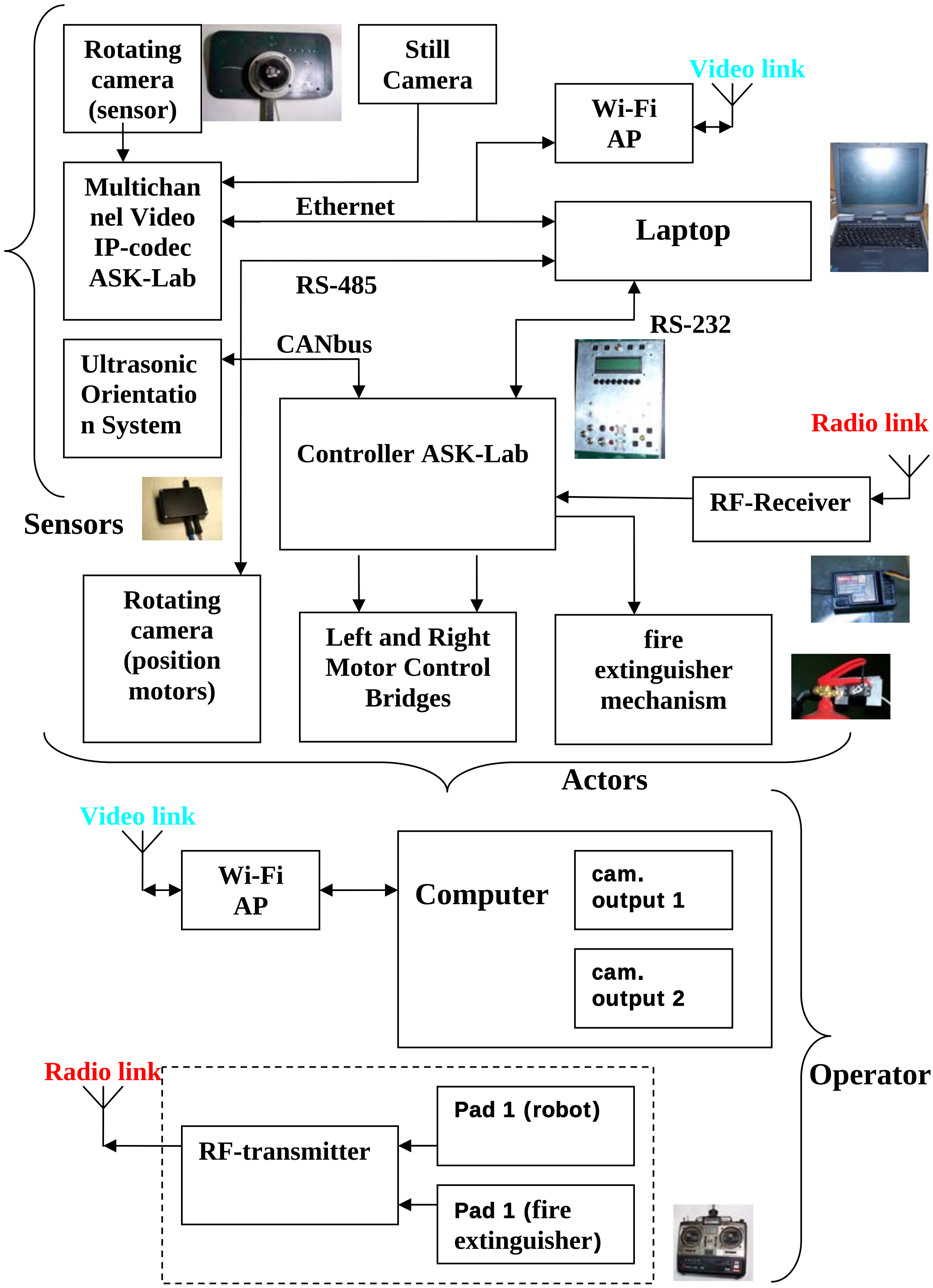


Fig. 4. Structure of the robot "Phoenix-3" for operator control mode

III. DISTANT CONTROLLING SYSTEM

In Phoenix-2 experiments, two control schemes were tested – one with the analog and one with the digital communication channel. It was noticed, that the digital control system has significant delays in the channel, so it was decided to use an analog control system for Phoenix-3 project. The scheme that uses analog radio channel is presented on the fig. 5.

It has to be pointed out, that Phoenix-3 project implements two channel control system: one for the robot movement control and another one for the control on board equipment. Structure of the two channel RF-control system are presented in fig. 5.

As it can be seen from the fig. 5, operator has a control pad with radio transmitter. Operator's control commands are transmitted and received by special radio receiver on board of the robot. These control commands are decoded by controller and then converted to executive signals for the actors. Simultaneously, video from camera is passed to the on board laptop, where it is written to a hard disk for further analysis, optical sensors synthesis and so on.

Hitec FOCUS 6 RC-equipment was use. It includes a control pad and receiver module. Structure of detected signal is presented in fig. 6.

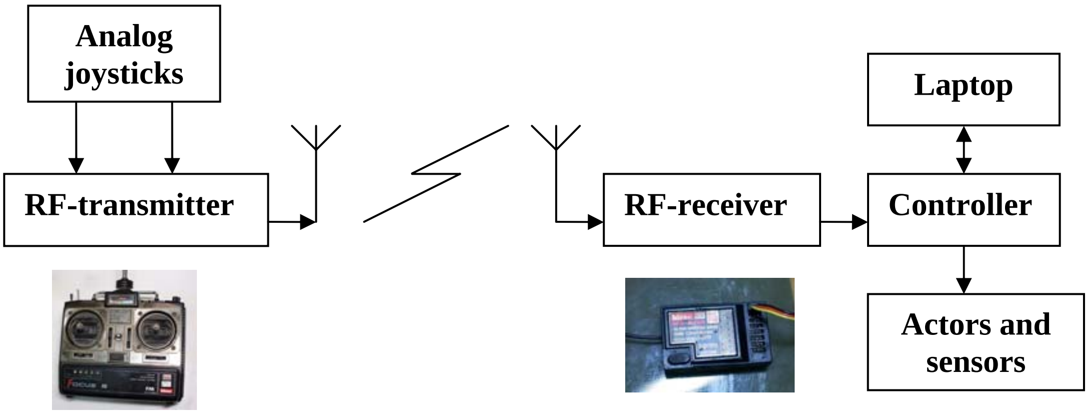


Fig. 5. Two channel RF-control system

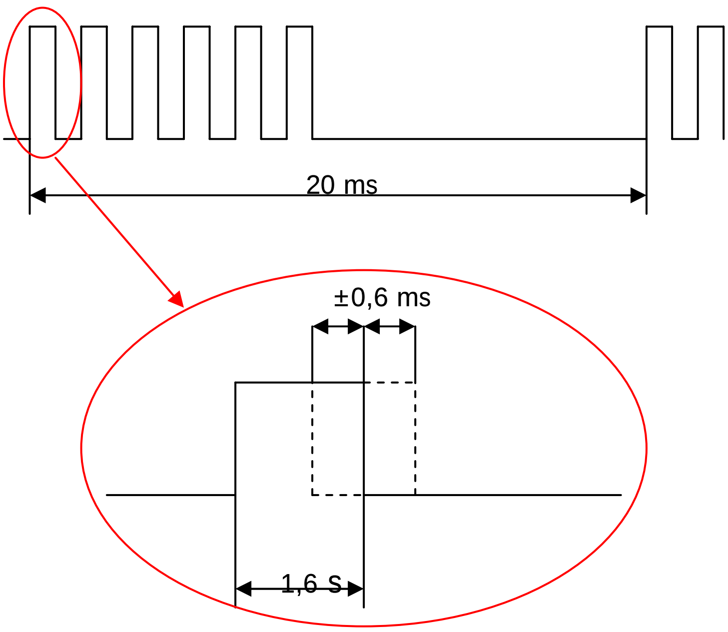


Fig. 6. Structure of signal, formed by the radio control set

The signal is represents a pack from 6 impulses. The first 4 pulses contain the information on position by axes X and Y of the first and second handles of pad. 5 pulse contains the information on position of the switch «gear», and the sixth - about position of handle "CH6 ". On the average position of handles duration of a appropriate impulse makes 1,6 ms. At change of position of handles duration of impulses accordingly increases or decreases. In extreme positions of handles duration changes approximately on 0,6 ms. Duration of a pause between impulses makes approximately 1,5 ms. After end of a pack, through 20 мс generation of a new pack begins according to current position of handles.

At the next step frequency modulation of a radio signal according to the generated signal is made. The central frequency of a radio signal is 40,675 MHz. The receiver of a radio signal allocates modulating pack from the accepted radio signal.

IV. ULTRASONIC ORIENTATION SYSTEM

Basic function of the ultrasonic system is to provide possibility of measuring distances to solid obstacles. For Phoenix-3 project it was decided to develop the multi channel system based on the uniform module with CAN bus interface to in board controller.

Ultrasonic distance measuring module based on MuRata MA40S8S and MA40S8R devices was developed. This module can measure of distances up to 2 m. with accuracy resolution approx. 0,2 mm.

Structure of the module is presented in fig. 7. Parts 3, 4 and 7 realized by using of Altera EPM7128 PLA.

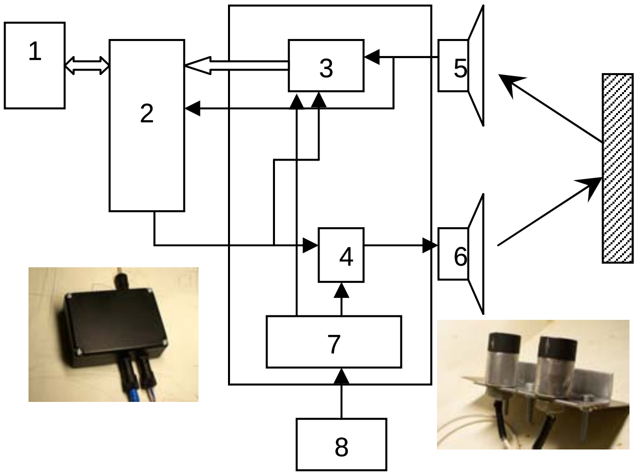


Fig. 7. Functional block diagram of the ultrasonic module
1 – MCP 2510 CANbus controller chip; 2 – PIC18F458 microcontroller chip; 3 – 16-bit counter; 4 – former of an ultrasonic pulses; 5 – ultrasonic receiver; 6 – ultrasonic transmitter; 7 – frequency divider; 8 – quartz generator.

V. VIDEO SUBSYSTEM

The important feature of the Phoenix-X projects is using a video channel for orientation in space. This method has some advantages in comparison with the others, such as a high flexibility, possibility to recognize complex objects etc.

It was demonstrated with Phoenix-1 project that camera inclination sensor is the necessary element of control system. The situation is illustrated by fig. 8 for "follow the white stripe mission".

So, now video subsystem of the robot includes a rotary shock-proof camera with the rotary mechanism and a zoom lens and a two-channel video digitizing module with an Ethernet interface. Camera is mounted on the special pedestal, which is fixed on the robot`s cover. This camera can change a direction of view and zoom number according to the commands, transferred by the RS-485 interface. This control is carried out by the laptop, connected to the camera across the USB to RS-485 converter module. Controlling commands are generated by the special application running on the laptop.

Camera has a build in inclination sensor and translates measured value on screen. This information can be used for supervised learning procedure if it is supposed that during autonomous operation inclination angler is constant. Operator can read instant inclination angler with software. Simple method to use fixed for every experiment inclination angle was proposed. The idea is illustrated by fig. 9. and oriented to be used with one step learning procedure [7].

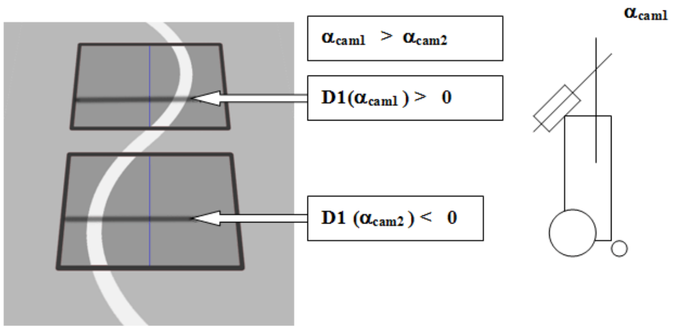
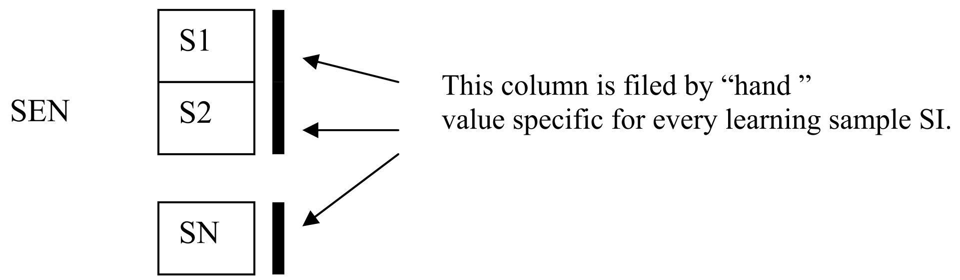


Fig. 8. Example that sign of the distance from stripe depends on camera angle



$w = (SEN^T\ SEN + \gamma\ E)^{-1}\ SEN^T\ Ua$ Weights calculation

Autonomous operation $S_{cia} = S_{cia\ (start\ moment)}$ $U\ a = (S,w)$

Fig. 9 Algorithm of using fixed inclination angler

Phoenix-3 video system provides possibility to process two video input simultaneously and record video in real time.

Every camera produces a standard PAL video signal which should be digitized. It`s realized by the special video digitizing module. This module receives video signal from the camera, digitize it, encode in MJPEG2000 video format and transmit it across the local network to the laptop. On the laptop video is decompressing and displays on the screen.

Two channel video controller ASK Lab that provide possibility to store video and telemetry data is used as base of user video system. This information cab be used for experiments also.

VI. VIRTUAL MOBILE ROBOT SOFA-2009

As a theoretical base of the project, studying and developing of mathematical model of the robot was made. This model is called SOFA-2009 and it was realized on the Mathcad 14 IDE.

Model SOFA-2009 is formed with seven ordinary differential equations and includes dynamics and kinematics of the robot, simple models of wheels and motors. Modeling of the robot moving is provided by solving of the Coushy problem. Examples of using SOFA-2009 model are presented in App.1.

VII. CONCLUSION AND ACKNOWLEDGEMENTS

More detailed description of the subsystems is presented in site http://guap.ru.

The author would sincerely like to thank staff of Student Design Center (SUAI) for support of the project.

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Appendix 1.

VMR SOFA _2009 (Virtual Mobile Robot)

SOFA-2009 PARAMETER LIST

Wheel diameter	$Dw := 0.3$
Distance between wheels	$Lr := 0.5$
Moment of inertia	$Jr := 25$
Left wheel gear parameters	$K11 := 75$ $K12 := 10$ $K13 := 1.5$
Right wheel gear parameters	$K22 := K11$ $K21 := K12$ $K23 := K13$
Motor resistance	$Rm := 0.1$
Motor inductance	$Lm := 0.01$
Maximal accumulator voltage	$VMAX := 12$

Problem description

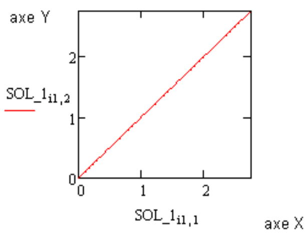
ROBOT INITIAL POSITION (VECTOR X0)

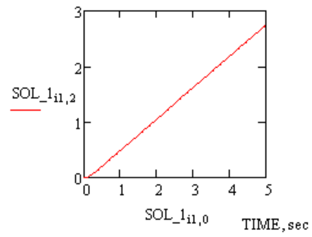
$$X0 := \begin{pmatrix} 0 \\ 0 \\ \frac{-\pi}{4} \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$$

Test N1 Moving along diagonal with maximal speed

$$U1(T,X) := \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ \frac{VMAX}{Lm} \\ \frac{VMAX}{Lm} \end{pmatrix}$$

$$FUN1(T,X) := \begin{bmatrix} \frac{(X_3 + X_4)}{2}\cdot\frac{Dw}{2}\cdot(-\sin(X_2)) \\ \frac{(X_3 + X_4)}{2}\cdot\frac{Dw}{2}\cdot(\cos(X_2)) \\ \frac{Dw}{2\cdot Lr}\cdot(X_4 - X_3) \\ \frac{-K11}{Jr}\cdot X_3 + \frac{K12}{Jr}\cdot X_5 \\ \frac{-K22}{Jr}\cdot X_4 + \frac{K21}{Jr}\cdot X_6 \\ \frac{-Rm}{Lm}\cdot X_5 - \frac{X_3}{Lm}\cdot K13 \\ \frac{-Rm}{Lm}\cdot X_6 - \frac{X_4}{Lm}\cdot K23 \end{bmatrix} + U1(T,X)$$





TEST_1. Moving along diagonal with speed 4/5 m/sec

SOLUTION

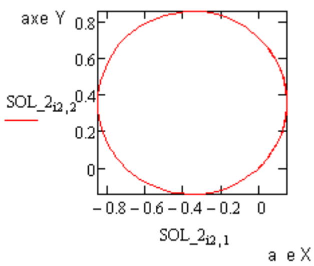
$T0 := 0$ $T1 := 5$

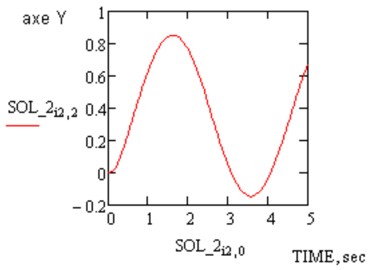
$NP := 100$ $SOL\_1 := Rkadapt(X0, T0, T1, NP, FUN1)$ $i1 := 0..NP$

Test N2 Rotation to left around left wheel initial position

$$U2(T,X) := \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ \frac{VMAX}{Lm} \end{pmatrix}$$

$$FUN2(T,X) := \begin{bmatrix} \frac{(X_3 + X_4)}{2}\cdot\frac{Dw}{2\cdot Lr}\cdot(-\sin(X_2)) \\ \frac{(X_3 + X_4)}{2}\cdot\frac{Dw}{2\cdot Lr}\cdot(\cos(X_2)) \\ \frac{Dw}{2\cdot Lr}\cdot(X_4 - X_3) \\ \frac{-K11}{Jr}\cdot X_3 + \frac{K12}{Jr}\cdot X_5 \\ \frac{-K22}{Jr}\cdot X_4 + \frac{K21}{Jr}\cdot X_6 \\ \frac{-Rm}{Lm}\cdot X_5 - \frac{X_3}{Lm}\cdot K13 \\ \frac{-Rm}{Lm}\cdot X_6 - \frac{X_4}{Lm}\cdot K23 \end{bmatrix} + U2(T,X)$$





TEST_2. Rotation around left wheel with speed π/4 rad/sec

$SOL\_2 := Rkadapt(X0, T0, T1, NP, FUN2)$ $i2 := 0..NP$