Decentralized Control of Cooperative Robotic System

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***Abstract*—This paper presents a decentralized control system for the cooperative group of robots moving via the signals from the remote workstations and receiving the signals from the technical vision based control system. The intellectual fuzzy logic based control system provides autonomous robot`s moving and obstacle avoiding for achieving different goals. The robot trajectories could be tracked in real-time via Internet.**

Keywords—control system; inductive charging; multiagent system; remote control

I. INTRODUCTION

In recent years an intellectual control of robotic systems obtain more interest, as well as the integration of motion control systems, navigation and professional diagnostics and the multiagent robotic systems research.

As an example of such a challenging tasks could be mentioned cooperative localization for moving target tracking [1]. For collision-free moving of multiagent systems a tracking systems could be tuned for obstacle avoiding and coordinated motion control [2]. Tasks of several robots` network collaboration in between and inside a network shows wide scope of different applications of such a cooperative robotic systems [3]. Decomposition of the objective into several parts and division of a labour into several groups of robots working in cooperation provides more rapid execution of the task in case of planning the execution steps, conflict management, communication between the groups and collaboration.

The intellectual control system is based on artificial intelligent components:

- modeling the environment (obstacles) by dint of sensor information and/or resources of virtual reality;
- shortest route planning in the environment avoiding predictable and unpredictable obstacles on path;
- pattern recognition and functional diagnostics.

One of the finest instruments for the data acquisition and processing parallelization is fuzzy logic and neural networks. Decentralization of the control system, so the operator to control the robots (in case the system is not autonomous) from the remote workstation is a feature to be realized for expansion of the control system capabilities. In case robot with battery full could change another robot when battery power of one is low it guarantees the non-stop robotic system operation.

The research works was partly supported by basic part of Russian Ministry state task (project number 2014/187 – the implementation of government works in the sphere of scientific activity).

II. HIERARCHY OF THE CONTROL SYSTEM

The proposed system consists of the wooden table with two inductive charging spots, infrared camera based high level control system on ARM microchip STM32, server with Debian OS and a group of robots with LC oscillating printed circuits. The hierarchical diagram of the control system is shown in Fig. 1.

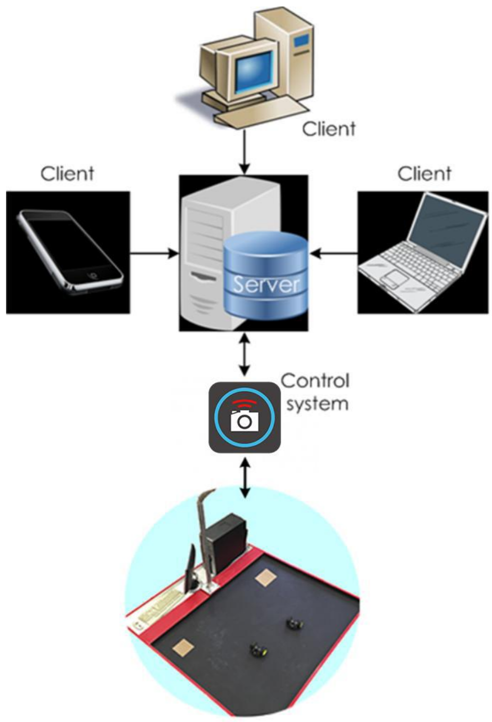

Fig. 1. Hierarchical control system diagram

There are two different operational modes of the system: either with the operator or without. In case of operator`s control the interface program provides an opportunity to choose the destination point for either one robot or a group of robots. The group of robots could be controlled from several workstations (desktops, laptops, smartphones and tablets) via Internet. The second mode is autonomous mode, when robots move according to the algorithm that provides the task

978-1-5090-5424-4/16/$31.00 ©2016 IEEE

completion (e.g. robot race or robot football) and robots` self-charging in automatic mode when the battery power is low. For color hindrance filtering tracking camera equipped with infrared filter and infrared backlighting.

The hierarchical structure provides step by step realization of the control system, it simplifies debagging and control system algorithmization. The low level includes control system for robots` spatial motion and the protocol for information forwarding from the high level server computer to the low level robotic system via infrared signal. The high level includes server and computer vision system that is based on a camera with infrared filter and infrared backlighting.

The presented robot that is shown in Fig. 2 consists of the support printed circuit board with LC resonant printed circuit, two DC motors with wheels and Li-Poly accumulator. The control system of the robot is based on the Atmel ATmega8 chip. For receiving the signals from the high level control system robot is equipped with the infrared receiver Vishay TSOP4038 that is tuned for receiving the modulated signal on 38 kHz frequency. Each robot is equipped with two reflective marks for current location and orientation determination because of the infrared backlighting of the camera based tracking system. The center of mass of the placed in such manner to provide stable and smooth motion of the robot on the table without inclines for continuous tracking of the reflective marks on the top of the body of the robot.

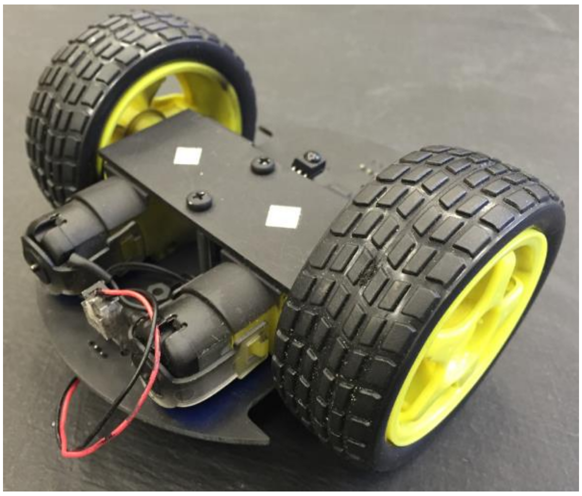

Fig. 2. The robot MicroRINA

Inductive charging spots on the table designed with two MOSFETs, auxiliary components and LC resonant circuit and provide charging of the accumulator for robots` non-stop working cycle.

The table with server and camera tracking system is shown in Fig. 3. Two charging stations are hide on the bottom side of the table so to limit the distance from the energy transmitter to receiver coil in 50 mm.

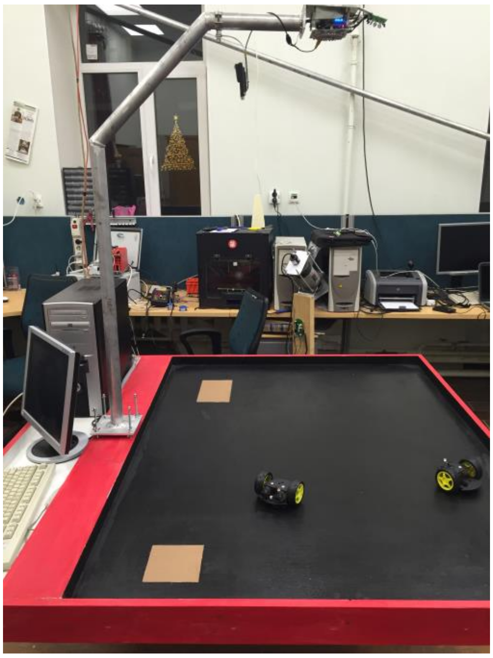

Fig. 3. The table with server and camera tracking system

Camera with infrared filter tracks the robot and transmits the information to the infrared receiver that transmits information to the microcontroller and after that, microcontroller, according to that information generates control action for the DC motors. So the robot moves. In case of tracking a group of robots the robot`s keyword precedes the control action.

III. The Positioning and Control Action Forwarding Systems

The positioning system is based on camera with infrared filter, infrared backlighting and ARM microchip STM32 for camera output signal acquisition and processing.

Using the infrared camera filter and infrared backlight, the camera receives image that is all black except pairs of robots` reflecting marks that are white. Current location of the robot could be determined according to the time interval between the frame start and the white point impulse of camera output analog signal. The current coordinates of the robot are sent via UART protocol on server that provides access for robotic system control [4].

The control action forwarding system is based on AVR microchip ATTiny2313 and infrared emitter. Due to the difference between the wavelengths of positioning system camera backlighting and infrared emitter of the control action forwarding system this signals do not interfere one another. ATTiny2313 chip addresses server computer for the information and keyword to be transmitted to the keyword related robot.

The picture of the positioning and signal forwarding systems are shown in Fig. 4.

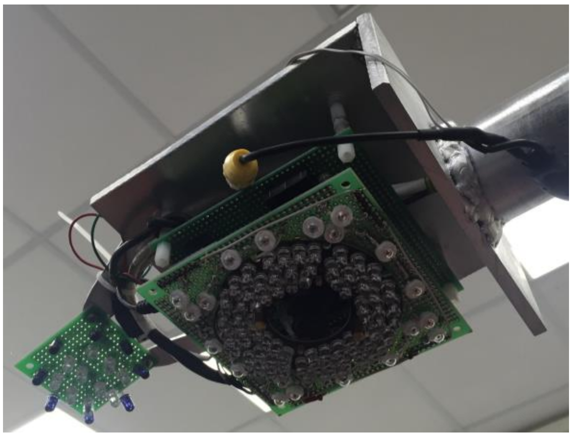

Fig. 4. The positioning system and infrared information transmitter

The positioning system equipped with the 6 inch screen for real time tracking the robots positions. The image duplicates on the server computer screen.

IV. CONTROL SYSTEM DECENTRALIZED REMOTE ACCESS

The positioning and control action forwarding systems connects to the server computer. Server provides remote access for several users via special software. This software launches TCP-server that receives control actions from several computers and sent them back coordinates of all the robots` positioning marks obtained from the positioning system [5]. Client applications receive current robots` positions and calculate control action to transmit it to the server. Such kind of system allows realizing decentralized remote control of the group of robots from several computers, each controlling one or several bots. Client application provides an opportunity to create virtual obstacles and destination points for testing different motion algorithms. Screenshot of the client application with one virtual obstacle and one virtual destination point is shown in Fig. 5.

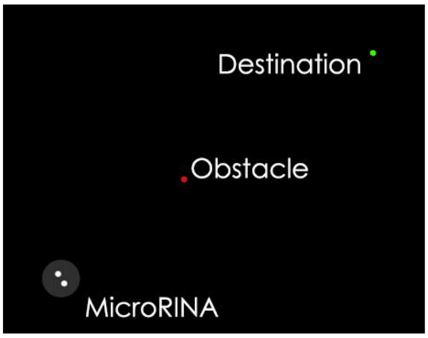

Fig. 5. Client application workspace

V. ROBOT MOTION FUZZY CONTROL SYSTEM

For the fuzzy controller designing let us consider the robot planar model that is shown in Fig. 6.

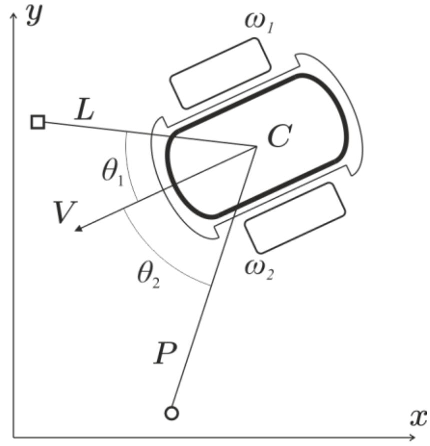

Fig. 6. The robot planar model

In Fig. 6 it is shown: V – robot`s velocity vector, $L$ and $P$ – distances to the obstacle and target respectively, $\theta_1$ and $\theta_2$ – angles between the robot`s velocity vector V and the obstacle and target shortcut respectively, ω_1 and ω_2 – angular velocities of the right and left wheels respectively, C – robot`s center of mass.

For the robot motion control system implementation a C++ open source library "fuzzytile" was applied. Fuzzy controller was arranged in fuzzy rules. Input variables to the controller are: distance to the obstacle, distance to the target, angle between the robot`s velocity vector and the obstacle shortcut, angle between the robot`s velocity vector and the target shortcut. Let the angles took positive when the obstacle or destination point is located on the right side while moving and negative when located on the left side. Outputs to the fuzzy controller are: the angular velocity difference between the left and right wheels (wheel angular speed correction) and vehicle linear velocity.

Fuzzy controller input variables distance to the obstacle/target contains two linguistic variables "close" and "far" that has s-shape and z-shape membership functions respectively. Angle between the robot`s velocity vector and obstacle contains linguistic variables "left" and "right" that has Gaussian membership functions. Angle between the robot`s velocity vector and target contains linguistic variables "left", "center" and "right" that has s-shape, Gaussian and z-shape membership functions respectively. Output variable of wheel angular correction contains three linguistic variables "left", "center" and "right" that has s-shape, Gaussian and z-shape membership functions respectively. Robot`s linear velocity contains linguistic variables "low" and "high" that both has triangle membership functions. As defuzzification method a centroid method was chosen. An approximate trajectory of the robot is shown in Fig. 7.

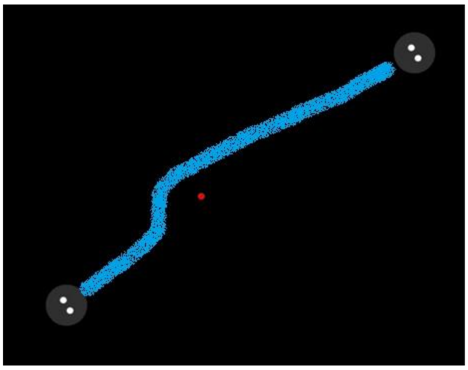

Fig. 7. Obstacle avoiding trajectory

The fuzzy controller provides robot obstacle avoiding and destination point reaching.

VI. Conclusions

A decentralized control system for the cooperative group of robots motion was presented in this paper. The robots moves via the signals from the remote workstations and receive the signals from the technical vision based control system. The intellectual fuzzy logic based control system provides autonomous robot`s moving and obstacle avoiding for achieving different goals. The robot trajectories could be tracked in real-time via Internet. Client application for robots` control provide virtual obstacles and destination points creation for the motion control system testing. For the non-stop working cycle of the robotic system the two inductive charging stations were designed. The future research would be aimed for the improving the intellectual and coordination system of the robots` network.

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