Hardware and Software of Mobile Robots Group

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Abstract[1]

This article deals with the questions of a choice of an architecture and hardware-software components for a group / team / collective of heterogeneous mobile robotic units (MRU). The number of solutions of the problem are offered and discussed.

1. Introduction

The article describes hardware and software system architecture for the set of heterogeneous mobile robotic units (MRU). This set of heterogeneous mobile robotic "lives" in the scientific and educational laboratory "Robotics." of MEPhI. The important feature of considered system is its heterogeneity which consists from two types:

- Mechatronics heterogeneity is MRU's mechanics organization alterity ("the cart", a walking design, etc.) or/and MRU's sensors difference (range finders, sonars, video cameras, etc.).
- Structure heterogeneity of hardware and software of MRU's computing module.

Such heterogeneity leads to necessity:

- The choice and maintenance of minimal functionality at everyone MRU.
- Differentiation and taking into account capabilities of the MRS's components at planning of problems solving.

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The heterogeneous mobile robotic system is synonym for the general problem solving by several different MRS's components. It means, at least, following necessary functionality of whole system and the MRUs:

- The hardware and software onboard components must be on everyone MRU to perform some known set of the tasks.
- The hardware and software onboard components must be on everyone MRU for information interchange with other members of MRS.
- The system general problem solving planning and scheduling must works on one or several MRS's components. That system distributes tasks to MRUs and collect the information received from each MRUs.

The most obvious architectural principle of similar systems software is the interaction and management of MRUs set through the allocated centre – the remote centre of information processing (RCIP).

2. Hardware and Software of Robotics

The RCIP is the hardware-software complex based on a personal computer or a more performance computing system.

The primary goals solved by RCIP are:

- Bidirectional communication with each of MRUs in real time maintenance.
- Information received from all MRUs gathering, processing and storage.
- MRU's tasks for general problem solving planning and scheduling.

Hardware and software components providing the bidirectional information transfer between MRU-RCIP are on the minimum necessary functional set of MRU's equipment. Characteristics of three real MRU used in scope of the work are shown below.

2.1. Pioneer 2AT - MEPhI

MRU Pioneer 2AT-MEPhI includes[3]:

- Robotic platform Pioneer 2AT (equipped by the onboard computer and sonars, located on the platform perimeter);
- Laser scanning range finder SICK LMS200;
- Two digital cameras (connected to onboard computer through USB interfaces);
- Robotic arm LynxMotion SES

Communication between MRU Pioneer 2AT-MEPhI and RCIP is provided by a wireless network (802.11g). MRU Pioneer 2AT-MEPhI photo represented on fig. 1.

2.2. Hexapod AH3-R

MRU Hexapod AH3-R is a walking robot with round body symmetry. The three degree of freedom leg design provides the flexibility required to walk in any direction. The robot uses 18 HS-645 servos for the legs.

Management of the robot can be carried out as directly, giving of commands on COM-port of a printed-circuit board of controller SSC-32 Servo Controller, and through intermediate programmed printed-circuit board Bot Board II-BASIC Atom 28.

For the integrating AH3-R as equal part to our heterogeneous MRS require installation on it following equipments:

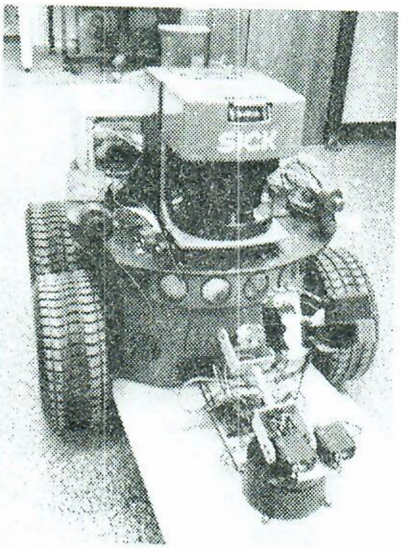

Fig. 1. MRU Pioneer 2AT-MEPhI

- Laser range finders,
- Ultrasonic sonars,
- Gyroscope,
- Digital chamber.
- Radio modem for communication to RCIP.

MRU Hexapod AH3-R photo represented on fig. 2.

2.3. PatrolBot

MRU PatrolBot includes next parts:

- Robotic platform equipped by the onboard computer, sonars and collision sensors (active bumper) located on the platform perimeter;

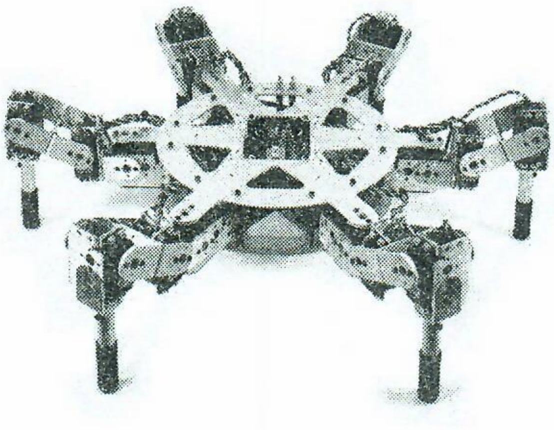

Fig. 2. MRU Hexapod AH3-R

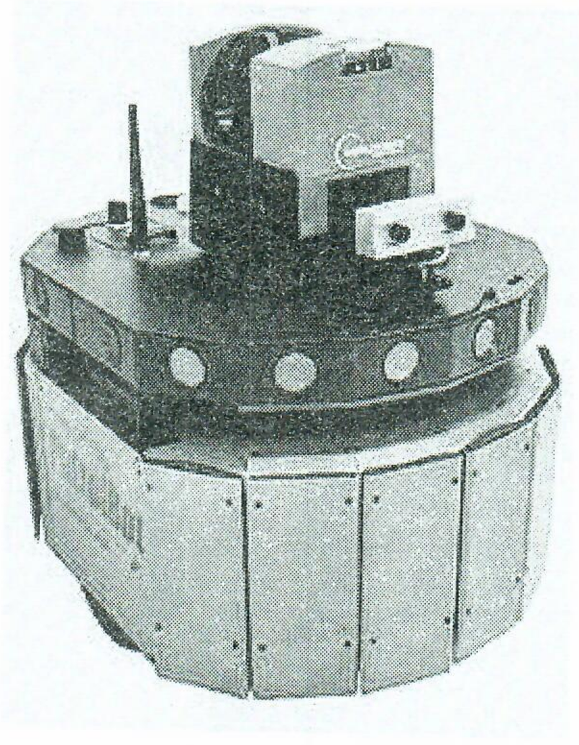

Fig. 3. MRU PatrolBot

- Two laser scanning range finders LMS200 – vertical-directed (it can be used for 3D model of area constructing) and horizontal-directed;
- Stereo vision system, connected through pan-tilt controller PTU-D46 installed on the front part of platform;
- Communication between MRU PatrolBot and CMU is provided by a wireless network (802.11g).
- MRU PatrolBot photo represented on fig. 3.

2.4. Robot MEPhI-RE ecologist

Robot MEPhI-RE (robot-ecologist) is completely designed and manufactured to the MEPhI. Currently, he is under active development board equipment and distributed decentralized control and navigation software (DDCNS). As an on-board computer used netbook, which in addition to its computing power, has a USB-ports, and WiFi-channel. To control the motors of the two driving wheels robot using a microcontroller. To provide an interface with a set of onboard sensors in a laboratory designed interface board controller.

All sensors robot MEPhI-RE can be divided into two groups:

1. Sensors control. Has two cameras, a group of distance sensors (such as sonar and laser spot, accelerometers). Plan to install sensors satellite navigation system GPS or GLONASS.

2. Sensors targets. These primarily include temperature and humidity sensors, the sensor radiation (Geiger-probe), and perhaps some others.

Robot MEPhI-RE photo represented on fig.

Fig. 4. Robot-ecologist MEPhI-RE

3. Hardware and software MRU's components for integration in heterogeneous MRS

Necessity of working out of a universal electronic printed-circuit board for the organization of bidirectional information transfer between RCIP and MRU (AH3-R) is shown above. The given The given component will be called further as a interface printed-circuit board (IPCB). Design of IPCB is constrained by sizes and power consumption.

The second important component of a communication system between all MRU and RCIP is the universal communication framework for MRS.

These components are described below.

3.1. The IPCB

The list of the basic knots of the interface printed-circuit board and their appointment:

- Converter COM – UART
- Interfaces for sensors
- Radio modem

The personal computer transmitter:

- USB-to-UART converter.
- Radio modem

Set of sensors for IPCB:

- Range finder - GP2Y0A700K (2)
- Range finder - GP2D12 (6)
- Sonar Devantech - SRF05 (3)
- Accelerometer - LIS3LV02DQ
- Gyroscope - MLX90609-75
- Video camera - CMUCam2

3.2. The universal communication framework

The software basis for heterogeneous robots system is universal communication framework (UCF). UCF represents a set of protocols and software designing templates for mobile robotic systems. Thanks to protocols of the UCF MRUs and RCIPs has ability to detect each other in the heterogeneous network environment using broadcasting and unicasting messages and, where it is possible, the infrastructure of the centralized directories on the basis of a domain names server. The client-server model of interaction is applied after accessible to interaction devices detection – MRU provides certain services (functions). RCIP can control various aspects of functioning MRU and-or obtain the data from the sensors installed on them using these services. Any MRU can represent itself as RCIP for others MRU. It allows MRUs to co-operate with each other without involvement of intermediaries. Basic tools for restrict access to various control loops are provided in the given model of interaction (it is supposed that authentication of co-operating agents and protection of data channels is provided with underlaying protocols, for example, IPSec in ESP mode). It provides rather flexible MRUs components interaction using decentralized model of control. Thanks to such approach and as to UCF enhancements [1] the MRS's software possesses a certain degree of reconfigurability that can raise MRS's reliability and performance for a number of tasks.

3.3. Intelligent software

Mobile robots collective control on district is a most hard control tasks.

Mobile robotic devices Pioneer 2AT-MEPHI, PatrolBot, Hexapod AH3-R and MEPhI-RE have various platforms (wheel, walking), an inhomogeneous set and characteristics of sensors. Its derivate robots collective in which operations of each separate robot are routed on reaching of the common, group purpose, for example, building a site plan.

The main advantages of robots collective consist in the following:

- Possibility of usage centralized and decentralized robots collective control strategy.
- Failure of the separate robots functioning in extreme conditions, influences performance of the task put before collective in a small degree;
- Collective operations of robots allow to reallocate the purposes of separate robots depending on a current situation for the best reaching of the collective purpose.

If the quantity of robots in collective is insignificant, and the environment situation varies slowly, it is necessary to use the centralized strategy of collective control when jobs for each robot arrive from centre.

From the robots view point operations coordination in collective it is possible to offer the following tasks classification arising at the organization of collective application of robots:

- Decomposition of the purposes (its breakdown on the subpurposes and distribution of the subpurposes among members of collective);
- Decomposition of the problems defined by these purposes (its splitting into subtasks and distribution of the subtasks); it concerns touch information gathering distribution with the subsequent exchange of it, to construction on this basis of environment models;
- Joint co-ordinated in space and in time performance of the general operations;
- Mutual aid (time transfer of separate functions and problems, the help in its restoration), including at achievement of the private purposes.

Problem of purposes operative redistribution between robots of collective depending on a current situation, i.e. from a current robots arrangement in space, and also their current condition, generates such problems, as operational planning of a robots movement trajectory to the chosen purposes and management of their movement on the given trajectories.

One of useful algorithms groups who is expedient for using at solution of the given task at the initial stage, detection and tracing algorithms behind objects are. To one of effective algorithms of this group is CamShift algorithm [2] which should be realized on each of MRU. It is important that it should carry out in a parallel way detection/tracking behind several objects in real time.

3.4. 3D images/scenes

For detailed consideration of the district three-dimensional model construction task it is necessary to formalize it within some mathematical apparatus. After formalizing it is possible to estimate the calculations complexity, method accuracy and time of processing for the computing system.

Initial data of the proposed algorithm are:

- The video streams received from cameras. They are synchronized on time.
- The data sets received from range finders.
- The cameras and range finders descriptions set - physical parameters (focal lengths etc.) and trajectories of their movement. Co-ordinates can be specified when the algorithm works from the image received from the device.

The main algorithm results are the geometrical primitives describing environment of the collective. In addition to co-ordinates, it is possible to define primitives' color, luminance etc. subject to algorithm variants.

Algorithmically the task can be divided on:

- The construction instant 3D-plan (according to one robot or whole collective data).
- Addition of the new plan (constructed at the previous stage) to available 3D-plan.

Both in the first and in the second case it is necessary to estimate accuracy of received co-ordinates by some mathematical apparatus.

Accuracy of model is limited of the following factors:

- The cameras and range finders positioning error on co-ordinates because of the inexact data about the robotic devices position.
- A positioning error in a direction.
- The point definition error defined by camera or a range finder quality.

First two kind's errors correction is possible by introduction of amendments according to already constructed model. Amendments are entered at the available plan addition stage on the old and new data divergence.

Necessary stages for the model construction are:

- Analyzing of simultaneous maps from all devices with reception of some characteristic parameters (for example, clusters boundaries at clusterization algorithms, characteristic points for correlative algorithms etc);
- Comparison of the paired previous stage results from various devices with reception of the describing primitives approximate co-ordinates;
- Gathering of available pictures – or in one new intermediate model, which will be then added to available (this method accelerates processing), or their addition to existing in turn (that lightens positioning errors specification).

Possible algorithms of the preliminary analysis of images are:

- Clusterization (the primitives are described by the characteristic area observed from one camera).
- Borders allocation (the primitive are described by the characteristic contour observed from one camera).
- Characteristic point's allocation (borders excesses, corners figures tops, etc.).

After preliminary analysis results comparison on the basis of cameras visible areas and individual offsets co-ordinates it is received preliminary point's co-ordinates. Thus it is necessary to limit comparison area to the possible errors registration caused by system geometry (to minimize false comparisons).

For a processing acceleration (as an ideal – real-time processing) the task parallelization is planned. It is evident that it is possible to make in a parallel way the time-lapse analysis for each camera without cross-process exchanges (the parallelism degree is equal to number of cameras), the paired analysis of instant pictures (the parallelism degree is equal to number of pictures pairs), and also pictures junction if it is not realized as addition of the new data to an initial picture. In the latter case parallelism is possible, but the computational scheme becomes more complicated.

The developed system is realized as the program unit with support UCF [1]. The optimization subsystem is realized at redirector level as a part of the optimization environment system. Other functionality is realized at the user's applications level.

4. Perspectives

Today's global trend in the design of robotic systems is the study of intellectualization systems the human-robot (robotics team), so the research and development in this direction are highly relevant and promising.

At the present time in the lab, "Robotics" conducted research and development on natural (for humans), the mechanisms of the human-robot (with indication of hardware and software, gestures, voice commands, with the help of brain-computer (BCI), and so) providing management and corrective action when the MRU intellectual tasks of navigation, self-localization in space, the construction plan, operating environment (including SLAM - simultaneous localization and construction plan for the functioning of the environment), etc.

The main activities of our laboratory can be summarized as follows.
A. Development of a distributed system of decentralized control and navigation software (DSDCNS), which will address a wide range of tasks a team of robots with an increase in their number in a group / team / collective: navigation, search facilities, moving, sorting, ensuring the operation of robotic systems in a pre-known, partly known or unknown environments, in a controlled, uncontrolled or partially controlled environment.
1. The development of the modeling environment that provides for a full cycle of design and introduction of new software and hardware solutions: simulation environment should allow to develop and debug software to check the availability of new equipment, quickly and without the programmer to transfer developed algorithms and software for specific hardware base.

2. The study of various models and mechanisms of interaction with the man for the job control and corrective actions using a variety of communication methods, including natural to man: gestures - indication, voice commands, brain-computer interfaces-BCI.

3. Study the possibility of transferring part of the computational load on the stationary minisuperkompyuternye computing systems (clusters, grid-system, a hybrid computing system based on the GPU (CUDA), etc.).

4. Development of a prototype RDUNPO functioning in real time.

5. Developed and studied a model of interaction of heterogeneous robots in a single environment, carrying out the general problem of the study area within the transportation problem.

6. Work is underway to develop protocols for interoperability of heterogeneous robots in a single environment, to address a group of the general problem.

Collective robotics laboratory "Robotics", consisting of multiple heterogeneous mobile robotic systems, the corresponding algorithms and software provides a wide field for research and applied work.

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References

1. A.A.Dyumin. "The architecture of reconfigurable software for mobile robotic systems". In: Proc. of 11th International Workshop on Computer Science and Information Technologies (CSIT'2009), Crete, Greece, 2009.

2. Chepin E.V., S.V.Danilov. "Improvement of mobile light emitting object traking CamShift algorithm". In: Proc. of 10th International Workshop on Computer Science and Information Technologies (CSIT'2008), Vol.2, Antalya, Turkey, Sept. 15-17, 2008, p.96-99.

3. I.V.Bogin, E.V.Chepin, A.A.Dyumin The Aim and the Technique of Designing Framework for Development Software for Distributed Mobile Robotic Systems. In: Proc. of 10th International Workshop on Computer Science and Information Technologies (CSIT'2006), Karlsruhe, Germany, 2006 Sept. 15-17, 2006, p.96-99.

4. E.V. Chepin, D.A.Parkhomenko. Development of the Adaptive System for Moving Control of the Mobile Robot Based on the Pioner-2 AT. CSIT'2006, Proc. of the 8^{th} Int. Workshop on Comp. Science and Inf. Techn., Karlsruhe, Germany, Sept.28-29, 2006, vol.1, Ufa State Aviation Technical University, 2006. ISBN 5-86911-609-0 c.56-64.

5. I.V. Bogin, E.V. Chepin, A.A. Dyumin, D.G. Kovtun, P.S. Sorokoumov. The universal remote control software for distributed mobile robotic systems. Proceedings of the 10^{th} Internftion Workshop on Computer Science and Information Technologies (CSIT'2008), Antalya, Turkey, September 15-17, 2008. Volume 1, Ufa State Aviation Technical University, 2006.ISBN 978-5-86911-787-8 c.69-72.