Mobile robots and their subsystems

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Abstract
Robotics represents complex area of application, research and education. On Institute of Control and Industrial Informatics, Faculty of Electrical Engineering and Information Technology takes place education and also research in area of robotics. There are designed and realized robotics mechanisms like little and big inspection robots, walking robots. Thus research area covers robot design and also complex problems coupled with sensor systems, control systems, environment exploration, navigation in environment, environment representation building and also reduction of manipulator endpoint vibration. Main goal in mobile robot research area is to build fully autonomous and intelligent mobile robots. Mobile robot is complex system consisting of many subsystems which must cooperate. Furthermore the robot must act in environment regarding to security of humans, objects in environment and also robot own security. Therefore the problem how to achieve autonomy and intelligence lies not only on control algorithms or information subsystems, but depends also on robot design, design of robot subsystems. In this case takes place mechatronic design, which considers many aspects of robot subsystems and their reciprocal cooperation.

Keywords: mobile robot, robot subsystems, mechatronic design

Introduction

Faculty of Electrical Engineering and Information Technology, Slovak University of Technology educates engineers with Automation specialization in area of Robotics. This specialization is based on research results from area of mechatronic systems specifically from mobile robotic systems area. Research activities are focused on robot components and also on complex robotic systems. Research topics are from area of driving systems (mainly synchronous motors), sensor systems (like localization systems [3][4], visual systems, etc.), control systems, communication systems, path planning [16][17][18][1][2], navigation, control algorithms, etc. Solved are also tasks related to vibration suppression [5][14], time suboptimal control [10][11], mobile manipulators control [12][13], visual servoing, etc.

There were developed little wheel inspection robot systems, four legged robot [6], robot with combined chassis (legs and wheels) [7], robot suitable for artificial intelligence tasks, environment recognition and planning tasks and robot for outdoor use. Article deals with sensor, actuator and control subsystem description of indoor mobile robot designed and build with ATEC automation Ltd. cooperation.

Insitute of Control and Industrial Informatics (ICII) indoor mobile robot

Demands on mobile robot before design and building

Initial demands on mobile robot properties were following. Mobile robot should be used only in indoor environment, therefore there is no need of terrain chassis. Indoor environment could be overfull of obstacles, so there is need of high robot maneuverability. There should be used distance sensors for robot vicinity detection. Hence good sensor placing will be in same distance from robot center point. So the suitable robot form could be cylindrical form. Also the robot maximal speed should be circa equal human walk (1 m/s). The first research application of mobile robot would be telepresence and maybe teleexistence. For telepresence are needed sensors and camera head, the best will be stereo vision. For teleexistence is required actuator – manipulation arm. Therefore must be defined arm basis placing considering also mobile robot stability. Adding manipulator arm to mobile platform will be mobile robot transformed to mobile manipulator.

Robot properties after building

ICII mobile robot system (Fig. 1, Fig. 2) was designed and build by ICII and ATEC automation Ltd.. ICII mobile robot system is designed for indoor environment. Chassis is designed only for flat surface, not for any obstacle overcoming. Mobile robot kinematics consists of two driving wheels and one castor wheel (differential drive) (Fig. 3, Fig. 4).

Kinematics design ensures mobile robot rotation over its own axis. In case of such kinematics could be achieved robot motion direction change without position change. Robot form is circular in top view. Thus when robot translation velocity is zero and there is no object colliding with robot, is possible to change robot heading without worrying about possible collision. Because of robot circular form and sensors placing on robot perimeter (Fig. 3) is possible to use robot rotation over its own axis for robot vicinity sensing precision improvement.

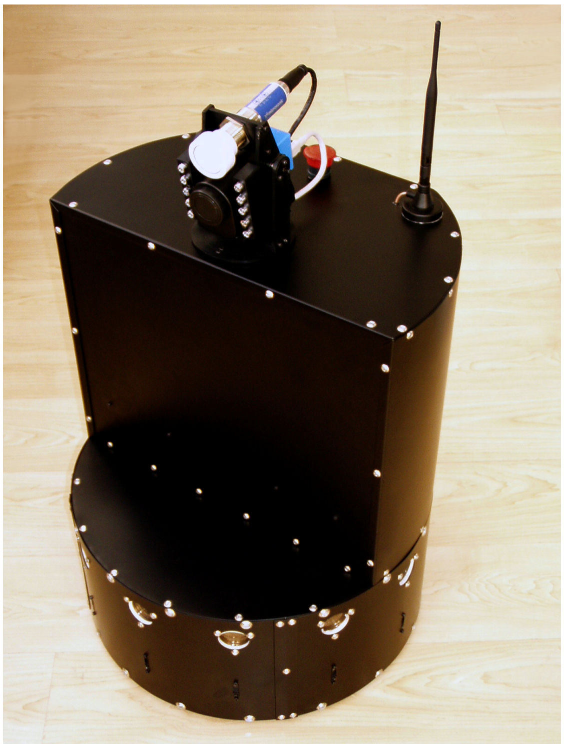

Fig. 1 ICII Indoor Mobile robot. Front view

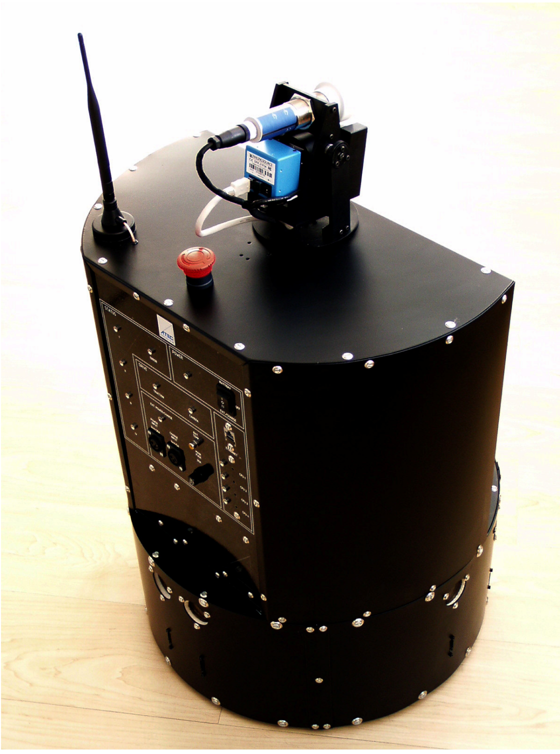

Fig. 2 ICII Indoor Mobile robot. Back view

Sensor subsystem

Mobile robot sensor subsystem consists of 9 ultrasonic and infrared sensors, which have the same configuration, 7 sensors are placed in robot front half circle and 2 sensors are in robot rear part (Fig. 3). These sensors serve for environment local map building. Local map is used for achieving collision free mobile robot navigation in environment. Local map alone could not ensure navigation in whole environment, but is effective tool for achieving fast collision free robot motion in environment.

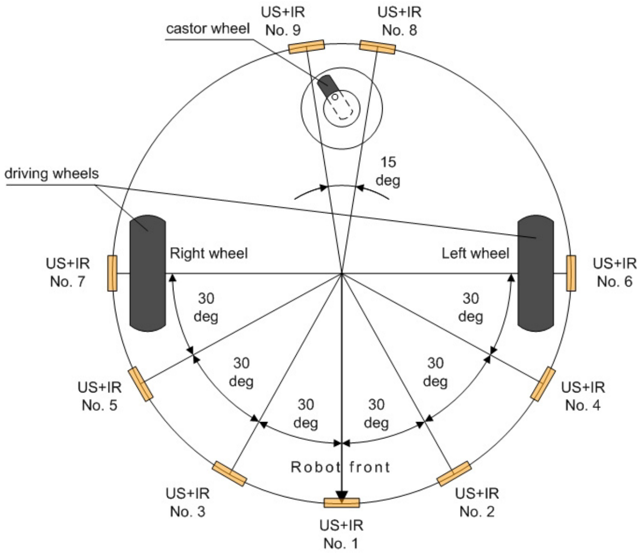

Fig. 3 Mobile robot sensors perimeter placing

To provide operator telepresence in environment where mobile robot acts, is sensor system equipped with rotation, pan/tilt camera head and precise ultrasonic range finder.

Robot telepresence is used in environments dangerous or not accessible for humans. Therefore must be mobile robot designed so, that there will be possible secure return to safe part of environment. Because of this reason is needed to sense and determine mobile robot internal state. One of assumptions for successful return to safe part of environment is sufficient battery energy. Moreover robot internal state depends on states of robot subsystems and also on state of operator communication channel

Actuators

There are traction actuators and camera head actuators. Both of them are part of actuator robot subsystem. Robot traction system consist of two driving axis. Every axis consists of Maxon motor RE40 (150W), gear GP42C(15Nm, 43:1) and incremental encoder MR ENC typ L with 1024 imp/rev. Incremental encoder is placed on motor axis and therefore impulse count of traction wheel is 1024 * 43 (gear ratio). Every robot traction axis is controlled with motor driver Maxon MIP50.

Camera head actuators are two Maxon motors A-max 26 (11W), planetary gear 26 (1.3Nm, 128:1) and incremental encoder MR ENC typ ML with 512 imp/rev also placed on motor shaft. Motor drivers are Maxon EPOS 24/5 units.

Communication with both Maxon MIP50 and Maxon EPOS 24/5 units is possible through CAN bus or RS232 serial link. We use RS232 serial link communication.

Maximal robot motion speed is about 0.8 m/s.

For robot navigation, path planning and obstacle avoidance is required information about robot state or robot relative state change in environment. Determination of robot state, in this case position and orientation is performed using odometry information based on robot wheels revolutions. For computation is used mobile robot model (Fig. 4).

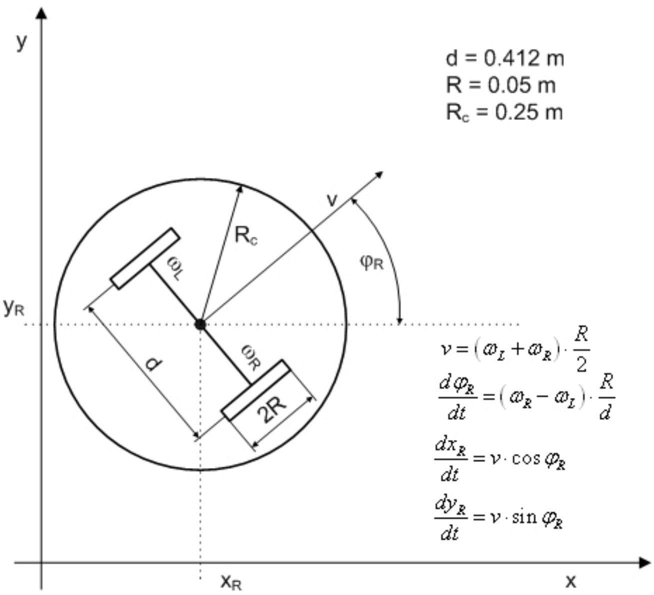

Fig. 4 Mobile robot model – differential drive

Control subsystem

Information subsystem of ICII indoor mobile robot consists of three CPUs Via EPIA. Block scheme of information subsystem is on Fig. 5. There is one CPU Via EPIA EN15000 (robot-cpu-high) with 1.5GHz VIA C7 processor responsible for visual processing and control of camera head. Middle control level consists of one CPU unit Via EPIA M6000 (robot-cpu-network) with 600 MHz VIA Eden processor responsible for communication with operator. Operator-robot communication could be through Ethernet cable or wireless. Lowest, but most important control level consist of CPU Via EPIA M6000 (robot_low) with 600 MHz VIA Eden processor. This level controls communication with motor drivers of traction wheels, acquisition and processing of sensors data and battery energy status checking.

Energy subsystem

Energetically subsystem ensures enough energy for mobile robot operation. It is build from NiMH batteries. There are two NiMH accumulator packets with output characteristics 12V/30Ah. All together there was used 20 Saft NiMH batteries VH F 15000, 1.2V/15Ah. Because of various voltage levels requirements there are used converters to 12V/4A and 5V/8A. Robot operation testing shows, that battery stamina time is about 3 hours by slow robot motion speeds and accelerations. By fast speeds and acceleration there are current peaks and therefore stamina time is shorter.

Conclusion

By comparison between desired robot properties and properties of real constructed mobile robot, there are some unequalities. This is because by design of mobile robot there must be considered interaction of all robot subsystems. All robot subsystems must cooperate and ensure proper work of whole mobile robot system. In this case takes place mechatronic design, which in cycles iterates design of subsystems and whole system and makes it possible to achieve optimal design.

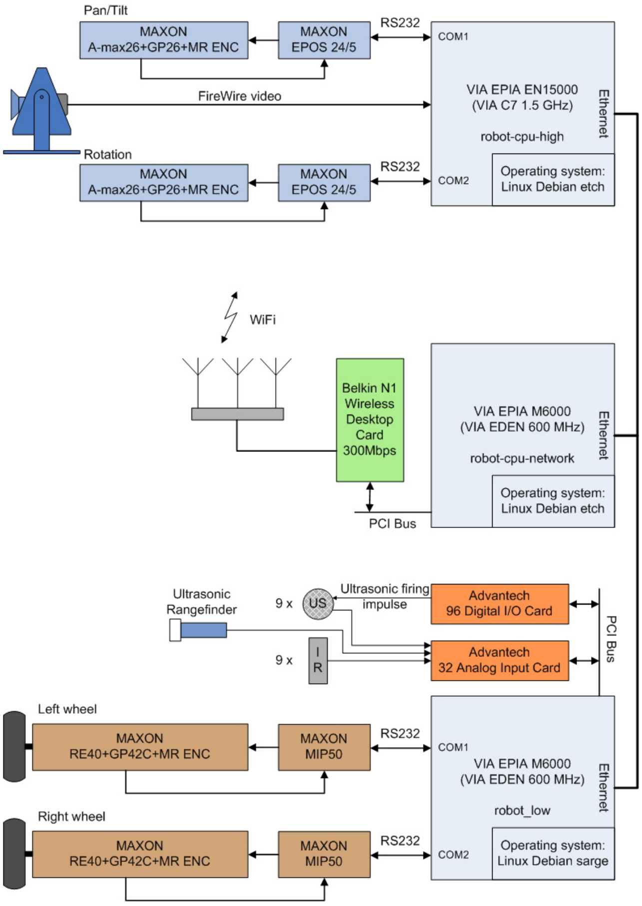

Fig. 5 Block diagram of robot subsystems

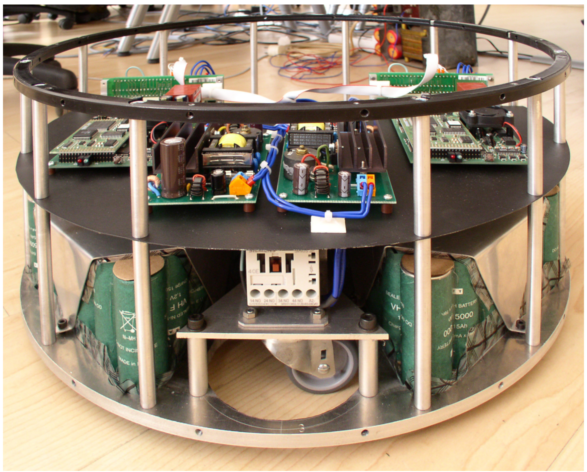

Fig. 1 Mobile robot basis – battery view

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