SELF DEPLOYED ROBOTIC NETWORK FOR LONG RANGE SEMIAUTOMATIC OPERATION

Robotics Network for Distance Data Connection, Areal Signal Connection Coverage or Areal Data Acquisition

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Abstract: This paper covers questions about long distance communication in a difficult hazardous environment. Distant communication is presented via number of robotics carriers determined to link communication between a centre of control and a remote controlled deployed robot in hostile area or gather data from certain area. The robotic network is autonomous cooperative system of vehicles to provide data connection for the tele-operated deployed robot for example in rescue mission. This robotic network acts autonomously and reacts with surroundings background to guarantee data connection. Two main issues are presented: the data communication and the robotic carrier. Communication can be created by own wireless system carried on robots or use accessible communication such Wi-Fi/Ethernet in urban areas to use the installed networks in buildings to increase a capability of network. The robotics carriers will be realized as modular system with capability to modify each main part of carrier to fit specific environment. Basic construction of the robotic carrier is traction unit with basic frame with motor(s) and lithium based batteries, control unit based on MCU/DSP controller and internal sensor unit with capability to install another set of the external sensors. To provide positions of the carriers to on operator a visualisation of their position is planned by Goole Earth like application.

1 INTRODUCTION

Nowadays advances in embedded systems computations and communication technologies provide support for the cooperative multivehicle systems – mobile robots.

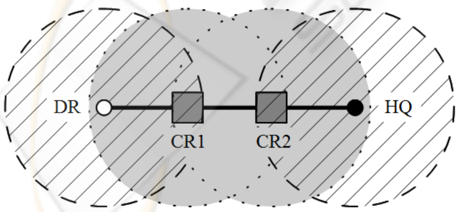

Figure 1: Extended communication by two repeaters.

Mobile robotics are part of our nowadays life, there is an amount of usage of them in explicit areas. Part of robots is designed to work in difficult areas dangerous to human. Environments like areas after or under natural (flood, wildfire) or industrial (chemical, mine) disasters could cause a human injury or even lost of life. They are available only for specific robotic unit equipped by specific tools, sensors or both to perform a search and rescue mission or gather data of the situation.

Employment of such robot can be complicated due to limitations of signal connection, to obtain an extended range. The communication problem can be caused by density of urban areas, difficult mountain landscape, complicated shaft net in mines, radio power limitations etc. Solving extended communication range from control centre to deployed robot can be via system of mobile signal repeaters carried on auxiliary robots (robot carrier).

Robot carriers can act autonomously and perform several nets topology to secure connection to deployed robot or perform data acquisition from area depended on sensor equipment on the robot carrier and its count. Figure 1 shows simple line topology to extend radio communication distance between control centre (HQ) and deployed robot (DR) by two robots carrying wireless repeaters (CR).

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Robot carrier himself is completed like multipurpose kit containing several independent units to rebuild carrier and fit it to specific area. Carrier kit contains a wireless communication unit, a control unit and a traction unit (chassis), optionally a sensor unit to gather interest data. Each robotic carrier's unit will act like a distributed system with control subsystem secondary to control unit.

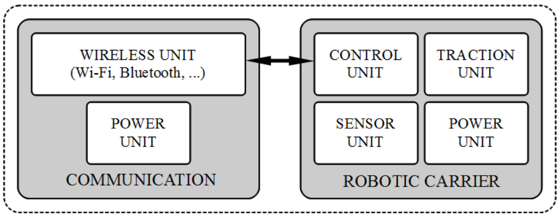

Figure 2: Block scheme of robot.

2 COMMUNICATION

There are many important parts and tasks to develop in this project. One of the most important parts is to develop open radio network for communication between service robot(s) and base station. Because usual teleoperator or a service robot use several communication channel to data exchange separated by purpose or origin of data (camera / video, control, telemetry, payload, etc).

To avoid collisions with this amount of data interface with different, frequency, bandwidth, data throughput rate, range and so on, we establish common interface to all robot internal system as well as transferred data to Ethernet. It causes that you can connect any existing or future device directly or through simple bridge whereas most of them are commercial accessible and also has not any influence to existing communication inside robots system as e.g. the control system and its peripheries. There is possible to transfer control command to the communication unit, telemetry data as well as multiple real time still or motion picture in this solution.

This kind of plug and play system for communication subsystem allows to mount the best suitable communication unit directly before robots mission and to use its all features during operation. As main communication standard we use cheep IEEE802.11b/g system which has sufficient data throughput and range for most of the robot applications. Also the using of modules with GSM/GPRS/EDGE is possible when they are available or robots operate on wide area.

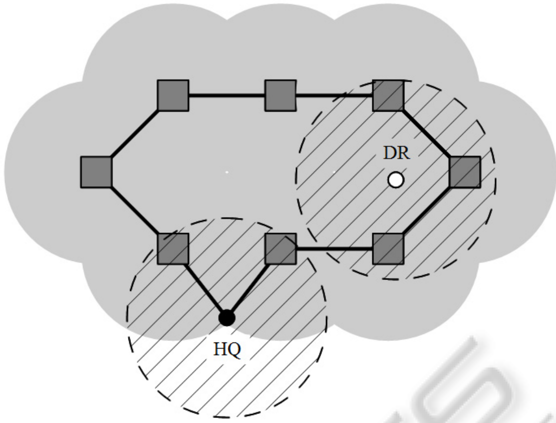

Figure 3: Areal signal covering.

Data exchange with operators or between service robots behind direct radio visibility during rescue and security mission is necessary to be all the time. We design semiautonomous robotics retranslation unit to solve this problem. This robotic mobile repeater can be carried on main robots and deployed in situation when direct communication is unstable or not reliable. There is a new issue to solve – how to organize the radio network to have the most optimal area coverage.

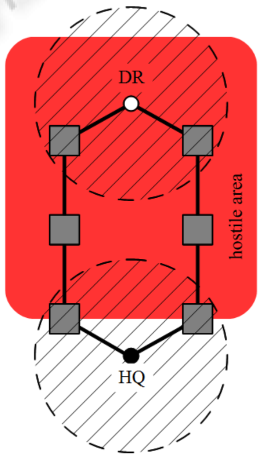

Figure 4: Doubled connection to deployed robot.

We have designed several basic scenarios for testing different type of radio signal inaccessible conditions. This model could be described as line, area, path, and circle coverage of hostile area. And in this model we are looking for best points to deploy the mobile repeater carriers. Advantage of repeater mobility could be exploited when surrounding condition are changed or is necessary adapted network topology. Higher mobility and climb ability in e.g. "Leg's" version of repeater allows finding better position to retransmitting data from source to destination. Some variation of scenario describes backup communication line with dual line of repeater. This is done for safety reason when noise, lost signal or failure causes a termination of one repeater carrier.

Second task is long term operation of service robots in wide area in cooperation with several mobiles robots and fixed station. This mode describes coverage of area with size over units or tens of square kilometres equipped of partial working infrastructure like Wi-Fi, GSM or private radio network. Robots communicate trough real dynamic reconfigurable heterogeneous network over TCP/IP protocol in this task. However it seems that small mobile repeater have no advantage and place in this scenario, relative small and cheap mobile robot carrier with cooperation with main services robots can keep well coverage of wide area radio network. Mobility of repeater carrier can help them to survive difficult conditions. Sensor equipped mobile repeater also provides support to environmental analyses not only useful for routing option.

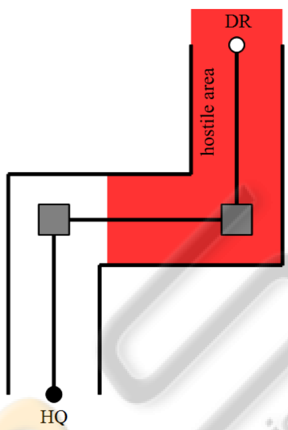

Figure 5: Using of two carried repeaters in urban or mine area.

3 ROBOTIC CARRIER

To provide a positional layout of signal repeaters, autonomous carriers are needed. In our case we will work with solution based on service robotics modular system. Modular means that key parts of the robotic carrier are interchangeable to fit specific area of interest.

Main idea is to split solution of robotic carrier into several units and solve them separately. Basic robot can be divided into units: traction, power supply, control and sensor. The traction is mostly entire mechanical problem due to containing frame (chassis) of robot. The chassis is depending on the traction system. Several traction solutions can be used mainly for indoor or outdoor purpose.

3.1 Traction Unit

By the traction unit we understand a subsystem of robot that provides movements and creates a frame for other parts of the robot. The traction unit contains: frame, gearing, motor(s) and driver (electric), eventually battery.

Simplified block scheme on Figure 6 shows a main part of the traction unit including a battery. Due to a lot of robot's construction possibilities the selection of battery is depended on traction. Nowadays we have to use battery pack based on Lithium due to very good power to weigh ratio and also a maximum current capability, like Li-Pol and others. Size of traction is related to battery capacity and nominal voltage (number of cells).

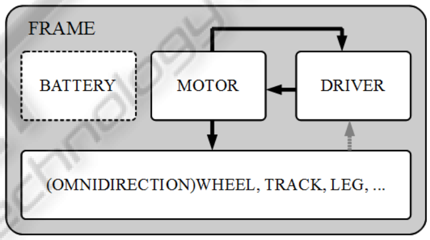

Figure 6: Block scheme of traction unit.

The frame of the robotic carrier is basic construction set for entire robotic system. It has to be light and solid and also suitable for areas of interest. Most used traction on robots nowadays is wheels and tracks (tank under cart). Wheels are very simple to control and robot can move in high speed. On the other hand tracks are slow but robust and can pass terrain with more obstacles.

There are several main environments which influence selection of suitable gears for robot. Generally there are indoor and outdoor. By outdoor we mean only land terrain.

Indoor conditions are represented by short distances and flat surfaces where the main obstacle is stairs. Capability to pass stairs can split indoors robots into two areas. The stairs passing robots have more complicated construction and they are similar as the outdoors robots. Indoor environment provide ideal surface to movement of robot with special traction based on omni directional wheel or walking robots. The omni-wheel is a segmented wheel with capability of two axis movement. The robots based on the omni-wheel can contain common wheels (two) and be completed with omnidirectional (third) to improve turning of the robot. Also a fully omnidirectional equipped robot can be possible, for example a three wheel robot. Movement of this kind of traction is by a various speed of omni-wheels, so robot can change its direction based on the actual speed of omni-wheels.

The indoor environment can be also very good for walking robots without special abilities to control balance on inclined or another complicated surfaces. Segment of walking robots are humanoids - but there are problems with balance and speed of them and so there are not very suitable. More useful robotic traction is based on spider like chassis – 6 or 8 legs. This traction unit provides stability without a complicated balancing system but still has limited speed due to complicated leg's movement. Also a 6 or 8 legs robots have to be equipped with a number of servomechanisms regardless to number of joints on each leg.

Pure walking robots are designated to indoors applications but there can be hybrid solution based on combination of wheel and leg. This solution provides a speed from wheels and agility from legs.

The outdoor conditions are more complicated and for the purpose of robotic network are more probable. Outdoor applications could be majority for robot's movement. Suitable traction for outdoor application is wheels (like in car) and tracks (tank). This kind of traction is very suitable for terrain, roads even in buildings and stairs. Outdoor designed robots can easily be used also in buildings even to climb stairs.

Figure 7: Tamiya TXT-1.

Regarding to high efficiency and speed of wheel based traction this kind of robot is very suited for outdoor application and to carry a wireless connection unit. Figure 7 presents a system from RC car which is very good for outdoor robot. This traction provides two DC motors for driving all four wheels (4x4) on entirely suspended base. Also both axletrees are steered. Tires are adjusted to work in complicated terrain.

Movement of the traction is based on electric motor of any kind. There is also gas-engine where endurance is enlarged, but this has to be more serviced and control of gas-engine is more complicated, so we will work only with DC or EC motor.

Part of traction unit is a driver for electric motor. Construction of driver is very similar even we have DC or BLDC motor. The driver is based on circuits called half-bridges and due to the DC or BLDC there are two or three half-bridges in driver. Half-bride is junction of two power switches which can amplify logic signal to provide power supply battery level and can provide required current. In mobile robotics are used almost only MOSFET based constructions. Advantages of MOSFET are very low power losses and high frequencies of work with minimum of driving energy. N-MOSFET work like ideal power switch and is widely used in power electronics like motor drivers with low voltage (<100V). The driver will be equipped with his own control to provide close loop control of motor. Based on traction system there can be feedback from sensor on shaft of motor or on a wheel, also sensors on legs etc. Control system in traction, based on MCU will communicate with his superior the Control unit of the carrier.

3.2 Power Supply Unit

Power supply or battery for the robotic carrier is very depended on the traction unit. The indoor and outdoor application may be very separate of each other in range and online time and also in a size/weight of robot. The battery pack will be then different. So we can think about including power supply to traction unit and have it together in kit. In this paper we will be talking about power supply unit as separate part of the system. But in the robotic carrier kit will be part of traction.

Batteries which can be used in mobile robotics are basically based on Lithium. Thinking about NiMH, SLA or even NiCd is obsolete. Advantage of Lithium based cells is power to weigh ratio and high current capability (Li-Pol). Also a minimum looses of energy stored that make robot less needed of service. Main disadvantage on Li-xxx is precise charging and watch on discharging to not outrun a minimum voltage limits. Due to this we need to precise charging with balancing/limiting system and when used (discharged) a system to count energy and estimate remaining capacity (to stop discharging in right time) and also watch limits especially minimum voltage per cell.

Power supply unit then contains a basics subsystems like: battery cells, protective circuits and fuel gauge. The protective systems are used in charging of series of cells and balance variance of each cell (capacity is not ideally similar, one cell is fully charged faster than another). Fuel gauge system based on MCU counts energy stored in cells and estimate remaining energy which can be provided. Method is based on simple current and time measurement and it can be determined a quantum of current which flows from battery to load (motor). Also current when charging can be measured (will be negative, current flows back) but there is a problem with protective systems because basic protective system change redundant charging energy into heat.

In mobile robots for outdoor application we can estimate a 7 to 10 cell needed to provide power supply up to 30-42V with continuous discharge current of 10 to 15A. This make an output power in range 300 to 600W which is ideal for mobile wheel based robot with traction based on system from Figure 7. For the indoor robot same cell can be used but only two or three will be needed.

Power supply unit is slave to the control unit (master on the bus) and contain separate control to measure capacity of power cell(s) and can estimate and report it to control unit.

3.3 Control Unit

Main unit in robotic carrier is the control unit. This unit have to decide how to ensure data connection, how to get to position, to drive traction unit and to communicate with others carriers and to establish connection from control centre to deployed robot.

Entire control of robotic carrier is distributed because all of units have their own control by MCU. The control unit act like a master on bus via which all MCUs are connected together. Preferred bus on such mobile robot is LIN, RS485 or even CAN based on required speed and data security.

The control unit depends on complexity of needed solution from algorithms. Based data are gained from sensor unit and from communication. The control unit calculates a position to move and control movement by sending required speed to closed loop control of motor in traction unit. Basically this can be covered by some newer MCU with 32 bit core to obtain a real time solved problems and results.

Power supply to control unit is from power unit, so there is a power supply shared with motor on the other hand a wireless unit have its own because primary function is to provide data connection.

3.4 Sensor Unit

In mobile robotics we can split sensors into two groups. Internal sensors are used to ensure a basic function of the robot. Typically internal sensors are incremental rotary sensors in motor (traction unit) or sense resistors in battery (power unit). These sensors are used to operate a basic system of robot. In the other hand external sensors are used to contact robot with his exterior, robot can operate self without it and this external sensors determine the basic type and purpose of the robot.

Internal sensors are then on unit which control basic function of the robot. Sensor unit contains external sensors to gather data from surrounded area of robot. Because a primary function of robot is to carry a wireless system and establish connection to deployed robot a sensor unit is basically equipped with sensors to obtain a global position of robot and to provide them to control unit to establish right network topology. Also safety ability has to be implemented to avoid contact robot with obstacle or to do not injure humans. Basically, the robot needs a set of tactile sensors to avoid obstacles. Tactile sensor is contact or contactless, where the simplest contact tactile sensor is a switch, but this is not very useful because a short range of operation. More useful sensors are contactless based on ultrasonic sensors or infrared optical sensor, both work like range finder so we can find an obstacle and also we can estimate range of it.

In indoor application of carrier a network topology can be determined basically on odometer (data from traction unit). Indoor due to short ranges and covering sky a global data cannot be provided and precise admeasurements have to be used. So there we need to know a start position of each carrier to work with this offset of position.

Additional sensors can be used to gather more data from area where carrier robot is used. This will work as additional function and area where are robotics carriers deployed can be better monitored than only with deployed robot. There can be used simplest sensors to measure temperature, pressure sound waves, chemical materials in air etc.

4 VISUALIZATION

The entire system needs a visualization system to provide human-machine interface, to simplify using and maintenance. Each system has specifics demands for visualization and for system described above is very important except of standard telemetry data also position data of each unit as well as give to operator overview and knowledge of terrain (etc.) where robots operate. For this purpose is useful include part of geographic information system to operator control panel to access terrain map data. It could be dynamically refilled and updated by e.g. aerial photography, laser scan or other robots sensor data or data from mobile repeater such as temperature, chemical sensor or camera.

"Wide are" scenario has huge requirement for GIS data source which could be very expensive. For this reason we are use public GIS source like Google Earth. This makes possible to visualize robots, repeaters and other position in 3D maps and terrain model. Big advantage of this system is possibility dynamic updating visualized data. It simplifies maintenance of whole system and allows online publishing of e.g. environmental data for community or government usage; depend on mission and devices type.

5 CONCLUSIONS

This work on mobile robotic network is basically in phase of prototype development. Presented information will be taken under test and will show us possibilities of next development and serves us as guide to how to continue on this project. Basic idea was to enlarge the range of wireless system to our robot. Nowadays we have knowledge on constructing mobile robots and this work is based on prototypes of them. We believe that our work will provide a functional prototype of robotic network to use in emergency and rescue operations.

Robotics system has also feature to join several branches of technical development. Traction is based on mechanical engineering, network is based on communication solutions, sensors and control unit need to be solved by electronics and finally visualization is based on computer programming.

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