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CONTROL SYSTEM OF THE RESCUE AND FIRE EXTINGUISHING ROBOT HARDY

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Abstract: *This paper presents the multipurpose service, emergency and rescue tracked mobile robot Hardy. The mechanical construction, technical solution, functions carried out by the robot and examples of potential applications are briefly explained in the beginning. Then follows description of the control system in the mobile robot and the operator's suitcase used for remote control. Presented are also experiences with modern electronic devices for control of hydraulic and electric motors in the robot based on the communication protocol SynqNET, implemented using technology from Robot System Integration (RSI). The next part of the paper deals with the user interface of the operator's application and some of the features that were designed to assist the operator, primarily the anti-collision system. The whole system is then critically evaluated using some experiences from practical use of the robot, even by a common user.*
Keywords: *Extinguishing robot, Hardy, control system, SynqNET, RSI*

DESCRIPTION OF THE ROBOT HARDY

Hardy is a remotely-controlled multipurpose service, emergency and rescue mobile robot designed for manipulations with objects of up to 300 kilograms of weight and also for other fire brigade and reconnaissance tasks. It is meant for use it emergency situations where a direct intervention of human rescuers or firemen is not safe. The robot is able to extinguish fire with a stream of water, with remotely adjustable shape of the stream.

The mobile robot consists of three main parts: a robust chassis providing perfect stability, a manipulation arm with high load capacity, and a multipurpose effector with three adjustable gripping fingers and integrated water jet. The tracked chassis has been taken from a mini-loader Bobcat, including the original diesel engine and hydraulic aggregate, which was then expanded by more hydraulic drives for the arm and effector. A new electric alternator was connected to the diesel engine, to provide enough energy for the control system electronics and for the 400-volts DC motors of the arm. The mechanical construction of the chassis was modified to secure mounting of the manipulator arm and other new devices and was also supplemented with further covering, a bumper (or optionally a ploughshare) in the front, and boxes for control system elements.

Figure 1: Robot Hardy

CONTROL SYSTEM OF THE LOCOMOTORY SUBSYSTEM

Locomotory subsystem is one of the most important modules of the robot and contains a tracked chassis powered by two rotational *hydraulic motors. Source of the pressure hydraulic media are hydraulic generators driven by the diesel engine. The locomotory subsystem is controlled by an electronic device (interface) designed for communication with the original control unit of the tracked chassis. The device simulates signals generated by the control joystick previously located in the driver's cabin.*

Control signals for driving are transmitted wirelessly from the operator's station (suitcase) via a separate communication channel on a lower frequency (866 MHz), in order to achieve higher range in industrial environment, because driving is the most crucial function of the robot. Directly on the chassis is realised service controlling, so that the robot can be moved in case of a failure.

The chassis from tracked loader Bobcat is driven by fully controllable tandem hydraulic piston pumps, which are powering two reversible hydraulic motors. Handling is realised by two joysticks, or the system can be reconfigured for just one joystick.

Remote control of driving could be done only by connecting to the original control system of the chassis. Direct regulation of the hydraulic motors would be very complicated, because it is necessary to control not only the mentioned hydraulic motors, but also the diesel engine and other components participating on the whole process.

A feasible way how to replace the original joystick with an electronic device proved to be to simulate the joystick angle by change of magnetic field over the corresponding sensors. Executed tests discovered, that reading of angles of the joystick is based on detection of magnetic field changes above the sensor board. These changes are induced by a permanent magnet located on the end of the moving stick. Magnetic fields around 4 sensors are measured and passed as an electric signal to other parts of the control module (see Figure 2).

This solution required an extensive analysis of magnetic values generated by the permanent magnet and their accurate imitation by a set of electromagnets (coils). The advantage of this approach is the fact, that the original electronics of the joystick is intact and the realisation is contactless.

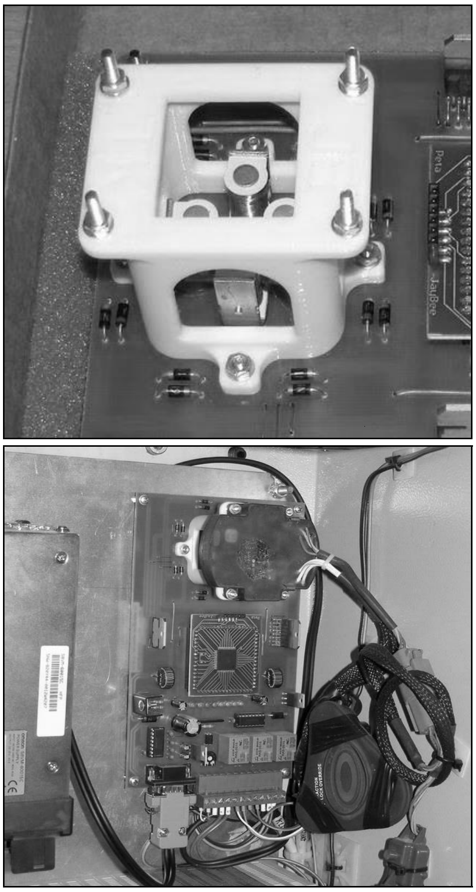

Figure 2: Components developed to replace the original driving controller

MANIPULATOR ARM

The manipulator has 5 degrees of freedom. The first two joints have rotational hydraulic motors and the next 3 joints use DC electromotors from the TGDrives Company. Lifting capacity of the arm corresponds to weight of the biggest existing pressure bottle, which is 300 kilograms. Gripper with three fingers powered by hydraulic cylinders can be set to one of two possible configurations: 3 fingers by 120 degrees or 2 fingers against one. This configuration change is automatic; the effector contains two Maxon DC motors for this function.

Figure 3: Effector detail

Through inner spaces of the arm, water is brought up to the effector and serves for cooling of the arm in case of operation in high temperatures, and also for fire extinguishing using the water jet located in the middle of the effector (between the gripper fingers). It is even possible to regulate the width (angle) of the water stream cone. This functionality is provided by another DC motor Maxon integrated into the effector. For cooling and protection of the whole robot near open fire or in high temperatures, the chassis contains water sprayers that create water mist around the robot.

ROBOT CONTROL SYSTEM

The whole control system consists of a part located directly on the robot and of an operator station. The operator has a suitcase with a computer running the operator application, by which is he using wirelessly all functions of the robot and has a visual feedback about the state of the robot. This feedback includes pictures from cameras (with optional stereovision), data from sensors and interactive 3D visualisation of the actual position of the arm and effector.

The application running on the operator's station is fully graphical, with stress laid on the camera pictures and comfortable control of all functions using a wireless gamepad and a touch screen.

The robot control system contains a durable industrial computer with an application executing commands from the operator – the bidirectional communication with the operator's computer is made via wi-fi.

Figure 4: Operator's station

Backbone of the system is a SynqNet bus [3] interconnecting three DC motor controllers for the arm motors and a Slice I/O module for analog and digital inputs and outputs for all auxiliary functions of the robot, communication with sensors and especially for control of the proportional hydraulic valves for arm and effector motors. The system also contains a CANOpen bus for the EPOS control units of Maxon motors located in the effector.

ANTI-COLLISION SYSTEM

The manipulation arm with strong motors could easily damage itself or some delicate components of the mobile robot (cameras, sensors, communication antennas …) situated in the operating area of the arm. When the robot is out of direct sight from operator, the operator has only very limited feedback from the robot in the form of video from robot camera(s). Actual angles of all arm joints usually are not clear from camera view and thus the operator cannot be fully responsible for prevention of collisions and the control system must assist him [2].

The collision detection is implemented using the separating axis algorithm [4] on pairs of bounding boxes enveloping individual mechanical parts of the robot [5, 6]. Finding an existing intersection between two OBBs would mean that the real arm already probably is in collision – which is too late. Algorithm in the control system of Hardy uses extrapolation of actual angular velocities of all arm joints to predict position of the joints after a chosen constant time. If a potential collision is detected, the arm is slowed. If the collision is imminent, the arm is completely stopped.

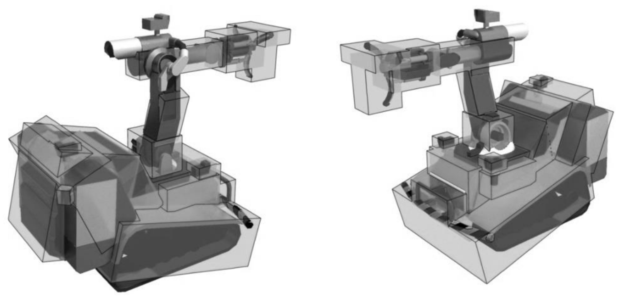

Figure 5: Collision boxes on a 3D model of the robot

CONCLUSION

During realisation of the emergency and rescue robotic system Hardy, it was necessary to solve a lot of technical problems and come with unique solutions of some components. One of the problems was how to control the original mini-loader (Bobcat T250) chassis by an external control *system. The Bobcat control unit communication bus and protocol are closed and even direct assistance of a service centre did not lead to a solution. Thus it was necessary to propose a way how to pass driving orders (speed, steering) without having to move the joysticks originally designed for control.*

Because of the extreme power of the robot and its remote control even without direct visibility from the operator, it was also necessary to design and implement many features assisting the operator during control and helping to prevent accidents. The anti-collision system with the separating axis theorem used to test intersections between pairs of oriented bounding boxes proved to be very efficient and requires insignificant amount of CPU processing time.

Many other problems were solved by a larger team of specialists and their description is not a part of this article.

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