HYDROGEN POWERED CAR CONTROL SYSTEM

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Abstract: The main goal of the research project was designing and realization a distributed control system of the hydrogen powered prototype car. Next goals of project were real time control, speed and final time optimizing with minimal fuel consumption and monitoring of driver biomedical parameters. The control system was realized by several mobile embedded systems and one central system. The embedded systems hardware was realized with Freescale processors and communication CAN bus. Central system hardware was realized by notebook and communication with embedded systems in car was realized by GSM communication. Control system software using of multi-agent technology with dynamic mutual negotiation of mobile system parts. This task allows in a form of control system for prototype race car modelling of distributed control system. The real hardware and software model is also important motivation for extended research.

1 INTRODUCTION

A team of several specialists and students of Department of Measurement and Control, VSB-Technical University of Ostrava have designed and realized a prototype of hydrogen powered car based on fuel cell technology and electrical DC drive. The project is called HydrogenIX and the works and testing activities came through between October 2004 and today.

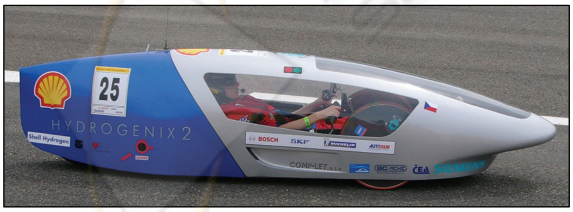

Figure 1: The HydrogenIX car.

The motivations for the project are following:

- There is The Laboratory of Fuel Cells at Department of Measurement and Control. The development of mentioned car is first application of fuel cell in mobile system at the laboratory.
- Activation of the interest of students, Ph.D. students, researchers and public in renewable and alternative energy sources.
- Involve students to design and development activities in interesting area and demonstrate the result of the project in a competition of economization of energy in mobile vehicles. The competition is called Shell Eco-Marathon.

The Shell Eco-Marathon is a competition organized by Shell Company and take place at race circuit in Nogaro, France. Teams of whole Europe try to reach highest distance with 1 liter of petrol, in the other words to have lowest consumption of the fuel. Even if the majority of teams use petrol engines in their vehicles, there are also vehicles powered by diesel, LPG, hydrogen and other alternative energies. The results are obtained by recalculating using calorific value of each type of fuel. So that it is possible to compare different types of fuel.

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2 CONTROL SYSTEM

The vehicle powered by hydrogen fuel cell needs electronic a control system assuring operation of its different parts. The complex electronic control is necessary already for basic operation of the vehicle, because there are lots of subsystems that have to be coordinated and controlled. The control system assures especially following tasks:

- Control of fuel cell operation – hydrogen input valve control, combustion products output valve control, fuel cell fan control, coupling of produced electrical energy to electric DC-drive system.
- Control of DC-drive system – motor current control, speed control.
- Processing security tasks – assuring safe operation of fuel cell system and drive system, processing of hydrogen detector information, temperature measuring.
- Managing the driver control panel – complete interface to pilot that allows controlling the car – start/stop, speed set point, time measuring, emergency buttons and indicators.
- Creating data archives with saved process variables – saving important process data to archives that can be then exported and analyzed.
- Sending actual data to display panel in car – display panel in the car is the "process" visualization of the system. All important data are online displayed on it.
- Communication with PC monitoring station – control system send data and receive commands from PC monitoring station using wireless communication system.

The car onboard control system is built on embedded system with Freescale HC12 microprocessors. The control system has distributed architecture and it is divided into two parts:

- A fuel-cell control block that controls whole installation of the fuel-cell, DC drive system and security tasks.
- An interface control block that assures interface to the pilot, a wireless communication with PC monitoring station. This block contains the text display, which is used to monitor important parameter of the car and makes possible to do important settings.

Both part of control system are connected via CAN communication network. The wireless communication between the car and with PC monitoring station is realized by GSM communication – GPRS data transfer. The data transfer is realized by dial-up connection.

The PC monitoring station operates a process visualization application that is realized by SCADA system Promotic. The process visualization displays all parameters measured during the car operation, all the system states and alarms, make possible to display trends of required values and log measured data in data archives.

The complete block diagram of the car control system is demonstrated in figure 3 and realization in figure 2.

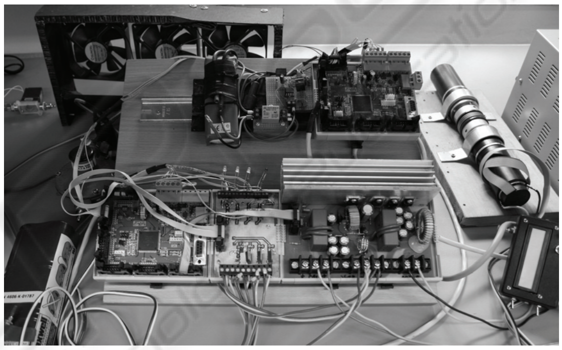

Figure 2: The HydrogenIX car control electronic testing workplace.

2.1 Operating Values Monitoring

The car control system monitors a lot of variables. Some of these variables are used for basic control activities, the others are used for optimization of operation. The measured variables are following:

- Electrical variables – fuel cell voltage and current, motor voltage and current, voltages of super-capacitor and on-board battery.
- Non-electrical variables – temperatures and pressures in fuel cell circuit, car speed.
- The system is ready for measurement of others supplementary variables that can be used for optimization of the operation – wind speed, outside temperature, track position.

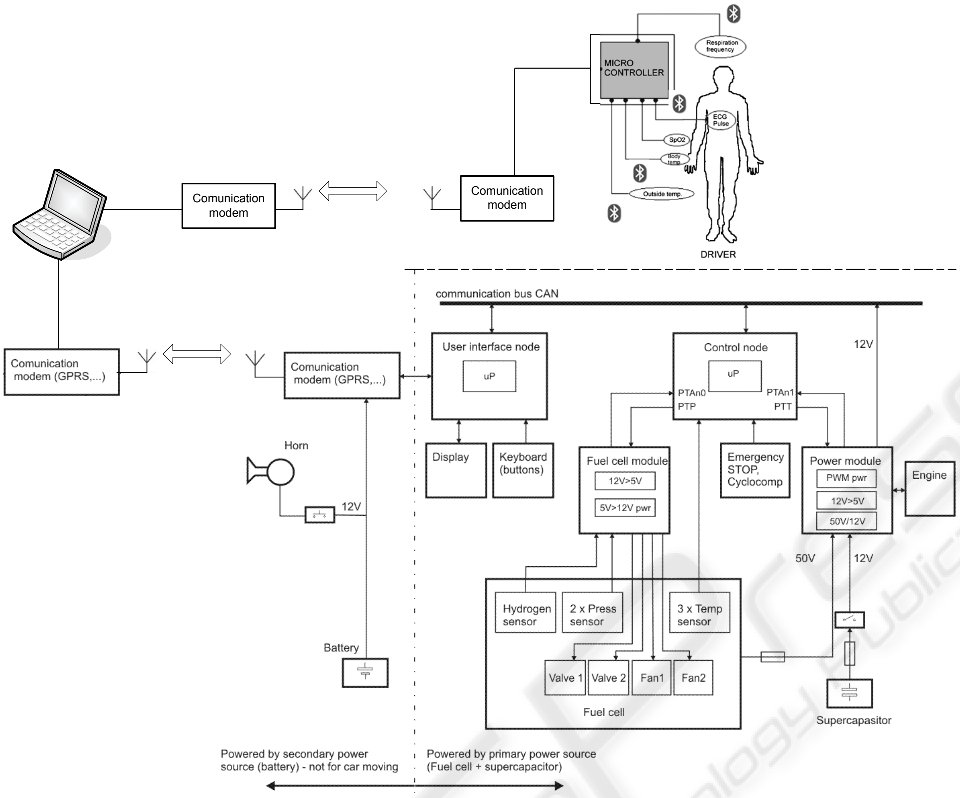

Figure 3: The HydrogenIX car control electronic block scheme.

2.2 Bio-telemetry System

The vehicle is also equipped by bio-telemetry system that makes possible to monitor biological functions of the pilot. The embedded portable telemetry system of biological parameters serves for reading and wireless data transfer of measured values of selected biological parameters to far computer.

The telemetric system can be used for real time monitoring of the basic life functions of race driver. The driver has to be very concentrated and the reactions of driver have to be very quick. The telemetry system provides better control of physical and psychical condition of driver during race. It is possible to analyze effect of a stress situations, high speed and high psychical stress on the race driver during the race and crisis situation, more precisely during high physical and psychical stress.

For biophysical monitoring were chosen these parameters: Electrocardiography – ECG, Pulse frequency, Oxygen saturation – SpO2, Body temperature, Outside temperature and Respiration frequency.

3 MULTI-AGENT CONCEPT OF CONTROL SYSTEM

The track passage optimization task of the laboratory car with minimal energy consumption in real time is quite complex.

Range of inputs and outputs of the control system, communication flows and safety of operation require the adaptability at occurred situations and environment changes – strategy control by multi-agent systems (MAS). Among basic expected properties of proposed MAS belong a strategic, targeted system behavior, robustness and adaptability at environment changes.

This can be provided by decentralization of control activities in the control system, by distribution of functions and by modularity based on fundamental elements – agents (Srovnal, V., Pavliska, A., 2002).

3.1 MAS Structure Description

The higher level of control system is represented by a personal computer. In the PC the signal from differentially GPS positioning system may be entered, which represents the relative coordinate system of environment – allow the precise of the position of the race car on the circuit. At the output is connected GPRS communication modem which transmits commands for race car.

The algorithm of agent's cooperation was proposed with the control agent on a higher level. The control agent determines the required behavior of the whole control system as the response to the dynamic behavior of car and to the one‘s own global strategy in the task and knowledge about the last situations, which are saved in the database. The agent on a higher level controls the other agents (Srovnal, V., Horák, B. and Bernatik, R., 2004).

The separate task is the transformation which converts the digital data position into the object coordinates (car position on the circuit) which are saved in the database of the circuit. This database is common for all agents in the control system. Each agent sees actual the whole data and is capable of controlling its behavior in a qualified way. The basic characteristic of a control algorithm of a subordinate agent is the independence on the number of decision making agents for car on the circuit.

Agent system has a common goal, to control of the car during race with optimizing - minimizing of fuel consumption and control of critical speed. For successful assertion of one's own race strategy the extraction and knowledge of changeable environment and learning capabilities are very important.

Main architecture of such hybrid agent system is characterized via:

- Layered control. Agent is described by number layers of abstraction and complexity.
- Layered knowledge base.
- Bottom-up activating
- Top-down execution.

Agent is connected with environment through interface with sensors, actuators and communication module. Control is allowed through layers at three levels: reactive layer, layer of local planning, and layer of cooperative planning. They are use information from knowledge bases (“world” model, “mental” model and “social” model), (Garani, G. and Adam, G., 2006).

Reactive layer is responsible for adequate reactions at the stimulations from environment that require immediate reaction and execution of called procedures from local planning layer. Fundamental characterization of such layer is:

- Use of effective algorithm of compare with patterns of behavior. Serve to pick-out of the actual situations.
- Situation description for timely actual reactions at received stimulus.
- Hard-wired links. Recognized situations are fix-connected with targets for reactive behavior. Immediate execution of program actions.
- Solution request of situations not–corresponding with couples situation-action are transmitted in local planning layer.
- Execution liability is coming from local planning layer activate procedures of reactive layer patterns of behavior.

Some situations can be not solved by execution of template action like an answer to stimulation from environment only, but they require certain level of deliberation. A function of plans creation for solving of the targets performs the layer of local planning.

Local planning layer have such fundamental data structures:

- Targets – state sets. Sets are characterized by attributes that are fulfilled at reaching targets.
- Planning – planning from second principles. Sets of plans are defined before in data structure – plans library. Mapping of target sets to plans library is existed. For each target is possible to assign the plan for its reaching.
- Plans library – contain the plans for reaching of agent targets.
- Scheduling – secure the timely limited plans stratification. Be created the plan schedules like the step sequences, to execute.

3.2 Cooperative Planning Layer

A basic control cycle of cooperative planning layer is creation, interpretation, decision making and execution of local plans.

In first phase the reports from nearby layers are processed. Reactive layer sends requests to solve new task or status of executed behavior templates. Schedules of active plans are actualized. Subsequently the status from reactive layer executed procedures is checked.

In case of successful procedures finalization the plan is erased from accumulator. Reports from highest layer are related to creation or cancellation of commitment for the plan execution at local base or plan evaluation. In case of plan execution request or his cancellation the accumulator of active plans is actualized.

The plan availability is a result of difference of his relative value for the agent and his costs for execution. The plan value is derived from target value that is possible reach by plan. The plan costs are determined by function that assigns for every plan a real number calculated at basis of his fundamental action costs according to specific rules.

4 CONCLUSIONS

The algorithm of the control system should be proposed in a way so that it would ensure the requirements for the immediate response of control, so that the system of race car would be controlled in real-time. That is why, it is very important so that the algorithm for critical speed and fuel consumption would be optimized. The system response should be shorter than the time between two data frames from a GPS station. In the event that this limit is exceeded, the frame is cut out and the control quality may be decreased.

The main possibilities of algorithm adjustment are as follows:

- Dynamic control in the control and decision module of a control agent.
- The control and decision modules and communication protocol of the decision agents.
- The strategy of planning in the control model of the action agent.
- Learning of a race strategy and using the extraction results for decision rules generation as a part of the rules decision database of a decision agent.

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