Diagnostics of Sensors and Actuators Within Distributed Control System

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***Abstract*—This article deals with the structure of diagnostics of sensors and actuators within distributed control systems. Proposed structure consists of several layers which can be separated and processed by multiple control systems. This makes diagnostics more transparent and gives a way to share computational load between control systems.**

***Keywords*—Mobile robot, diagnostics, sensor, distributed control system.**

I. Introduction

Diagnostics of dynamic systems is very current topic, whether in system with increased reliability where the error of the sensor can cause big financial loses or a threat to life. Diagnostics is also required in system with poor maintenance access such as satellites, research rovers, etc.

Diagnostics is wide concept which includes detection, localization, identification and isolation of the error, alternatively reconfiguration of the control system.

Diagnostics as a whole should make the system more resistant to errors and in the case of occurrence of the non critical error, the system should be able to continue functioning without losing nature of its function. For proper function there need to be some sort of redundancy in the form of redundant sensors or analytical redundancy.

Since the final form of diagnostics will be implemented on mobile robots which are equipped by microcontroller(s) with limited computational power, the diagnostics should be modular to provide the tool for distribution of processing load between multiple control systems.

II. Initial state

In previous work there were introduced few ways of fusing data from multiple sensors, especially focusing on Multisensor data fusion (MSFDF) using Extended Kalman filter (EKF).[1]. There were also developed prototypes of mobile robots (MR) like MR for MiroSot competition [2] and mobile robot ALFRED [3]

III. Task solved in previous year

Diagnostics of sensor system is quite difficult task, which consists of multiple steps. Based on the analysis the current state of diagnostics, there was created diagnostic system divided into several logic parts (layers), whose together form a pyramid shown in Fig.1 where every layer can be implemented using several different ways. Block diagram of sample diagnostics system with interconnections between layers is shown in Fig. 2.

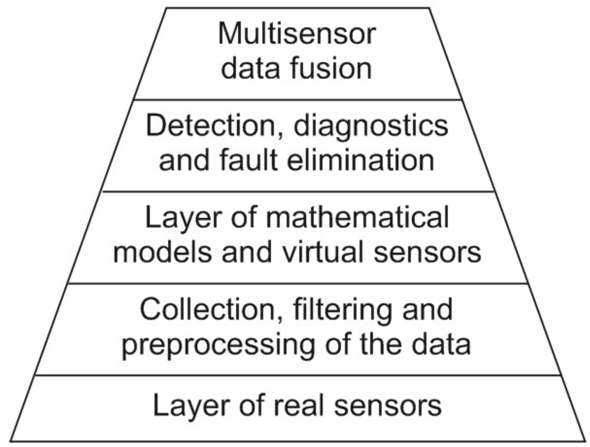

Fig. 1. Proposed structure of diagnostics within distributed control systems.

A. Layer of physical sensors

On this layer there are real (physical) sensors, whose output is analogue signal in the form of voltage or current, or digital signal transfered using communication interfaces (I2C, SPI, UART, CAN, Ethernet, etc.). This layer also includes scaling of the range of sensor to the range of analog to digital (AD) converter. Sensors within mobile robotics can be divided into three sections:

Sensors of internal state are sensing units directly associated with internal states of mobile robot like voltage of the battery, current flowing trough motor coils, linear or angular velocity of the wheels, etc.

Position sensors are used to determine current position and angle of the robot. Position sensor may be subdivided into two categories namely absolute (GPS, accelerometer, compass) and relative (accelerometer, rotary sensors, gyroscope) position sensors.

External environment sensors are measuring units environment outside the mobile robot (distance sensors, environment quality sensors, cameras, etc.).

B. Collection, filtering and preprocessing of the data

Raw data from the sensors often need to be preprocessed, so the control system will know to work with them.In this case the preprocessing of the data is considered filtering (smoothing) and transformation of the data from engineering to physical units.

This layer is based on hardware and software. Hardware part consists of communication buses, hardware filters and AD converters and software part includes software filtering and transformation of the data. Some of the sensor and communication bus errors can be detected on this layer

C. Layer of models and virtual sensors

On this layer there are mathematical models of the system as kinematic and dynamic model, as well as models describing relationships between measured and state values of the system. Mobile robots are described by kinematic and dynamic model.

Based on complexity, dynamic model may include the weight of MR, moment of inertia of MR and wheels (including gears in gearbox), frictions, etc. [4].

Kinematic model describes the relationship between linear or angular velocities of wheels (tracks, legs, etc.) and the position and angle of the MR in space. Kinematic model with association with wheel speed sensors can be used to calculate relative position of the mobile robot. Basic kinematic model can be enhanced to include parameters line slippage between wheels (tracks) and surface.

On this level there are also virtual sensors, which take readings from real sensors and calculate the outputs using some system models [5].

D. Detection, diagnostics and elimination of errors

For diagnostics and to improve reliability of the system, it is advantageous to have multiple sensors sensing the same value, ideally with sensors based on different physical sensing method.

Detection of the errors is done using residues which are next used to determine exact error of the sensor or actuator. Residue is indicator of an error derived from the difference between the results from sensors and models of the system. Analytical methods which uses residues as error indicators are generally called as a method of analytical redundancy.

Diagnostics - its most basic problem is to differentiate between unnatural or faulty state of the sensor and between non standard state of the system. In real dynamic systems such a mobile robots it is difficult task, because dynamics of the system and outer influence may hide actual fault of the sensor. Accurate diagnostics of the sensor fault may obstruct the fact, that multiple sensor faults can be described by similar symptoms [6].

Fault elimination is the process when the fault data from corrupted sensors are eliminated to ensure that incorrect data wouldn't affect the result of measured unit. In the case when the data from specific sensor are used as a feedback for control system, it is necessary to modify (reconfigure) the control system to get the feedback data from another real or virtual sensor.

E. Multisensor data fusion

This layer serves to join data from multiple sources (real or virtual sensors) to create one more robust and precise result than by using just one sensor. For application of MSDF there are several ways, for more informations see [1] or [7].

The proper function of MSDF depends on few conditions, namely the noise in data from sensors should be uncorrelated white noise, median of difference between measured and real values should be close to zero and data from faulty sensors must be eliminated before entering MSDF.

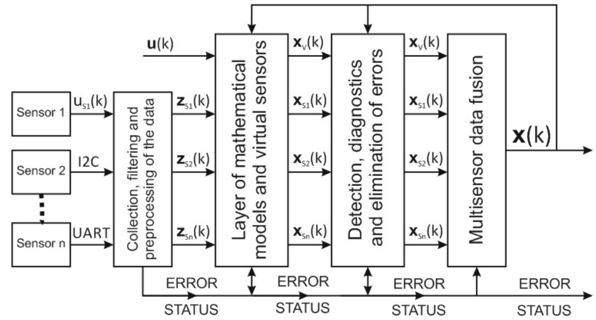

Fig. 2. Block diagram of sample diagnostics.

F. Development and construction of new mobile robots

During last year were developed and constructed several mobile robots for robotic soccer category MiroSot V2 based on the prototype from the past [2]. These MR are more accurate, reliable, lighter, compact and durable than prototype. There was also developed and constructed tracked mobile robot TrackBot which is controlled by Arduino board with custom made sensor and communication shield.

IV. Future Research

Future research will be focused on creating of the algorithms for every layer of proposed diagnostics system. After this phase will follow testing of the created algorithms on the real models of mobile robots, which will consists of three parts:

1) Off-line testing of algorithms and creating of mathematical model based on measured data.
2) On-line testing of algorithms using mobile robot as a remote agent.
3) On-line testing of algorithms with their execution on mobile robot's control system.

Testing of the algorithms of diagnostics will be performed on the mobile robots for robotic soccer category MiroSot V2 and on tracked MR TrackBot.

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