Microelectronics Reliability 55 (2015) 671–678

Contents lists available at ScienceDirect

Microelectronics Reliability

journal homepage: www.elsevier.com/locate/microrel

# Extended Sensor Reliability Evaluation Method in multi-sensor control systems

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A R T I C L E  I N F O

*Article history:*
Received 14 August 2014
Received in revised form 14 November 2014
Accepted 20 November 2014
Available online 6 December 2014

*Keywords:*
TULCOEMPA
Truck recognition
Sensor
Credibility coefficient
Structural health monitoring
Measurement system

A B S T R A C T

This article discusses a reliability evaluation method of sensors in multi-sensor control systems. Based on performed analysis and research work a universal method for the credibility evaluation of information from sensors was developed. The purpose of this method is to estimate a level of effectiveness of sensors, assign a proper weight to them during the voting process and utilization in multi-sensor control systems as a decision unit. The Sensor Reliability Evaluation Method for estimation of credibility coefficients processes results of a decision module, which, on the other hand, uses credibility coefficients evaluation of participating voters to reach a right verdict. In this case, the voting process takes a form of a weighted voting system. The method can be also used to identify sensors with some malfunctions. When a sensor reliability falls to 0 or other declared value an alarm signal can be generated. In order to forward the tests of the Sensor Reliability Evaluation Method a simulation was proposed. Presented results verify assumptions of described method and show high effectiveness of this solution.

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## 1. Introduction

During a research, in many cases, there is need to estimate the state or behavior of an object influenced by many factors. Investigation of the relationships between them requires model development or, if possible, making an experiment. On this basis it is possible to determine what is happening with the object at some precise moment. A wide range of methods and tools used to analyze information from multiple sources during an experiment let us also predict what will happen with the object in the future.

There are more and more solutions, which involve more than one kind of a sensor to investigate the same phenomenon and/or increase the capabilities of intelligent systems. For example, a gyroscope and an accelerometer can be used to determine in which position, horizontal or vertical, an object is. But to increase precision it is necessary to use data from both sensors [2]. Those types of systems are used among others to acquire the most accurate data or to evaluate which of the available sources of information are the most reliable under given conditions and circumstances. Additional advantages gained through the synergistic use of multisensory information are that the information can be obtained in less time and at a lesser cost [3]. Implementation of multiple sensors requires appropriate processing or integration of input data. In many cases it is linked with target detection, pattern recognition, safety monitoring, etc. Commonly, a decision has to be made on whether or not to accept an hypothesis. In cases like this, one of schemes to determine and improve reliability of an output can be a voting process. Depending on a desired effect, it is possible to use one of the many well-known types of voting systems [4,5].

In the TULCOEMPA project [6] there is an issue whose possible solution involves the discussed topics. Independent modules will be identifying appearance of a specified event using different methods. The system modules, equipped with various types of sensors, based on an information from different sources should generate signal when the event is detected. A decision unit has to consider each of those signals and take (or not) a suitable action. Unfortunately, communication with the modules is limited and there is not any confirmation that the modules work properly.

## 2. TULCOEMPA

In the context of the Swiss-Polish cooperation in research and development of innovative methods for monitoring in the civil engineering infrastructure, the Lodz University of Technology (TUL) and Empa[1] carry out multidisciplinary project entitled "*Innovative Structural Health Monitoring in Civil Engineering Infrastructure Sustainability*" (TULCOEMPA). The basis of the project is the pioneer

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http://dx.doi.org/10.1016/j.microrel.2014.11.016
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worldwide usage of the innovative strengthening method of a selected bridge (located in Szczercowska Wies) using unanchored prestressed carbon fiber reinforced polymer (CFRP) laminates. Reliability of this new technique will be confirmed by a long-term monitoring of the facility and any additional environmental influences (temperature and humidity) as well as static and dynamic effects on the object. Monitoring will be realized with utilization of a multi-point measurement system composed of a different sensor network, transducers, nodal points, a base station with the GSM modem and a computer system for collecting, processing and data coding. In addition, a lack of proper infrastructure in the mentioned localization enforces usage of solar and wind energy harvesters. As a consequence, particular attention is paid to the energy efficiency of the system [6].

The measurement data, which will be collected constantly by the measurement system, requires selection. To achieve that, utilization of a specialized system which recognizes weight, speed and number of vehicles crossing the bridge was proposed. In terms of the project, the Truck Recognition System will cause the limitation of irrelevant information. The solution consists in triggering a measurement only in a situation when the investigated bridge is crossed by a vehicle heavy enough to affect the structure. This approach will also significantly reduce energy consumption by putting particular elements of the measurement system and communication modules into standby mode.

### 2.1. Truck Recognition System

One of the main tasks in the TULCOEMPA project is a development of the Truck Recognition System (TRS). Vehicles approaching to the supervised object will be monitored to recognize the ones with a total mass over 3.5 tons. After detection of such a vehicle, the TRS will trigger the Structural Health Monitoring System [10,11]. Block diagram of the Truck Recognition System is presented in Fig. 1.

There are various methods of a vehicle type verification. One of the most credible is weighting. However, it is an expensive solution. Especially when it comes to installation of a weighting system, which allows for weight measurement of moving objects [7]. In addition, it is not always acceptable or possible to install this type of system (for example in short-term monitoring in a city center). These are the reasons why it was decided to conduct studies to find the most relevant alternative solution. Among all of possible methods, it was chosen to implement an analysis of:

- magnetic field,
- sound,
- vibration,
- camera image.

A management unit of the Truck Recognition System will be an Open Multimedia Application Platform (OMAP). A dedicated software will be scanning general input–output ports and waiting for a detection signal from identification modules. These modules will be working independently of each other and other parts of the system. Each of them will be equipped with a sensor of one of the above-mentioned types and will generate a signal for the management unit only in a case of a suitable vehicle recognition.

Decision about triggering of the Structural Health Monitoring System will be made based on a voting system. The modules, after event detection, will inform the OMAP about this fact by setting their output pin to a high level logic state for a certain period of time. It will be interpreted as a vote for starting a measurement. At the same time, the identification modules which do not take any action maintain a low logic level at the output pin. It will be interpreted as a vote against starting the measurement. In the presented solution there will be only a one-way communication between the management unit and the identification modules.

### 2.2. Structural Health Monitoring System

The Structural Health Monitoring System will operate in two modes. It makes it possible to observe the effect of both static and dynamic phenomena influences on the bridge structure. During a normal operation a strain will be measured with very low frequency. The investigation of the dynamic load influence on the

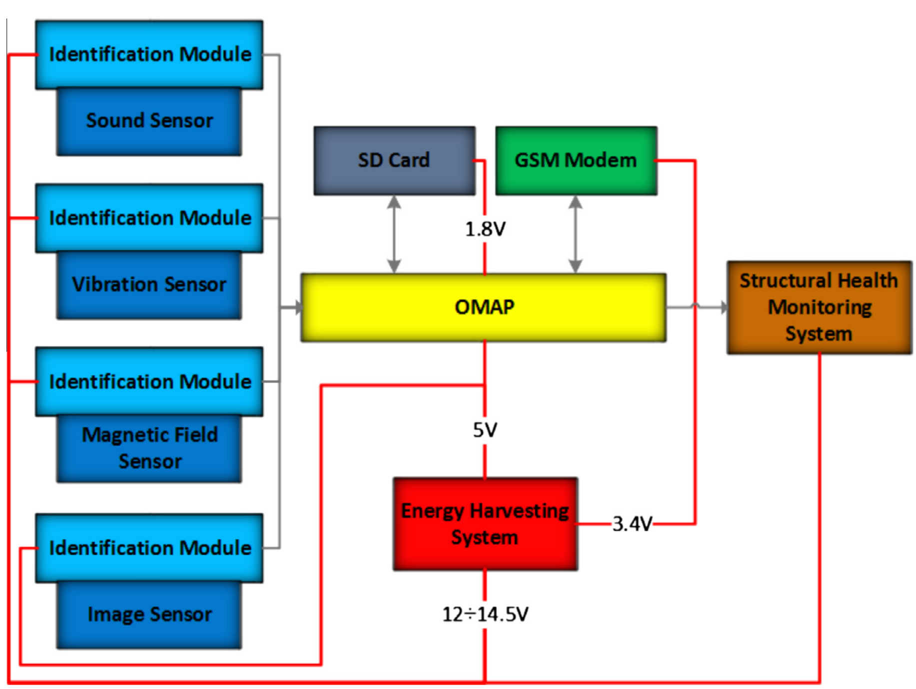


**Fig. 1.** Block diagram of the Truck Recognition System with the Energy Harvesting System.

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