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Assisting the design of sensor and information fusion systems

Uwe Mönks[a,]*, Henning Trsek[a], Lars Dürkop[a], Volker Geneiß[b], Volker Lohweg[a]

[a]inIT – Institute Industrial IT, Ostwestfalen Lippe University of Applied Sciences, Liebigstr. 87, 32657 Lemgo, Germany
[b]Fraunhofer ENAS, Warburger Straße 100, 33098 Paderborn, Germany

Abstract

The increased deployment of information technology for information processing, extensive networking, and system/environment monitoring using sensor and information fusion systems are essential characteristics of cyber-physical systems. They allow an autonomous recognition and evaluation of the system's status leading to autonomous reactions improving or maintaining the status to operate adaptively, robustly, anticipatory, and user-friendly. Assisting the operator in handling such complex systems is rather important and requires self-configuration, self-diagnosis, and self-optimization capabilities. In this paper, a new assisted design methodology for sensor and information fusion systems is proposed. It is based on an innovative system architecture consisting of the information fusion system itself, intelligent adaptable sensors, and the communication architecture of the "Intelligent Technical Systems OstWestfalenLippe" (it's OWL) Leading-Edge Cluster project "Intelligent Networking" providing an intelligent network for self-configuration and the required real-time data exchange.

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1. Introduction

Mechatronic systems are currently subject to change towards intelligent technical systems. Recent years were marked by an increased application of information technology for information processing, extensive networking, and system as well as environment monitoring using *sensor and information fusion* (SEFU/IFU) systems. Thus, these systems become more intelligent in order to assist the operator in handling such complex systems.

Industrial printing processes, like a newspaper printing process depicted in Fig. 1, are typical applications in which the printing presses evolve from mechatronic to intelligent technical systems. Today's state-of-the-art printing systems are driven by hundreds of actuators in the application, along with a number of sensors in the same order of

* Corresponding author. Tel.: +49-5261-7025993; fax: +49-5261-702312.
E-mail address: uwe.moenks@hs-owl.de

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magnitude to acquire different types of data. Hence, thousands of parameters are to be supervised for the determination of a printing press' state, but each set of supervised parameters changes from one printing press to another, because every press is highly customized. In every case, the sensors must be chosen and parameterized properly (e.g., regarding the appropriate measurement range). Furthermore, novel sensory concepts which turn actuators into sensors get introduced nowadays, e.g., the *Motor as Sensor* (MaS) concept [2].

Fig. 1. KBA Cortina newspaper offset printing press (with kind permission of KBA – Koenig & Bauer AG, Würzburg [1]).

Currently, it is due to the sheer number of data sources a complex, time consuming, and error-prone task to provide such systems manually with self-diagnosis abilities in form of a SEFU/IFU system: The system developer has to select, parameterize, operate, and validate problem-adjusted sensors and evaluation algorithms (for signal acquisition and preprocessing) as well as possible additional information sources. Since the number of possible solutions is most frequently too vast, the developer must be very experienced and will probably create a system based on already existing solutions which in only very few cases represents the optimal solution. Furthermore, setting up a communication network with real-time capabilities is also required comprising several manual steps. The project "Intelligent Networking" [4] deals with *self-configuration* of both the communication and the fusion system enabling *self-diagnosis* for *self-optimization*, hence autonomous recognition and evaluation of the technical system's status leading to autonomous reactions improving or maintaining the status.

This paper is structured as follows. Related work and existing research gaps are discussed in section 2. Based on these findings and the identified challenges of the introduction, an innovative information fusion system architecture and a corresponding design assistance are proposed in section 3. In section 4 the architecture and the design flow are preliminary evaluated in the context of a real setup. The paper is concluded in section 5 followed by a brief outlook towards future work.

2. Related work

The main challenges described in section 1–or similar challenges–have also been tackled by others. Work leading towards first partial solutions for intelligent technical systems can be categorized in the three classes, (i) *sensor and information fusion*, (ii) *intelligent sensors*, and (iii) *self-configuration of networks*, which are discussed accordingly.

Sensor and information fusion systems appear in various kinds. They all have in common, that the information originating from a number of homogeneous or heterogeneous sources are combined in order to reduce the data's amount and dimensionality, and obtain information of higher quality. Comprehensive overviews over information sources, general fusion system models, and theoretical backgrounds of the fusion algorithms provides [5].

For modeling the sensor information and carrying out the fusion, one of the evidence theories (probability, possibility, belief theory) as well as concepts derived from them are applied most likely [6], [7], [8]. We identified a hybrid approach consisting of a possibility theory-based information model and a belief theory-based fusion as beneficial for machine condition monitoring applications of various kinds [9], [10]. This fusion system, referred to as *multi-layer attribute-based conflict reducing observation* system MACRO, is capable of resembling the physical