Chapter 11

Sensor-Based Decision Making in Uncertain Context

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ABSTRACT

Decision makers, whether human or computer, using sensor networks to instrument information collecting necessary for decision, often face difficulties in assessing confidence granted to signals transmitted and received in the network. Several organizational (network architecture or nature, distance between sensors ...), internal (sensor reliability or accuracy ...) or external (impact of environment ...) factors can lead to measurement errors (false alarm, non-detection by misinterpretation of the analyzed signals, false-negative ...). A system-embedded intelligence is then necessary, to compare the information received for the purpose of decision aiding based on margin of errors converted in confidence intervals. In this chapter, the authors present four complementary approaches to quantify the interpretation of signals exchanged in a network of sensors in the presence of uncertainty.

INTRODUCTION

Automation and complexity of technological systems are experiencing a continuous growth. Therefore, decision making related to these systems is generally based on sensor networks which are becoming more complex and more heterogeneous. These sensors allow the collection of information concerning the system state by redundant measurements of the same variable or by a variety of measures of different variables. These multiplicity and heterogeneity of measures make the analysis of this information for decision-making complex and can lead to ambiguities or inaccuracies in the measurement (Daniel & Lauffenburger, 2014; Frikha & Moalla, 2014). Moreover, the confidence about the various sensors can be variable depending on their nature or their environment of use.

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Therefore, there is a real need for mechanisms to assist the decision based on multiple sensor inputs. These mechanisms have to formalize the collected knowledge in the light of the uncertainty inherent to the system. They also enable the knowledge fusion from multiple and/or heterogeneous sensors taking into account the physical structure of the system (e.g. the spatial position or the immediate environment of the sensor) (Chen, Jiang, Li, Gao, Xu & Ding, 2013; Flammini, Marrone, Mazzocca, Nardone & Vittorini, 2015; Mkrtchyan, Podofillini & Dang, 2015; Savic, Wymeersch & Zazo, 2013; Shang, Yang, Huang & Lyu, 2014). In addition, these mechanisms should take into account the quality and the quantity of the capitalized knowledge to provide the decision-maker (whether human or computer based) information concerning the knowledge uncertainty to make its decision easier and wiser.

In this context, this paper aims to present four complementary approaches to quantify the interpretation of signals exchanged in a network of sensors in the presence of uncertainty. The following section introduces concepts regarding the uncertain knowledge formalization. Then the four approaches are detailed and illustrated through case studies. Finally, the last section provides a formal outlook of these approaches compared to each other to identify strengths, weaknesses and the conditions of use of each approach.

INTEREST AND BACKGROUND ON MULTI SENSOR FUSION

Multi-sensor fusion can provide more accurate and reliable information than the information given by each sensor individually. In addition, data from multiple heterogeneous sensors have different degrees of uncertainty and confidence. Among the techniques of multi-sensor fusion, Bayesian methods and Theories of evidence such as the theory of Dempster-Shafer (DS), are commonly used to treat the degrees of uncertainty in the merge process. The research carried out takes place within this context. The multi-sensor fusion refers to the combination of sensory data from multiple sensors to provide more accurate and reliable information. The potential benefits of the multi-sensor fusion are redundancy and complementarity of the acquired information. The fusion of redundant information can reduce the overall uncertainty and thus helps to provide more accurate target information. Multiple sensors providing redundant information may also be used to increase reliability in the case of error or failure of the sensors. Additional information from multiple sensors provide environmental characteristics that would be impossible to collect using only each isolated sensor information.

Within the field of science and engineering, data imperfection requires the use of tools to define mechanisms for reasoning with partial knowledge and uncertain information. In the work of Dubois and Prade (2009) several types of imperfections are discerned:

- Incompleteness and inaccuracy are used to qualify the status of a data. It is said to be incomplete if it is impossible for the source to provide information regarding all or part of the aspects of a problem. Inaccuracy is considered to be a form of incompleteness as when the source provides an imprecise data, the resulting information is necessarily incomplete.
- Uncertainty applies when the source is unable to distinguish the veracity of a piece of information (that is to say whether the information is true or false). It therefore characterizes the extent of information compliance compared to reality. It is possible to distinguish two kinds of uncertainty. Random uncertainty is induced by the variability of an entity in a population and is the outcome