Evidential Network-Based Multimodal Fusion for Fall Detection

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ABSTRACT

The multi-sensor fusion can provide more accurate and reliable information compared to information from each sensor separately taken. Moreover, the data from multiple heterogeneous sensors present in the medical surveillance systems have different degrees of uncertainty. Among multi-sensor data fusion techniques, Bayesian methods and Evidence theories such as Dempster-Shafer Theory (DST) are commonly used to handle the degree of uncertainty in the fusion processes. Based on a graphic representation of the DST called Evidential Networks, we propose a structure of heterogeneous multi-sensor fusion for falls detection. The proposed Evidential Network (EN) can handle the uncertainty present in a mobile and a fixed sensor-based remote monitoring systems (fall detection) by fusing them and therefore increasing the fall detection sensitivity compared to the a separated system alone.

Keywords: Dempster-Shafer Theory, Evidential Networks, Fall Detection, Multi-Sensor Fusion, Remote Health Monitoring

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INTRODUCTION

It is well known that multi-sensor fusion can provide more accurate and reliable information to detect distress situation for elderly persons living in their home (Medjahed, Istrate, Boudy & Dorizzi, 2009). The potential searched benefits of multi-sensors fusion is the redundancy and complementarity of information. The fusion of redundant information can reduce the overall uncertainty. Moreover, the data from multiple heterogeneous sensors of the medical surveillance systems present varying degrees of uncertainty and confidence (Lee, Choi & Elmasri, 2009; Hong, Nugent, Mulvenna, McClean, Scotney & Devlin, 2009).

Among multi-sensor fusion techniques, we can find Bayesian methods (Becker & Naïm, 1999) and the Theory of Evidences based on the Dempster-Shafer theory (DST) (Dempster, 1976; Shafer, 1976) which are commonly used to process and estimate degrees of uncertainty in the fusion process (Hong, Nugent, Mulvenna, McClean, Scotney & Devlin, 2009). These theories are based on graphical representations: Bayesian Networks (Becker & Naïm, 1999) and Evidential Networks (EN) (Yaghlane, Smets & Mellouli, 2003; Hong, Nugent, Mulvenna, McClean, Scotney & Devlin, 2009; Cavalcante et al., 2011).

The introduction of Bayesian networks for knowledge representation and probabilistic inference has represented a breakthrough in the development of expert systems. However, the limitations of Bayesian networks as a formalism to deal with uncertainty issues consist in the assumption that all data (domain knowledge, accumulated evidence) can be represented by probability functions. In reality, this is not always possible, if the data amount is not sufficient (Benavoli, Ristic, Farina, Oxenham & Chisci, 2007).

Indeed the use of Bayesian statistical classifiers in the context of the remote medical monitoring (or “Télémédecine”) depends on the availability of adequate databases in order to model with reliability distress situations such as person’s falls, cardiac events (e.g. bradycardia, arrhythmia). Modeling a fall’s cinematic is not a straightforward task. Indeed the weight, the size and corpulence of the person have a substantial impact on the fall characteristics: in that respect soft falls are particularly difficult to detect. Therefore falls databases are very limited even inexistent due to the lack of records made in real situations.

To this aim, this article investigates and implements an Evidential Network to detect fall situations and estimate its uncertainty degree through a heterogeneous multi-sensors fusion (Lee, Choi & Elmasri, 2009; Hong, Nugent, Mulvenna, McClean, Scotney & Devlin, 2009). This network is also appropriate knowing, on one side, the lack of falls databases as here-above stressed, and on the other side, its property allowing direct inference mechanisms on input observations such as actimetric data (body’s movement, inclination) and vital data (cardiac frequency and fall index). The Evidential Networks are acyclic-directed graphs similar to Bayesian networks, but they use belief functions instead of probability functions. They are designed to handle uncertainty through the Dempster-Shafer Theory formalism.

In the following sections, first we describe the remote medical monitoring platform constituting our targeted application, then we review the basics of Dempster-Shafer theory, afterwards we develop the Evidential Network application to the remote medical monitoring context by explaining how we implement the network and estimate the degree of belief on a detected distress event such as a hard or a soft body’s fall. Finally we then provides provisional evaluation results and conclude on this work with perspectives.

REMOTE MEDICAL MONITORING PLATFORM

A remote medical patient’s monitoring system with alarm management (Medjahed, Istrate, Boudy & Dorizzi, 2009), if integrated in a smart home environment, can use the fusion results of several observation data such as actimetric and
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