A Research Review on Multisensor Data Fusion Techniques in Intelligent Health Care Monitoring

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Abstract: Introducing intelligence in a sensor based health care system provides smartness capabilities in monitoring human health conditions. Such systems particularly involving multiple sensors need abundant intelligence in collecting data, processing the information and presenting the data in more useful manner. Implementing multisensor data fusion (MSDF) techniques in health care monitoring (HCM), provides a powerful platform to combine raw sensory data resulting in smart information with cognitive capability and context awareness. Moreover, applying data fusion techniques in HCM improves system performance in terms of intelligence with smart decision making capability and further enhancing reliability in patient monitoring. The focus of this paper is to review the current research about the role of MSDF techniques in health care monitoring. It also discusses various key issues, challenges and methods of modeling data fusion techniques. Finally this paper proposes a suitable intelligent MSDF technique using fuzzy based algorithm for monitoring vital signs of patients in real time hospital environment.

Keywords: Health care; Multisensory data fusion; Intelligence; cognition; Patient monitoring; Fuzzy

I. INTRODUCTION

Atleast 44,000 people die in hospitals each year as a result of medical errors that could have been prevented [1]. Also, delayed detection of clinical deterioration results in high rates of aviodable in-hospital deaths [2]. The most commom errors include faulty systems, process and conditions which inhibit clinical attendants to notice emergency situations in prior. These errors can be avoided by designing health care monitoring systems incorporating intellegence at all stages to make it more safe and relaible. Over the past few years demand for more intelligent systems in health care has increased heavily. This demand leads to invention of new intelligent techniques that can be employed in health care monitoring systems for hospital and home based health care automation and monitoring applications [3].

In this context, Multisensor Data Fusion (MSDF) finds important place in incorporating intelligence in sensor based health care monitoring systems. With different biosensors employed to monitor the health condition of patients, it becomes more difficult to asses the overall condition of the patients. In such situations, MSDF techniques can be used to fuse the information from various biosensors in an intelligent manner to provide trustworthiness in health care monitoring. The term sensor data fusion means combining data obtained from different sensors such that the resulting information is better than if these sensors were used individually[4]. In addition, MSDF provides high confidence in data with high reliabilty, accuracy and redundancy for medical diagnosis and treatment [5]. Such intelligent health care systems with data fusion capabilities invloves combination of several smart sensors inorder to detect abnormal events or anomalies at an early stage, thus

facilitating clinical persons to take necessary prior actions. Rest of this paper is organised as follows. In Section II, a brief literature review in regard to the role of MSDF in HCM system is presented. Section III outlines the methods of MSDF techniques and suggests best suitable method for HCM. In section IV, a fuzzy based data fusion algoithm is proposed for designing an intelligent HCM system.Finally conclusion and future work is stated in Section V.

II. LITERATURE REVIEW

Several reviews related to intelligent techniques in health care monitoring platforms have been presented. Many such reviews focused on new technologies such as machine learning techniques, smart wearable sensors, wireless body sensors networks and distributed intelligence [6, 7, 8]. Considering intelligence techniques, this review presents the current scenario about the role of MSDF techniques in health care monitoring. The role of such techniques is to develop a model for identifying instabilities in patient's physiological conditions and to predict the adverse events in time [9].

Hyue Lee et al. proposed a pervasive health care architecture using data fusion, where several sensors collect vital signs and send data to the information systems (IS) using wireless communication [10]. This IS processes the data using MSDF technique to alert the clinical person about the patient's condition.

Abdelhamid Salih et al. reviewed the concepts of Ambient Intelligence (AmI) assisted health care's monitoring. Artificial intelligence and data mining approaches were used in AmI to implement sensor data fusion in health care monitoring [11]. Several sensor fusion models were developed based on performance, case based reasoning and cognitive diversity approaches to predict stress levels of patients [12, 13]. Sou-young Jin et al. and several other researchers designed different intelligent MSDF architectures for surveillance system for elderly care patients to detect physiological activities [14, 15, and 16]. Cicilia Leite et al. developed an intelligent fuzzy alert system to monitor and classify the vital conditions of ICU patients [17]. Nisarang Vyas et al. devised a Body Media FIT armband with MSDF technology for estimating energy expenditure in physiological parameters monitoring [18]. Carolina Zato et al. proposed a Health care Context Aware Computing (HCCAC) architecture using intelligent information fusion system capable of supervising and monitoring health care situation contexts [19]. Several probabilistic data fusion models using intelligent algorithm were proposed and developed for monitoring and predicting the vital signs of deteriorating patients [20, 21]. Henry W. Zheng proposed a MSDF for prosthetic control and suggested a new algorithm for motile fusion [22]. Hamid Medjahed proposed a telemonitoring system with MSDF capability using fuzzy logic rules to fuse the sensor outputs and alert the critical condition of patients [23].

Based on the literature review, it is observed that intelligent data fusion algorithms in patient health care system allows automation in monitoring vital signs and provides context information resulting in an expert system in medical diagnosis. Different MSDF techniques are discussed in the following sections and the best suitable method for health care applications is suggested.

III. MULTISENSOR DATA FUSION TECHNIQUES

Multisensor data fusion is the process of combining data or information obtained from heterogeneous sensors to produce more specific and unified data set or event [24]. According to Joint Directors of Laboratories (JDL), MSDF is defined as a "multi-level, multifaceted process of handling automatic detection, association, correlation, estimation and combination of information from several sources," [25]. MSDF technique selects useful information from various sensors, uses certain rules to combine those mutual information to provide the most reliable and accurate information for better

performance of the system [26]. Data level fusion, Feature level fusion and Decision level fusion are the three levels of MSDF.

Data level fusion refers to integrating raw data from sensors to provide subtle information. This method is not suited for real time applications as it suffers from long processing period. Feature level fusion deals with extraction of feature and pixel information from raw sensory data for further processing. This method is best suited for vision or image based sensors. Decision level otherwise called as Symbol level fusion obtains only specific information from sensors for processing. This method naturally inherits fault tolerance characteristics and results in better data integration. Decision level fusion can be well devised using Bayesian Inference theory, Dempster Schafer evidence theory, Artificial Neural networks and Fuzzy Inference system (FIS). Among all the methods mentioned, FIS finds a special place as it encompasses the ability to learn on its own and simulate the experience using knowledge base and rule base inference methods. Therefore FIS fits to be an excellent tool to distinguish and evaluate the data from heterogeneous sensors in MSDF based health care monitoring applications.

IV. PROPOSED WORK

This section describes FIS based Data Fusion Algorithm (DFA) that uses the vital sign data obtained from biosensors placed on patient's body. The proposed DFA performs fuzzification, Inferential and defuzzification process using knowledge base and rule base to produce crisp outputs, which can act as early warning mechanism in patient's vital sign monitoring system. The vital sign sensors considered are non-invasive Blood Pressure (BP) sensor, Heart Rate (HR) sensor and Body Temperature (BT) sensor. Let X, Y, Z represent data obtained from BP, HR and BT sensor respectively. The data acquired from each sensor at a given time can be represented as

$$X = \{x_1, x_2 \ldots x_n\},\ Y = \{y_1, y_2 \ldots y_n\} \text{ and } Z = \{z_1, z_2 \ldots z_n\}. \quad (1)$$

As shown in fig.1, next step is to calculate average and absolute values of the sensed sensory data. Monte Carlo computational algorithms can be well used for this purpose.

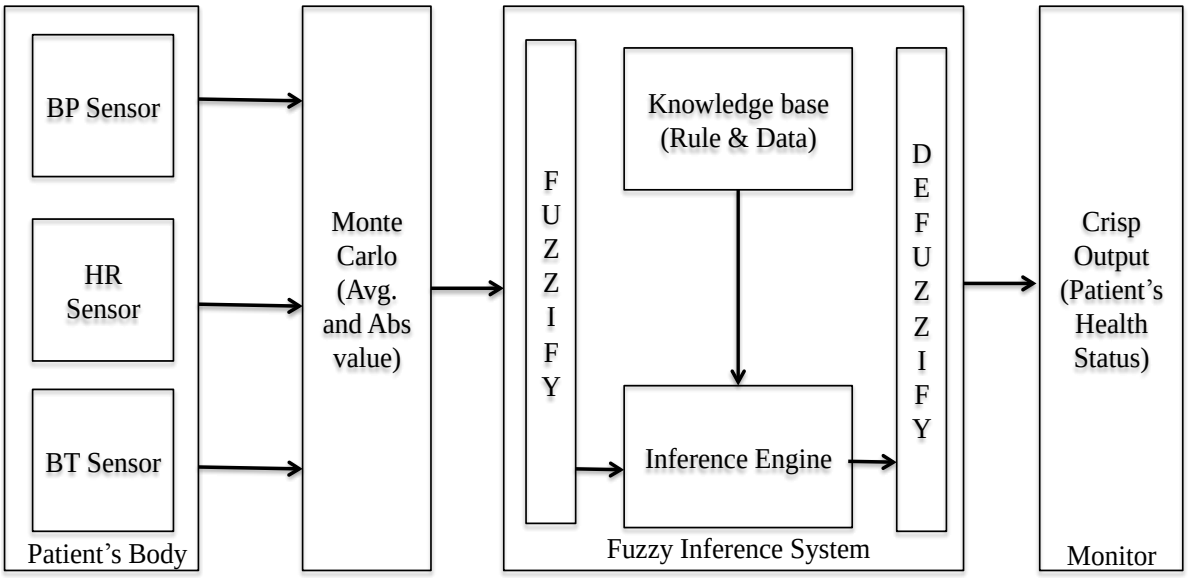

Figure 1 : Architecture of Fuzzy based Multisensor data fusion system.

The average value of first 'k' elements of 'X' is given by (2) in which the value of 'k' is not to be chosen too low or high.

$$\tilde{x} = \frac{1}{k}\sum_{i=1}^{k} x_i \qquad (2)$$

Similarly for other sensors too average values are formulated. Absolute value or crisp set of sensory data can be calculated as the difference between $\tilde{X}$ and each element of X. Hence crisp set is,

$$\tilde{x} = \{\tilde{x}_1, \tilde{x}_2 \ldots. \tilde{x}_n\}, \text{ Where } \tilde{x_i} = |x_i - \tilde{x}|. \qquad (3)$$

A. Fuzzification

Fuzzification refers to the process of converting crisp values into fuzzy linguistic variables or also referred as membership functions [27]. In our proposed algorithm BP, HR, and BT are fuzzy input variables and the probabilities of patient's health condition are regarded as output variables. Membership functions LOW, NORM, HIGH are graded with crisp values for each sensor respectively. The input variables can be graded using trapezoidal or triangular membership functions with crisp values varying between 0 and 1.

B. Fuzzy Inference System

A fuzzy inference engine maps fuzzy input sets into fuzzy output sets [28]. It employs rule base that mimics human decision-making. Mamdani type fuzzy inference system, which adapts if-then rules, can be well utilized to devise an expert knowledge in correlating input and output variables. In our proposed method there are 3 input variables BP, HR, BT and each 3 linguistic variables low, normal and high. Therefore the total number of rules obtained using several possible combinations would be 3^3=27. Table I shows a few possible combinations out of total 27 rules.

Table I. Examples of FIS rules of our proposed algorithm

IF					***THEN***
BP	***Operator***	***HR***	***Operator***	***BT***	***Probability***
Low	And	Low	And	Low	Very Critical
Low	And	Low	And	Normal	Critical
Normal	And	Normal	And	High	Normal
Normal	And	Normal	And	Normal	Very Normal
High	And	High	And	High	Very Critical

C. Defuzzification

Defuzzification is the final phase of fuzzy system, which transforms fuzzy inferred results into crisp values. In or proposed DFA algorithm, defuzzification role is to transform final inference results into the probability of health conditions of the patient. The output crisp values critical, very critical, normal, very normal are the four probable conditions of the patient. Centroid method of defuzzification can be well utilized in obtaining output crisp values, stated by formula given in (4).

$$H^{*}H^{\star} = \frac{\int \mu_{A\,(H)} * H dH}{\int \mu_{A\,(H)}\, dH} \qquad (4)$$

The term μ_A in (4) is the new membership function for all the probability after aggregation of outputs with respect to the inputs. H* refers to final result of the proposed data fusion algorithm. The proposed architecture can therefore be used to implement FIS based data fusion algorithm for monitoring vital signs of the patients in real time hospital environment.

V. CONCLUSION AND FUTURE WORK

The aim of this paper is to provide a review on current role of MSDF techniques in sensor based intelligent health care monitoring. This paper is an attempt to reveal the classifications of data fusion methods and how these methods are chosen based on their characteristics to suit health care applications. Further, this paper suggested best suitable MSDF technique based on fuzzy inference system to perform intelligent monitoring of patient's vital signs in a hospital environment. This proposed intelligent system can facilitate medical professionals to monitor vital signs of patients and can act as an aid to detect abnormal conditions in prior.

Our future work is to develop a prototype of wireless health care monitoring system and incorporate the proposed fuzzy based intelligent MSDF technique to monitor vital signs of patients in hospital environment. Our further works extends to integrating more number of wireless smart sensors from multiple patients using wireless sensor networking and applying MSDF technique to create a wireless intelligent health care system.

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