ADAPTIVE SENSOR FUSION METHOD FOR AGRICULTURAL AND ENVIRONMENTAL MONITORING

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ABSTRACT

Environmental and agricultural monitoring involves continuous observation in areas such as grains crop, in order to evaluate changes in the environment. Wireless Sensor Networks may be employed in this context allowing the use of several sensors to collect data. The aim is to present the design of an Adaptive Sensor Fusion method appropriate for agricultural and environmental monitoring applications through Wireless Sensor Networks. The proposed method integrates Adaptive Technology mechanisms to enable it to dynamically adapt to changes that may occur in real time resulting in better data analysis and processing by fusion techniques and, consequently, in a data series with better quality for decision-making systems. The method focuses on sensor fusion in order to obtain inferences about the environment in a complementary way, trying to infer information from different sensor sources (different properties) in a dynamically changing environment. The employment of sensor fusion methods is to provide agricultural and environmental monitoring a better understanding of the place under observation. Sensor Fusion methods can abstract information from raw data collected by the sensor nodes in order to show the environment real condition. The Adaptive Sensor Fusion method proposed can be set to behave adaptively to input stimuli and adjust to changes in real time seeking better results for decision-making systems. By the application of the method proposed, the error rate is expected to be reduced by making applications based on these data more reliable.

Keywords: Wireless Sensor Network, Adaptive Technology, Precision Agriculture, Water Quality.

INTRODUCTION

Wireless Sensor Network (WSN) is a sub-class of ad hoc networks and it has been used widely in two application categories: monitoring (closed and open environments, health and wellness, process automation, seismic and structural) and location (objects, animals, people and vehicles) (GAJBHIYE; MAHAJAN, 2008).

In the case of agricultural environment applications, its use provides better coverage and control of the monitored area, because sensor nodes can be spread out in the field, covering large areas. The requirement of large areas cover requires large scale networks composed of many sensor nodes that monitor the environment continuously or at predetermined time intervals, consequently resulting in a large volume of data collected.

In environmental monitoring applications, for example, evaluating the water quality of rivers can be made by WSN, which allows a faster response than the conventional way, which requires manual collection of water samples and laboratory analysis. Hence, one of the advantages in using WSN is the possibility of real-time monitoring, allowing to take action more promptly to problems encountered.

MOTIVATION

Sensor Fusion (SF) mechanisms can be employed to evaluate a large volume of data collected by WSN. According to Llinas and Hall (1997), sensor fusion is the combination of data from various sensors (with related information provided by associated databases) to obtain better accuracy and more specific information than the inferences achieved by using data from a single sensor. In agricultural monitoring, environmental changes occur dynamically during the data collection process, the Sensor Fusion mechanism being appropriate to adapt to these changes; consequently, fine results can be achieved.

Thereby, this work proposes the design of a SF model with characteristics of an Adaptive Device (AD), designed in accordance with the concepts of Adaptive Technology (AT). Neto (2001) defines an AD as a formalism that has the ability to dynamically change its topology and its behavior autonomously, self-modifying to detect situations that require changes in response to input stimuli.

This research focus is the design of an Adaptive Sensor Fusion Model (ASFM) responsible for evaluating and analyzing data collected by WSN in agricultural and environmental monitoring applications, providing reliable information to decision-making systems, trying to reduce error rates in these systems. The proposal to provide adaptively to a sensor fusion model aims to contribute adjusting its operation rules in accordance with the changes that may occur in the environment or at the sensor network, such as failures or loss of some sensors. Thus, the lack of data from sensors that may fail temporarily should have the minimum impact possible on the monitoring purpose.

Another intention of this model is the use of sensor fusion to infer information that could not be collected from the raw data, using a fusion of different variables. This new information will aid decision making, be it in the activation of some action or issue alerts, for example.

METHODS

The ASFM seeks to implement sensor fusion at different levels of data processing. As shown in Figure 1 (an example of WSN configuration), nodes are organized in clusters, the cluster head holding a first level of SF. At point A, SF mechanisms would be employed in order to improve data quality, eliminating false readings, estimating values in temporary failure of any sensor, and aggregate data to reduce traffic to the root cluster head. Examples of mechanisms to be considered: Maximum Likelihood Estimator, Least Squares, Kalman Filter. At point B, the root cluster head accounts for implementing the data merger to infer and abstract information to improve the performance of the identification process of the present situation, and to support decision making. Examples of mechanisms to be used have been: Bayesian inference, Dempster-Shafer Theory, Fuzzy Logic and Neural Networks.

In Figure 1, each cluster consists of five sensor nodes and one cluster head, responsible for sensor fusion to improve the quality of collected data. The root accounts for inference, and can communicate with other mobile devices or servers.

AT can work both point A and point B, making the input selection of SF mechanism and dynamically adjust actions in accordance with the available sensors and other environmental changes, as shown in Figure 2.

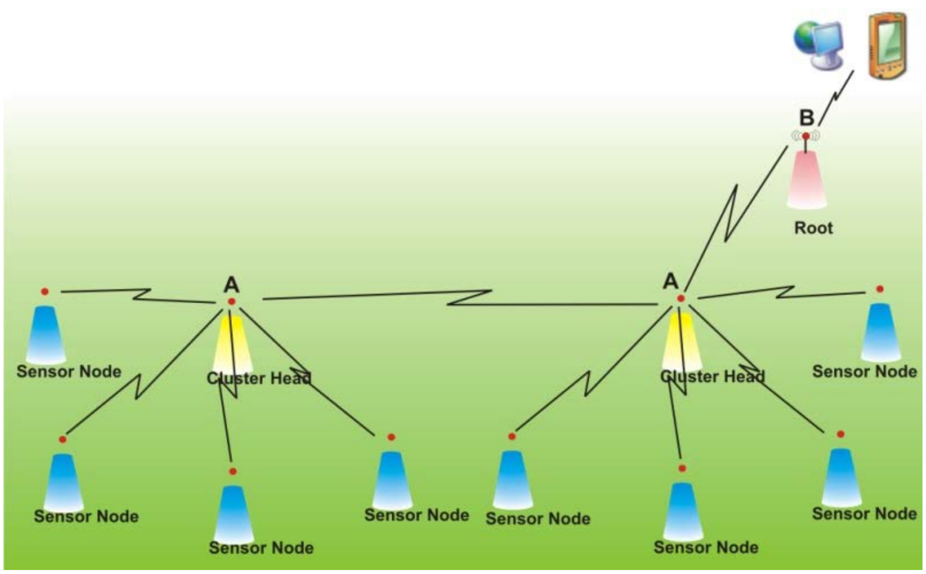

Figure 1 - Adaptive Sensor Fusion Model: initial proposal. Based on (BITENCORT, 2007).

The model is based on fusion models oriented action, such as the Waterfall Model. The complexity of the subtasks is increased, from the sensor data to the feature extraction and decision making (RAOL, 2009).

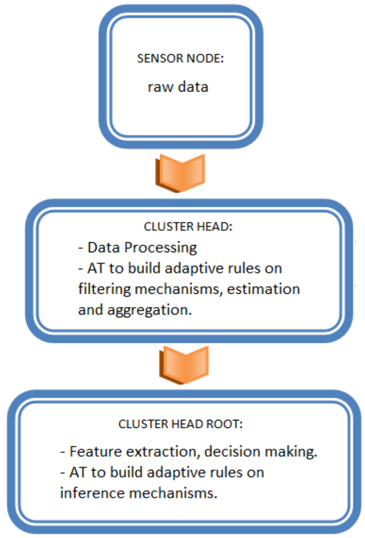

Figure 2 - Proposed model main components.

RESULTS

The proposed model is still at an early stage of defining which SF mechanisms AT to use. The next study involves the detailing of the model, as well as defining mechanisms for TA to be included in the mechanisms of SF seeking better data quality. The intention is to conduct an experiment in environmental monitoring, evaluating water quality in rivers, offering a real-time monitoring, exploring the application of SF to generate new levels of water quality, based entirely on data collected by sensors in a WSN.

Some applications in the literature show the use of SF mechanisms in agricultural equipment (instrumentation), and it is not easy to find SF applications with data collected via WSN. Sun et al. (2007) developed a SF system that, using data collected by sensors, allows estimating soil water retention, mechanical strength and electrical conductivity in real-time monitoring. The authors state that this system, combined with location data (GPS), can provide further valuable information on soil properties for the AP (SUN; ZENG, ZHU, 2007). Some examples of SF mechanisms applications, together with WSN are presented in precision irrigation, as the experiment described by Xiong and Wang (2009). In their experiment, the authors present the application of certain technologies in WSN for precision irrigation based on the acoustic signals monitoring of water stress in the crop using SF to improve data accuracy and to ensure reliable decision making.

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CONCLUSION

The need of computational methods, such as Sensor Fusion for the data processing generated by sensor nodes from a WSN arises, among other factors, from the demand for information. Based on reliable information, decision-making by managers may follow more elaborate technical criteria. SF mechanisms can be applied to data collected by the WSN in order to reduce data inconsistency. The environmental damage generated by agricultural production, especially water contamination, needs monitoring tools that allow a continuous, faster and more effective automated decision making system. WSN has thus great potential when used in solutions for environmental quality evaluation.

The Adaptive Sensor Fusion Model proposed for water quality monitoring is intend to infer the possibility of new quality indices that use fewer sensors, low cost (less variable) providing a similar level of reliability of existing IQA.

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