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MONITORING OF TOXIC GAS IN WATER BY USING DATA FUSION METHOD

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INTRODUCTION

Water is a limited resource and is essential for agriculture, industry and for creatures’ existence on earth including human beings. Water quality monitoring is essential to control the physical, chemical and biological characteristics of water. It provides information about the current health of the water body, whether the water body meets the designated use and how it has changed over time.

Information gathered can be used to suggest that the water body requires improvement to meet its designated use and lead to actions to protect and restore the health of the water body. For example, drinking water should not contain any chemical materials that could be harmful to health; water for agricultural irrigation should have low sodium content; water for industrial uses should be low in certain inorganic chemicals. In addition, water quality monitoring can help with water pollution detection, discharge of toxic chemicals and contamination in water.

Temperature, pH and turbidity are the typical parameters collected in river/lake water quality monitoring systems. The goal of this project is to design and manage a Wireless Sensor Network (WSN) that helps to monitor the quality of water with the help of information sensed by the sensors immersed in water, so as to keep the water resource within a standard described for

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domestic usage and to be able to take necessary actions to restore the health of the degraded water body. A WSN featuring a high power transmission Zigbee based technology together with the data fusion method is chosen because of the simplicity of its deployment, low cost, minimal power consumption, reliability and high scalability. To get the optimal result, both sensors are usually combined. Because, the result of both measurements contain error. A special method has to be used to combine the results. The commonly used method is fusing those two measurements so it will produce the best desire estimation.

**DATA FUSION**

Data fusion is the process of integration of multiple data and knowledge representing the same real-world object into a consistent, accurate, and useful representation. Fusion of the data from 2 sources (dimension #1 & #2) can yield a classifier superior to any classifiers based on dimension #1 or dimension #2 alone.

Data fusion processes are often categorized as low, intermediate or high, depending on the processing stage at which fusion takes place. Low level data fusion combines several sources of raw data to produce new raw data. The expectation is that fused data is more informative and synthetic than the original inputs.

For example, sensor fusion is also known as (multi-sensor) data fusion and is a subset of information fusion. In applications outside of the geospatial domain, differences in the usage of the terms Data integration and Data fusion apply. In areas such as business intelligence, for example, data integration is used to describe the combining of data, whereas data fusion is integration followed by reduction or replacement.

Data integration might be viewed as set combination wherein the larger set is retained, whereas fusion is a set reduction technique with improved confidence.

**SENSOR FUSION**

Sensor fusion is the combining of sensory data or data derived from sensory data from disparate sources such that the resulting information is in some sense better than would be possible when these sources were used individually. The term better in this case can mean more accurate, more complete, or more dependable, or refer to the result of an emerging view, such as stereoscopic vision (calculation of depth information by combining two-dimensional images from two cameras at slightly different viewpoints).

The data sources for a fusion process are not specified to originate from identical sensors. One can distinguish direct fusion, indirect fusion and fusion of the outputs of the former two. Direct fusion is the fusion of sensor data from a set of heterogeneous or homogeneous sensors, soft sensors, and history values of sensor data, while indirect fusion uses information sources like a priori knowledge about the environment and human input.

![Figure 1: Mutisensor Fusion](image)
Sensor fusion is also known as (multi-sensor) Data fusion and is a subset of information fusion.

Sensory fusion is simply defined as the unification of visual excitations from corresponding retinal images into a single visual perception a single visual image. Single vision is the hallmark of retinal correspondence Double vision is the hallmark of retinal disparity.

**SYSTEM’S FUNCTION DESIGN**

The system consists of PIC controller, because there is no need of external ADC is connected to the system. The analog and digital signal interface can be easily achieved by the PIC controller itself. The zigbee based wireless sensor network is implemented in this system. The sensors such as gas sensor, temperature sensor, humidity sensor, color sensor, carbon dioxide sensor are used to monitor the necessary indicators in the water. The data from various sensors are collected and fused together to form a single output. This fusion method can be achieved by using Dempster-Shafer Theory (DST). In terms of data transmission, our design can achieve wired communication through RS232 serial communication and wireless communication through zigbee module. Therefore we can choose it for industrial application environments.

The functional block diagram for water quality monitoring by using data fusion method is given in fig.2.

The fusion of sensor data can be achieved by using Dempster-Shafer Theory. This theory is based on the measurement of the data from sensor. The output of the sensor data gives the priority to the maximum weight of the sensor measurement. At each time step, the algorithm propagates both a state estimate and an estimate for the error covariance. It is also known as priori estimates. The measurement provides the necessary prior information to use the algorithm. The fused output of sensor data can be simulated by using labview software. The RS232 is the serial cable used to interface the system with PC.

**IMPLEMENTATION OF DEMPSTER-SHAFER THEORY**

The theory of belief functions, also referred to as evidence theory or Dempster–Shafer theory (DST) is a general framework for reasoning with uncertainty, with understood connections to other frameworks such as probability, possibility and imprecise probability theories. The theory allows one to combine evidence from different sources and arrive at a degree of belief (represented by a mathematical object called belief function) that takes into account all the available evidence.
In a narrow sense, the term Dempster–Shafer theory refers to the original conception of the theory by Dempster and Shafer. However, it is more common to use the term in the wider sense of the same general approach, as adapted to specific kinds of situations. In particular, many authors have proposed different rules for combining evidence, often with a view to handling conflicts in evidence better. The early contributions have also been the starting points of many important developments, including the Transferable Belief Model and the Theory of Hints.

The monitoring equipment installation is shown in the fig.3.

![Figure 3: Schematic diagram of monitoring equipment installation](image)

A. FORMAL DEFINITION

Let \( X \) be the universe: the set representing all possible states of a system under consideration. The power set

\[ 2^X \]

is the set of all subsets of \( X \), including the empty set. For example, if:

\[ X = \{a,b\} \]

Then

\[ = \{ \emptyset, \{a\}, \{b\}, X \} \]

The elements of the power set can be taken to represent propositions concerning the actual state of the system, by containing all and only the states in which the proposition is true. The theory of evidence assigns a belief mass to each element of the power set. Formally, a function

\[ m : 2^X \rightarrow [0,1] \]

is called a basic belief assignment (BBA), when it has two properties. First, the mass of the empty set is zero:

\[ m(\emptyset) = 0 \]

Second, the masses of the remaining members of the power set add up to a total of 1:

\[ \sum_{A \in 2^X} m(A) = 1 \]

The mass \( m(A) \) of \( A \), a given member of the power set, expresses the proportion of all relevant and available evidence that supports the claim that the actual state belongs to \( A \) but to no particular subset of \( A \). The value of \( m(A) \) pertains only to the set \( A \) and makes no additional claims about any subsets of \( A \), each of which have, by definition, their own mass.

From the mass assignments, the upper and lower bounds of a probability interval can be defined. This interval contains the precise probability of a set of interest (in the classical sense), and is bounded by two non-additive continuous measures called belief (or support) and plausibility:

\[ bel(A) \leq P(A) \leq pl(A) \]

The belief \( bel(A) \) for a set \( A \) is defined as the sum of all the masses of subsets of the set of interest:
The plausibility $\text{pl}(A)$ is the sum of all the masses of the sets $B$ that intersect the set of interest $A$:

$$\text{pl}(A) = \sum_{B \subseteq A \neq \emptyset} m(B)$$

The two measures are related to each other as follows:

$$\text{pl}(A) = 1 - \text{bel}(\overline{A})$$

And conversely, for finite $A$, given the belief measure $\text{bel}(B)$ for all subsets $B$ of $A$, we can find the masses $m(A)$ with the following inverse function:

$$m(A) = \sum_{B \subseteq A} (-1)^{|A - B|} \text{bel}(B)$$

where $|A - B|$ is the difference of the cardinalities of the two sets.

It follows from the last two equations that, for a finite set $X$, you need know only one of the three (mass, belief, or plausibility) to deduce the other two; though you may need to know the values for many sets in order to calculate one of the other values for a particular set. In the case of an infinite $X$, there can be well-defined belief and plausibility functions but no well-defined mass function.

**DEMPSTER’S RULE OF COMBINATION**

The problem we now face is how to combine two independent sets of probability mass assignments in specific situations. In case different sources express their beliefs over the frame in terms of belief constraints such as in case of giving hints or in case of expressing preferences, then Dempster’s rule of combination is the appropriate fusion operator. This rule derives common shared belief between multiple sources and ignores all the conflicting (non-shared) belief through a normalization factor. Use of that rule in other situations than that of combining belief constraints has come under serious criticism, such as in case of fusing separate beliefs estimates from multiple sources that are to be integrated in a cumulative manner, and not as constraints. Cumulative fusion means that all probability masses from the different sources are reflected in the derived belief, so no probability mass is ignored.

Specifically, the combination (called the joint mass) is calculated from the two sets of masses $m_1$ and $m_2$ in the following manner:

$$m_{1,2}(\emptyset) = 0$$
$$m_{1,2}(A) = (m_1 \oplus m_2)(A)$$

where

$$K = \sum_{B \subseteq A} m_1(B)m_2(C)$$

$K$ is a measure of the amount of conflict between the two mass sets.

**INTERFACING OF HARDWARE WITH SOFTWARE**

The RS 232 is the serial cable used to connect the hardware with PC. The labview simulation

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software is used to simulate the data from sensors.

MAX-232 is primary used for people building electronics with an RS-232 interface. Serial RS-232 communication works with voltages (-15V to -3V for high) and (+3V to +15V for low) which are not compatible with normal computer logic voltages.

To receive serial data from an RS-232 interface the voltage has to be reduced, and the low and high voltage level inverted. In the other direction (sending data from some logic over RS-232) the low logic voltage has to be “bumped up”, and a negative voltage has to be generated.

The MAX232 is a dual driver/receiver that includes a capacitive voltage generator to supply EIA 232 voltage levels from a single 5v supply. Each receiver converts EIA-232 to 5v TTL/CMOS levels. Each driver converts TLL/CMOS input levels into EIA-232 levels.

**APPLICATION IN WATER QUALITY MONITORING**

With gradual improvement of people’s environmental protection consciousness, environmental monitoring has become an important direction of WSN application in IoT environment. Environmental monitoring has higher requirements for equipment and more complex environmental information is needed. Water environmental information should be collected water environmental information as much as possible on the kinds and the accuracy. But the environmental monitoring equipment used now has many disadvantages, such as bulkiness, complex design, and high cost, etc. It is not suitable for monitoring conducted by small organizations or individual. In terms of water quality monitoring, it mainly involves the following aspects.

1) We can monitor water purity, internal and external water temperature, concentration and light intensity on the surface of water in real time.

2) Multiple nodes are distributed in different areas of pond.

3) Low power battery provides power for the system.

**CONCLUSION**

This project describes a sensor interface for industrial WSN by data fusion method. The system can collect sensor data intelligently. It was designed based on Dempster Shafer Theory (DST) by combining with PIC and the application of wireless Sensor Networks. It is very suitable for real-time and effective requirements of the high-speed data acquisition system. The application of data fusion greatly simplifies the design of peripheral circuit, and makes the whole system more flexible and extensible. Application of Dempster Shafer Theory enables the system to combine sensor data intelligently. Different
types of sensors can be used as long as they are connected to the system. Main design method of the sensor interface device is described in this project. Finally, by taking real-time monitoring of water environment by data fusion method as an example, we verified that the system achieved good effects in practical application.

Nevertheless, many interesting directions are remaining for further researches. For example, the Dempster Shafer Theory (DST) can be perfected and the function of spreadsheet should be expanded. It will have a broad space for development in the area of WSN.

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