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Intelligent Fuzzy Event Detection for Border Monitoring in Noisy Environment

By

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Abstract:

The use of wireless sensor networks to protect sensitive facilities or international borders has recently attracted more and more attention [1-3]. It has become a high-priority issue in many countries. In addition to the physical fences built for stopping illegal intruders from crossing the border, smart fencing has been proposed to extend intrusion detection capabilities. Event detection is a central component in numerous wireless sensor network (WSN) applications [4, 5]. In spite of this, the area of event description has not received enough attention. The majority of current event description approaches rely on using precise values to specify event thresholds [6, 7]. However this crisp values cannot adequately handle the imprecise sensor readings.
Therefore, In this paper, Event-detection algorithm based on two layers fuzzy Logic system (FLS) is used, which conveys the idea of using fuzzy values instead of crisp ones which significantly improves the accuracy of event detection. Each sensor node has an acoustic signal sensor and one-axis acceleration sensor to improve the precision of the detection system, as well as reducing false alarm rate specially in a noisy environment.

Keywords:
Sensor Network, Fuzzy Logic System, and Event Detection

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1. Introduction:

Wireless sensor network (WSN) consist of large number of sensor nodes deployed densely in the environment. The deployed sensor nodes collect data and disseminate the collected data towards sink[4]. This concept can be used for many crucial applications where manual involvement of humans is difficult.

One of the hottest applications of WSN nowadays is in Border Monitoring [2] [8]to protect sensitive facilities or international borders as shown in Fig. 1. Also one of the most problems in border monitoring is to observe any slowly moving or stopped vehicles in the wayside, which may be used in the bombing of military vehicles or Terrorist acts. Deploying such sensor nodes require the use of appropriate and suitable control system and sensors as well. Therefore, a suitable control technique is needed to describe invasion alarm level events in a way that sensor nodes can understand them. Most previous work on event detection in WSNs uses precise, also called crisp, values to specify the parameters that characterize an event [5, 9, 10]. However, sensor readings are not always precise. In addition, different sensors, even if located close to each other, often vary in the values they register. Therefore wrong decision will be taken which can be classified as a false alarm. The situation becomes even more convoluted because more than two sensor measurements are involved often be used to raise the precision of the event. This makes determining the precise event thresholds an extremely hard task which has led us to believe that using crisp values to describe WSN events is not the most suitable approach. Fuzzy logic, on the other hand, might be able to better address the problems that are challenging for crisp logic.

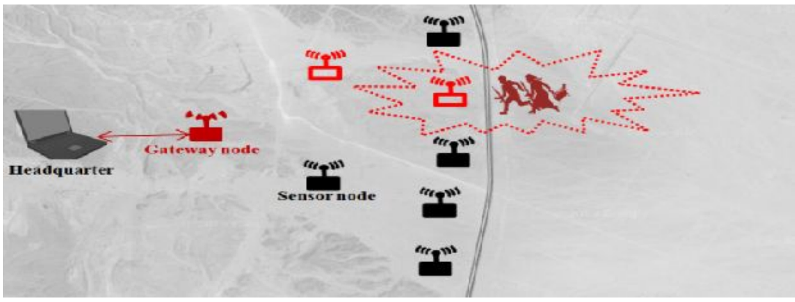

Fig. 1 Border Monitoring using WSN.

The Fuzzy Logic System (FLS), is known to be robust and has excellent immunity to external disturbances, can tolerate the unreliable and imprecise sensor readings, and much more intuitive and easier to use [4]. Our contribution is to design a FLS in a WSN node to detect the slowly moving or stopping vehicles in the wayside as shown in Fig. 2 , and tests the stability of the results even in the presence of a high Gaussian noise environment. This paper is organized as follows. In the next section, a briefly overview of fuzzy logic system is given., Event Detection algorithm and the reasons for chosen hybrid event detection algorithm will be then briefly discussed in section 3. In section 4, the proposed system design block diagram is introduced. The simulation results assuming Gaussian Noise in each of the two sensor input values to show the designed system response in such noisy environments are presented in section 5.

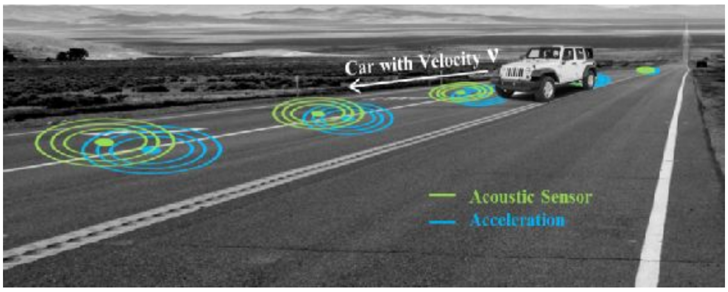

Fig. 2 Deployed Fuzzy Logic System in each WSN node along the wayside.

2. **Overview of Fuzzy Logic System**

2.1 Fuzzy System

The structure of a general FLS is shown in Fig. 3 [11]. First, the fuzzier converts the crisp input variables x ϵ X, where X is the set of possible input variables, to fuzzy linguistic variables by applying the corresponding membership functions. An input variable can be associated with one or more fuzzy sets depending on the calculated membership degrees. Second, the fuzzified values are processed by if-then statements according to a set of predefined rules derived from domain knowledge provided by experts. In this stage the inference scheme maps input fuzzy sets to output fuzzy sets. Finally, the defuzzifier computes a crisp result from the fuzzy sets output by the rules. The crisp output value represents the control actions that should be taken. The above three steps are called fuzzification, decision making, and defuzzification, respectively[12].

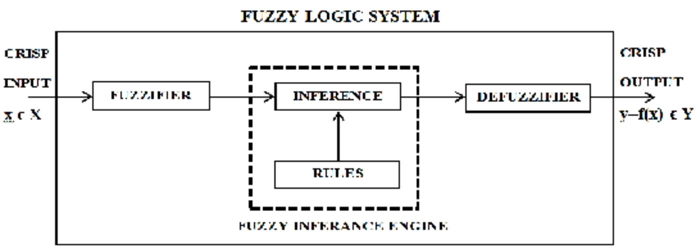

Fig. 3 The structure of a fuzzy logic system.

2.2 Fuzzy Rules

A typical fuzzy rule assumes the form of a conditional statement as follows: IF (a set of conditions is satisfied) THEN (a set of consequences can be inferred). Each rule has an antecedent (or IF) part containing several preconditions and a consequent (or THEN) part that describes the output action [12]. The antecedent and consequent parts are characterized by appropriate membership functions.
Since the fuzzy predicates are inherently range based, fewer rules are required than is the case with typical Boolean-based expert systems, which demand precise matches. In this paper, without loss of generality, we assume that each fuzzy rule has two inputs (X and Y) and one output (O), and is expressed in the following form:

Rule Ri: IF (X is Ai) and (Y is Bi) then (O is Ci)

, where Ai and Bi are the antecedent membership functions associated with the linguistic input variables X and Y, respectively, and Ci is the consequent membership function associated with the linguistic output variable O.

2.3 Fuzzy Inferences

A fuzzy inference is characterized by a set of fuzzy rules. Assume that the knowledge base has *r* fuzzy rules, including *R*1, *R*2, …, and *Rr*. With the fuzzified inputs *X* and *Y*, the fuzzy inference process can be depicted in the following steps .
Firstly, *X* and *Y* are simultaneously broadcasted to all fuzzy rules to be compared with the antecedent parts. The matching degrees between (*X* and *Ai*) and between (*Y* and *Bi*) are obtained with the max-min calculation method as in the following two equations:

$$\alpha_i^A = \max_m(\min_m(X(m), A_i(m))), \quad (1)$$

$$\alpha_i^B = \max_m(\min_m(Y(m), B_i(m))), \quad (2)$$

The weight of rule Ri is calculated as follows:

$$\omega_i = \min(\alpha_i^A, \alpha_i^B). \quad (3)$$

Hence, rule *Ri* recommends a control decision as follows:

$$O_i(m) = \min_m(\omega_i, C_i(m)). \quad (4)$$

Lastly, the linguistic output *O*, which combines the control decisions of all the fuzzy rules, is given by

$$O(m) = U_i O_i(m) = \max(O_O(m),....,O_{r-1}(m)). \quad (5)$$

Since the inference process should output some crisp control results in practice, it requires the use of a defuzzifier. If the center of gravity (COG) algorithm is employed, the final crisp output *O* can be calculated as follows [13]:

$$O = \frac{\sum_m (m \times O(m))}{\sum_m O(m)} \quad (6)$$

3. **Event Detection Algorithm**

Event detection algorithm is the core of the environmental monitoring and object tracking applications[14]. Ambulatory medical monitoring, vehicle tracking, forest fire, and military surveillance detection are some sample applications that event detection plays a key role[5]. Several wireless senor networks middleware provide the required primitives, such as event notification to facilitate event detection tasks in various applications. The invasion of enemy forces detection sensor networks are deployed to set an alarm if a movement starts somewhere in the monitored area. So, whenever the invasion is detected the nodes will send information to their respective cluster head as shown in Fig. 1. This will reduce processing cost at each node which can be used for further computations.

The most common event detection algorithm comes from detecting the signal energy value from a sensor in a fixed period of time is integrated, as in [15], when it exceeds a threshold, $T_{h,}$ the system claim a detection of event occurred. However, this simple method suffers from a significant drawback. When there is no event occurring in the sensing range, the sensed signal consists of only noise. The level of the noise power value is generally unknown and can change when the environment changes or if unwanted interferers go on and off. Therefore, it is quite difficult to set a fixed threshold. The design of double sliding window algorithm [7] for event-detection so as to alleviate the threshold value selection problem. The double sliding window event-detection algorithm calculates two consecutive sliding windows of the sensed signal energy. The basic principle is to form the decision variable as the ratio of the total energy value contained inside the two windows. Fig. 4 shows the windows A and B and the response of the ratio m_n to a sensed event. It can be seen that when only noise is sensed the response is flat, since both windows contain ideally the same amount of noise energy.

The advantage of this approach is the decision variable m_n does not depend on the sensed signal energy, but on the ratio of the energy of two consecutive windows.

However, if an event continuously appears in the sensing range of a node, the ratio m_n will still be flat. The probability of detection will decrease accordingly. In order to solve this problem, a hybrid event-detection algorithm based on FLS is presented where the accumulated signal energy in a fixed period of time and the ratio of the accumulated signal energy in two consecutive sliding windows m_n become the inputs for the FLS.

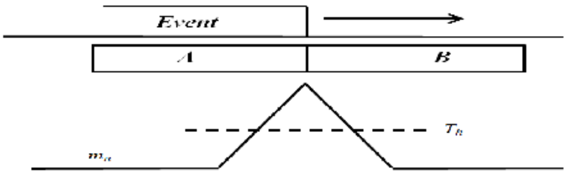

Fig. 4 The response of the double sliding window event-detection algorithm.

4. **Proposed FUZZY system for border monitoring**

In this paper, The Proposed system in each Wireless sensor node consists of two layers of fuzzy logic system to reduce the false alarm, uncertainty and noise appears in the sensors readings. The first layer deploy on two different sensors; acoustic sensor and one axis acceleration sensor which used to detect illegal intruders. The number and type of sensors in each node may be varied depends on the environmental conditions of the desired system. Each sensor in the first layer depends on a hybrid event-detection algorithm which depends on the energy value and the rate of change of sensor energy in two Consecutive windows. The second layer analyzes the output from the first layer to decide the level of alarm to each event detected, as shown in Fig. 5. The first signal conditioning unit in the first layer and the second signal conditioning unit in the second layer functions are to process and generate the rate of change of each of the sensors reading, determine the sliding window width for hybrid event-detection algorithm, which is assumed to be 182 msec, this time is varying according to the illegal intruders maximum speed required to be detected which is in our case 20 Km/h. So every 182 msec if the two sensors readings are high and their corresponding rates are positive high the final output of system will give an alert, if only one sensor detect a vehicle in this window time then the system will be in steady state, otherwise the output of the system will be safe according to the MF for output decision in the second FLS layer as shown in Fig. 16.

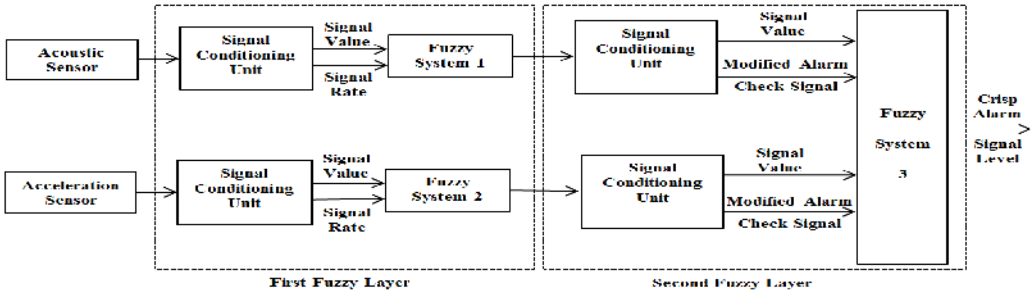

Fig. 5 Proposed system Block diagram.

The input Membership Functions [MF] defined for acoustic, and acceleration sensors outputs and their rate of change are low, medium and high as shown in Fig. 6 to Fig. 9. Whereas weak, and strong are defined for the output Membership functions for the two sensors as shown in Fig. 10 to 11. For the four inputs in the second layer, The Membership Functions [MF] defined for acoustic, acceleration sensor outputs are low, and high for the first FLS, the Modified alarm check signal rate of the first FLS, the second FLS, and the Modified alarm check signal rate of the second FLS. Whereas safe, steady, and alert are defined on the output MF Probability of this layer as shown in Fig. 12.

The resulting control surface of the Acoustic, one-axis acceleration sensor, and second layer outputs are crisp number from the set [0, 1] from MALTAB as shown in Fig. 13 to 15. The second layer control surface is the scale of detection of illegal intruder probability. Decision making could be done on the basis of output obtained by making few conditions.

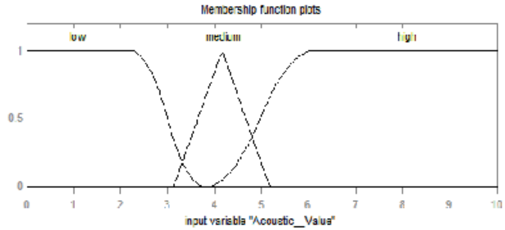

Fig. 6 MFs for acoustic value in the first FLS layer.

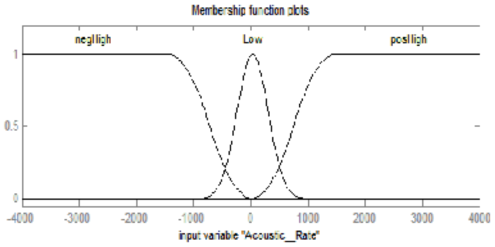

Fig. 7 MFs for acoustic rate in the first FLS layer.

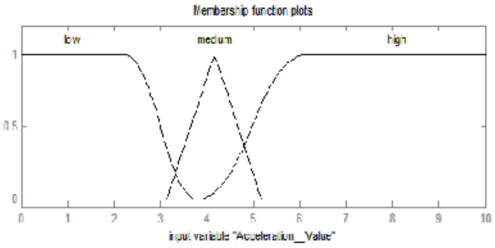

Fig. 8 MFs for acceleration value in the first FLS layer.

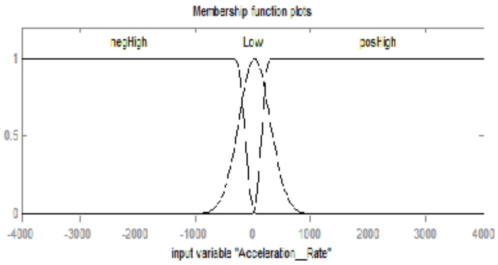

Fig. 9 MFs for acceleration rate in the first FLS layer.

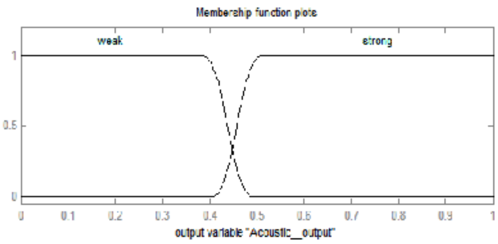

Fig. 10 MFs for Acoustic output decision in the first FLS layer.

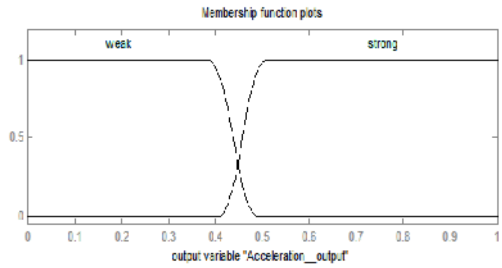

Fig. 11 MFs for Acceleration output decision in the first FLS layer.

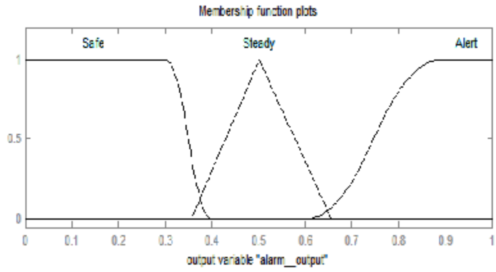

Fig. 12 MFs for output decision in the second FLS layer.

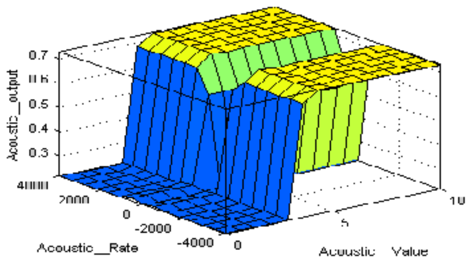

Fig. 13 Surface view of acoustic sensor probability with respect to Signal value and rate of change.

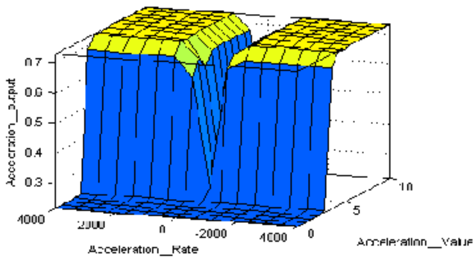

Fig. 14 Surface view of one-axis acceleration sensor probability with respect to Signal value and rate of change.

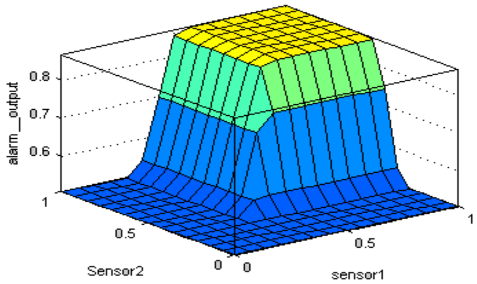

Fig. 15 Surface view of second layer FLS probability with respect to outputs from the Acoustic FLS and one-axis acceleration FLS.

5. SIMULATION RESULTS

Simulation is performed to the proposed system using MATLAB/Simulink, we also added a Gaussian Distributed Noise to all the input signals to test the system response in a noisy environment. the simulation results divided into 2 different cases: in the first case both the input signal value of the two sensors are identical to each other and with a period more than 182 msec to indicate the stopped or slowly moving car case as shown in Fig.16. The simulation of the crisp value output response of the second layer FLS is shown in Fig.17.

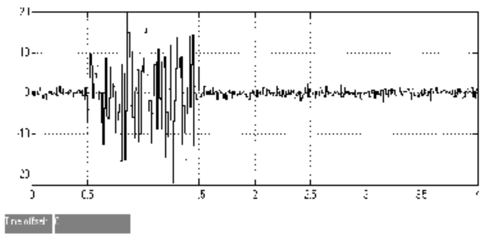

Fig. 16 Sensor input signal value for both the two sensors in the first case with the presence of Gaussian Distributed Noise.

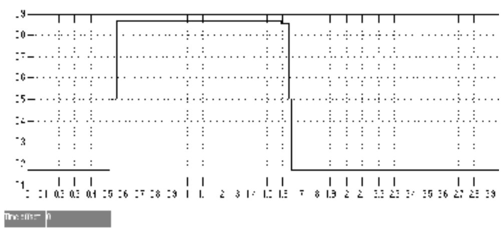

Fig. 17 The simulation result of output response of the second layer FLS in the first case.

In the second case, both the input signal value of the two sensors are identical to each other and with a period less than 182 msec to indicate a car with high speed crossing the wayside issue as shown in Fig.18. The simulation of the crisp value output response of the second layer FLS is shown in Fig. 19 which is always in the safe mode due to the low pulse width from the both sensors input readings corresponding to the high speed crossing the wayside more than the assumed limited value 20Km/h.

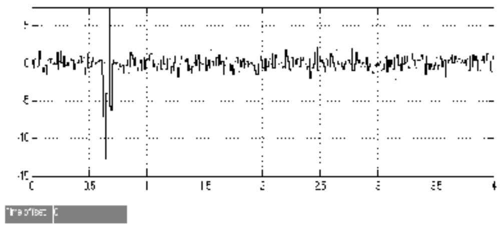

Fig. 18 Sensor input signal value for both the two sensors in the second case with the presence of Gaussian Distributed Noise.

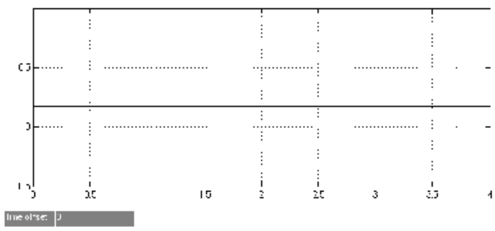

Fig. 19 The simulation result of output response of the second layer FLS change in the second case.

The proposed Fuzzy system outputs in the two cases, as shown in Fig. 17 and Fig. 19, shows a high rapid response and stable output decisions to the inputs of the sensor signals even in the present of Gaussian noise environment or other expected external disturbances.

6. CONCLUSION

In this paper, a smart fence to extend intrusion detection capabilities by using a hybrid event detection mechanism for detection of illegal intruders using fuzzy approach is introduced The proposed system calculates the probability of intrusion using multi-sensors and handles the vagueness presented in the statistics successfully. The system simulation shows that it gives good results with very low false alarm rate despite the presence of noise. The decision based on this approach gives accurate results with variation of time and other physical parameters. The membership functions and the parameters can be changed and modified as required. Rules also could be altered and adjusted according to parameters the proposed environment model.

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Comment [m1]: Again give some attention to the references please review them again

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