Real Time Wireless Sensor Network for Coastal Erosion using Fuzzy Inference System

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Abstract**—**Wireless sensor networks (WSN) are one of the research areas in 21st century, which provide platform to scientists with the capability of developing real-time monitoring systems. This paper discusses the development of a WSN to detect coastal erosions, which includes the design, development and implementation of a WSN for real time monitoring, the development of the algorithms needed that will enable efficient data collection and data aggregation, and the network requirements of the deployed coastal erosions detection system. The actual deployment of Puri Sea Beach is in the Puri district of the state of Orissa, India, a region renowned for the sand sculptures and become a favorite haunt of both Indian and foreign beach lovers.

Keywords- *wireless sensor network, distributed algorithms, heterogeneous networks, coastal erosion.*

1. Introduction

India has a long coastline of 7516.6 km (according to National Hydrographic Office, Dehradun), spread along the nine maritime states of Orissa, Andhra Pradesh, West Bengal, Tamil Nadu, Kerala, Karnataka, Goa, Maharashtra, Gujarat and the Union Territories of Pondicherry, Andaman & Nicobar Islands, Lakshadweep Islands and Daman & Diu. A substantial portion of the country's coast is affected by sea erosion. The causes of coastal erosion can be natural and/or man-made [4].

Environmental disasters are largely unpredictable and occur within very short spans of time. Therefore technology has to be developed to capture relevant signals with minimum monitoring delay. Wireless sensors are one of the latest technologies that can quickly respond to rapid changes of data and send the sensed data to a data analysis center in areas where cabling is not possible.

WSN technology has the capability of quick capturing, processing, and transmission of critical data in real-time with high resolution. However, it has its own limitations such as relatively low amounts of battery power and low memory availability compared to many existing technologies. It does, though, have the advantage of deploying sensors in hostile environments with a bare minimum of maintenance. This fulfills a very important need for any real time monitoring, especially in unsafe or remote scenarios.

We aim to use the WSN in the coastal erosion scenario for estimating the occurrence of erosions. In India, about 1,500 kilometers' or 26 % of the mainland coastline faces 'serious erosion' and is 'actively retreating', according to the Asian Development Bank.Coastal erosion is responsible for the loss of land, houses, infrastructure, and business opportunities and poses a high risk to human well-being, economic development, and ecological integrity. Coastal erosion has resulted in loss of life, property, valuable beaches and coastal land used for habitation, agriculture and recreation and continues to be a serious threat to many important buildings, factories, monuments of historical importance, highways and strategic installations along the country's coast. It affects negatively the livelihood of costal communities, particularly poor households, and ultimately the coastal economies. The annual land losses due to coastal erosion in India is estimated at around $127 million; potentially the impact could be much more extensive and widespread in the period ahead as the coastline is increasingly subject to a wide range of economic developments; many of which create conflicts and pressures on the already disturbed natural coastal environments.

This paper discusses the design and deployment of a erosion detection system using a WSN system at Puri beach, Puri (Dist), Orissa (State), India. The increase in depressions during the monsoons over Bay of Bengal is directly related to rise in the temperature of sea surface. It is an impact of global warming. Abnormal behavior of sea surface temperature has started to affect the atmospheric climate over the Bay of Bengal. The increased number of continuous depressions over the Bay of Bengal has also led to increase in the height and velocity of the sea waves, which causes more erosion on the sea coast.

The remainder of the paper is organized as follows. Section 2 describes Research Background and Related Work. In Section 3, we describe the Neural Network Algorithm. Section 4 Wireless Sensor Test Bed. Section 5 Conclusion and Future Work.

2. Research Background and Related Work

The research background and relevant technologies includes: (1) the definition of erosion, (2) wireless sensor network technology, and (3) the neural network algorithm

2.1 Definition of Coastal erosion

What is Coastal /Sea erosion*?*

The landward displacement of the shoreline caused by the forces of waves and currents is termed as ***coastal erosion*** [1].

Causes of Erosion?

Coastal erosion occurs when wind, waves and long shore currents move sand from the shore and deposits it somewhere else.

Major Causes of Coastal Erosion are:-

Natural Causes

- Action of Waves.
- Winds.
- Tides.
- Near-shore currents.
- Storms.
- Sea Level Rise

Anthropogenic Causes (Human intervention causes)

- dredging of tidal entrances
- Construction of harbors in near shore.
- Construction of groins and jetties
- River water regulation works
- Hardening of shorelines with seawalls.
- Construction of sediment-trapping upland dams
- Beach nourishment.
- Destruction of mangroves and other natural buffers
- Mining or water extraction

2.2 Wireless Sensor Network Technology

WSN technology has generated enthusiasm in computer scientists to learn and understand other domain areas which have helped them to propose or develop real time deployments. One of the major areas of focus is environmental monitoring, detection and prediction.

The Drought Forecast and Alert System (DFAS) has been proposed and developed in [3]; it uses mobile communication to alert the users, whereas the deployed system uses real time data collection and transmission using the wireless sensor nodes, Wi-Fi, satellite network and also through internet. The real streaming of data through broadband connectivity provides connectivity to wider audience.

An experimental soil monitoring network using a WSN is presented in reference [2], which explores real-time measurements at temporal and spatial granularities.

In this paper, real time deployment of a heterogeneous network for coastal erosion detection has been discussed. This study incorporates both theoretical and practical knowledge from diverse domains such as coastal erosion and geomechanics, wireless sensor, Wi-Fi, and satellite networks, power saving solutions, and electronic interface and design, among others, which covered the design, development and deployment of a real-time coastal erosion system using a WSN.

3. Mamdani fuzzy model

There are 3 types of fuzzy control system/model used.

1. Mamdani Fuzzy model
2. Sugeno Fuzzy model
3. Tsukamoto Fuzzy model

The most commonly used fuzzy inference technique is the so-called **Mamdani** method. In 1975, Professor Ebrahim Mamdani of London University built one of the first fuzzy systems to control a steam engine and boiler combination. He applied a set of fuzzy rules supplied by experienced human operators.The Mamdani-style fuzzy inference process is performed in four steps:

1. Fuzzification of the input variables
2. Rule evaluation (inference)
3. Aggregation of the rule outputs
4. Defuzzification.

Step 1: Fuzzification

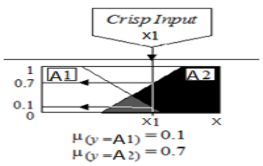
The first step is to take the crisp inputs, x1, y1 and z1 (depression over sea, temperature over sea and height& velocity of wave), and determine the degree to which these inputs belong to each of the appropriate fuzzy sets. We examine a simple three-input one-output problem that includes two rules:

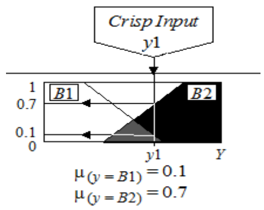
<u>Rule: 1</u> IF x is A2 AND y is B2 THEN r is O2
<u>Rule: 2</u> IF x is A2 AND z is C2 THEN r is O2

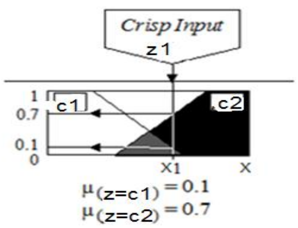
The Reality for these kinds of rules:

<u>Rule: 1</u> IF depression over sea is more AND temperature over sea is more THEN erosion is more.

Rule: 2 IF depression over sea is more AND height, velocity of wave is more THEN erosion is more.







Step 2: Rule Evaluation

The second step is to take the fuzzified inputs, $\mu_{(x=A1)} = 0.1$, $\mu_{(x=A2)} = 0.7$, $\mu_{(y=B1)} = 0.1$, $\mu_{(y=B2)} = 0.7$ and $\mu_{(z=C1)} = 0.1$, $\mu_{(z=C2)} = 0.7$. Apply them to the antecedents of the fuzzy rules. If a given fuzzy rule has multiple antecedents, the fuzzy operator (AND or OR) is used to obtain a single number that represents the result of the antecedent evaluation.
RECALL: To evaluate the disjunction of the rule antecedents, we use the **OR** fuzzy operation. Typically, fuzzy expert systems make use of the classical fuzzy operation union:

$\mu_{A \cup B}(x) = \max\,[\mu_A(x),\, \mu_B(x)]$

Similarly, in order to evaluate the conjunction of the rule antecedents, we apply the **AND** fuzzy operation intersection:

$\mu_{A \cap B}(x) = \min\,[\mu_A(x),\, \mu_B(x)]$

Rule: 1 IF x is A2 (0.7) AND y is B2 (0.7) THEN r is O2 (0.7)

Rule: 2 IF x is A2 (0.7) AND z is C2 (0.7) THEN r is O2 (0.7)

Step 3: Aggregation of the Rule Outputs

Aggregation is the process of unification of the outputs of all rules.We take the membership functions of all rule consequents previously clipped or scaled and combine them into a single fuzzy set. The input of the aggregation process is the list of clipped or scaled consequent membership functions, and the output is one fuzzy set for each output variable.

r is O2 (0.7)→ r is O2 (0.7)=∑

Step 4: Defuzzification

The last step in the fuzzy inference process is defuzzification.Fuzziness helps us to evaluate the rules, but the final output of a fuzzy system has to be a crisp number.
The input for the defuzzification process is the aggregate output fuzzy set and the output is a single number.There are several defuzzification methods, but probably the most popular one is the **centroid technique**. It finds the point where a vertical line would slice the aggregate set into two equal masses. Mathematically this **centre of gravity** (**COG**) can be expressed as:

$$COG = \frac{\sum_{x=a}^{b} x.m(x)}{\sum_{x=a}^{b} m(x)}$$

Centroid defuzzification method finds a point representing the centre of gravity of the aggregated fuzzy set *A*, on the interval [*a*, *b*].A reasonable estimate can be obtained by calculating it over a sample of points. The final output of defuzzification will be the erosion degree.

4. Wireless Sensor Test Bed

The WSN follows a two-layer hierarchy, with lower layer wireless sensor nodes, sample and collect the heterogeneous data from the sensor column and the data packets are transmitted to the upper layer. The upper layer aggregates the data and forwards it to the sink node (gateway) kept at the deployment site. Data received at the gateway has to be transmitted to the Field Management Center (FMC) which is approximately 500mt away from the gateway. A Wi-Fi network is used between the gateway and FMC to establish the connection. The FMC incorporates facilities such as a VSAT satellite earth station and a broadband network for long distant data transmission. The VSAT satellite earth station is used for data transmission from the field deployment site at puri sea beach, Orissa, India to the Data Management Center (DMC), situated within the state.

The DMC consists of the database server and an analysis station, which performs data analysis and coastal erosion modeling and simulation on the field data to determine the erosion probability. The wireless sensor network architecture for coastal erosion detection is as shown in Fig-3.

The puri coastal region experiences frequent erosion and has erosion prone areas within 30k.m (konark, puri_konark marine drive) which can be utilized as future extension sites for erosion detection systems. The different deployment sites can connect to the FMC via a Wi-Fi network.

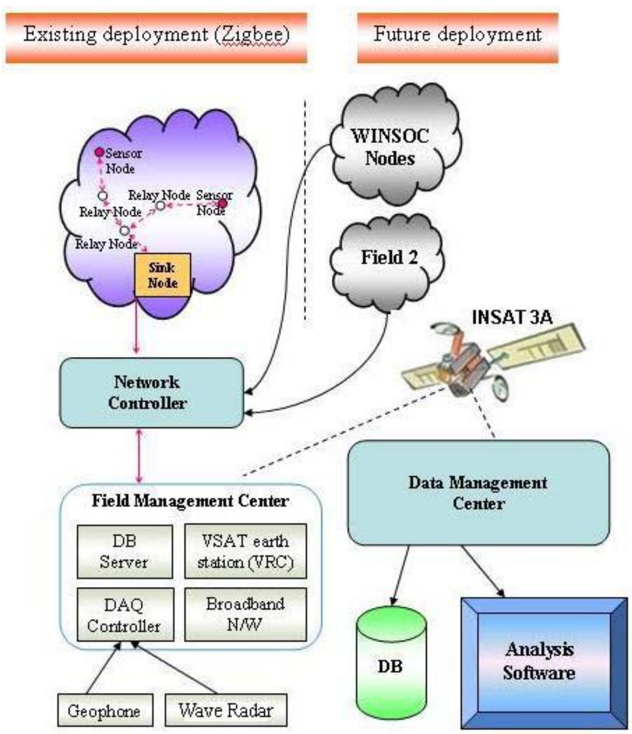


Fig-3 Wireless Sensor Network Architecture for Erosion Detection

5. Conclusion and Future Work

Real time monitoring of coastal erosion is one of the research areas available today in the field of geophysical research. This paper discusses the development of an actual field deployment of a WSN based coastal erosion detection system. This system uses a heterogeneous network composed of WSN, Wi-Fi, and satellite terminals for efficient delivery of real time data to the DMC, to enable sophisticated analysis of the data and to provide erosion warnings and risk assessments to the inhabitants of the region. In the future, this work will be extended to a full deployment by using the lessons learned from the existing network. This network will be used for understanding the capability and usability of WSN for critical and emergency application. In the future, we plan to experiment with this method, including a simulation and implementation, to evaluate its performance and usability in a real sensor network application.

References

[1] Coastal & Sea Erosion: Current Science,Vol-91,No-4,Aug 2006.

[2] E. R. Musaloiu, A. Terzis, K. Szlavecz,A.Szalay, J. Cogan, and J. Gray, “Life under your feet: A wireless soil ecology sensor network”,2006

[3] H. Kung, J. Hua, and C. Chen, “Drought forecast model and framework using wireless sensor networks, Journal of Information Science and Engineering, vol. 22, 2006, pp. 751-769

[4] J. Chandrasekhar Iyer, “Workshop on coastal protection Measures, 5^{th} & 6^{th} Nov. 2004.

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