

Wireless Sensor Network for Coastal Erosion: A National Perspective

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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 coastal 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 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. NEURAL NETWORK ALGORITHM

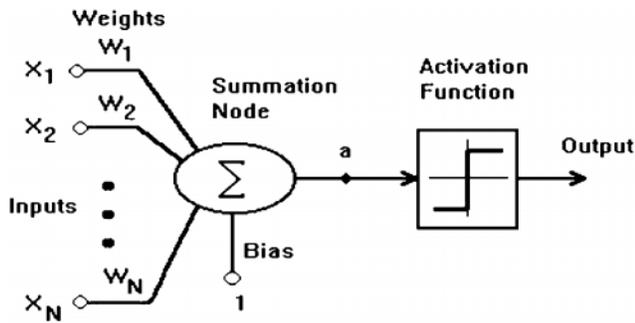
A neural network is a powerful data modeling tool that is able to capture and represent complex input/output relationships. The motivation for the development of neural network technology is to develop an artificial system that could perform "intelligent" tasks similar to those performed by the human brain. Neural networks resemble the human brain in the following two ways:

1. A neural network acquires knowledge through learning.
2. A neural network's knowledge is stored within inter-neuron connection strengths known as synaptic weights.

Fig-1 depicts the neuron model of the neural network and describes as follows.

1. X_i = Input of a neuron i .
2. W_i = Synaptic weight to represent the linkages strength of neuron i .

The high synaptic weight highly effects the operation of the neural network. On the other hand, the low synaptic weight has lightly effects on the neural network. The low synaptic weights usually are removed to reduce the computing time of the neural network. The operation of the neural network is to adjust the synaptic weights of neuron linkages and determine the suitable synaptic weights to have accuracy results.



$$a = W_1 X_1 + W_2 X_2 + \dots + W_N X_N + \text{Bias}$$

$$\text{output} = \text{Threshold}(a)$$

$$\text{where } \text{Threshold}(a) = \begin{cases} 1, & \text{for all } a \leq 0 \\ 0, & \text{for all } a > 0 \end{cases}$$

Fig. 1: The Neuron Model of Neural Network

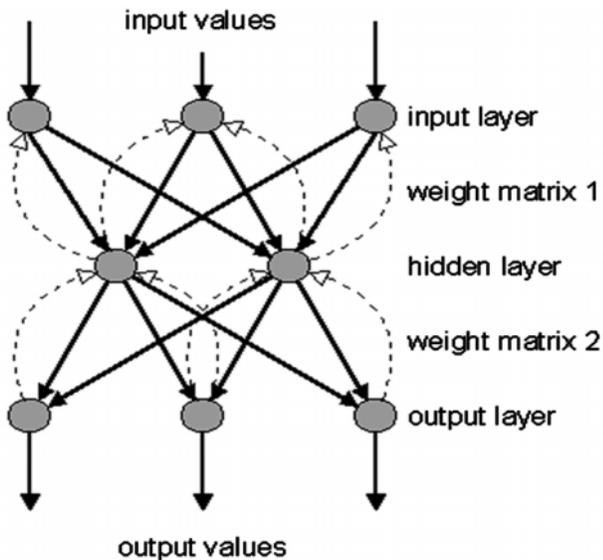


Fig. 2: The Back-propagation Network Model

3. Σ is responsible for the summation of each neuron's synaptic weight.
4. $\phi()$ is the activation function, which is the non-linear type to convert the summation value into the output.
5. Y_j = Output of the neural network.

This paper utilizes the most popular Back-Propagation Network (BPN) algorithm to analyze the potential erosion degrees. The BPN algorithm is a typical Supervised.

Learning Network, which is to learn the internal reflection and regulations between inputs and outputs? The regulations are the synaptic weights of network neurons. For analyzing any new cases, the input values or independent variables are inputted into the neural network and get the inferential related output values quickly.

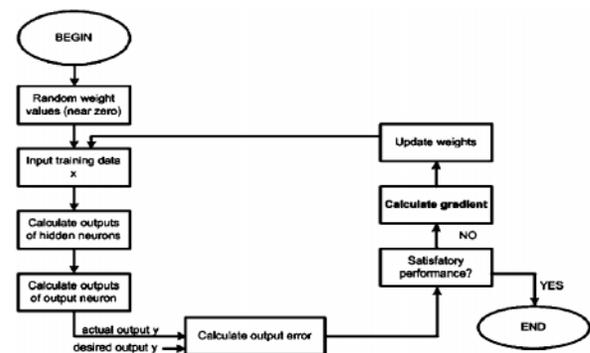
Fig-2 depicts the Back-Propagation Network model, which have three system layers and described as follows.

1. Input Layer comprises the inputs of the BPN and represents the initial values of decision.
2. Hidden Layer comprises the neurons, which are responsible for adjusting the synaptic weights of neuron linkages and determining the suitable synaptic weights. To have accuracy results, the hidden layer is composed of several sub-layers to learn the internal reflection and regulations between inputs and outputs.
3. Output Layer comprises the outputs of the BPN and represents the final decision results at this training operation.

The control procedure of the BPN algorithm divides into the following operation:-

Two phases of computation:

- **Forward Pass:** Run the NN and compute the error for each neuron of the output layer.
- **Backward Pass:** Start at the output layer, and pass the errors backwards through the network, layer by layer, by recursively computing the local gradient of each neuron.



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.

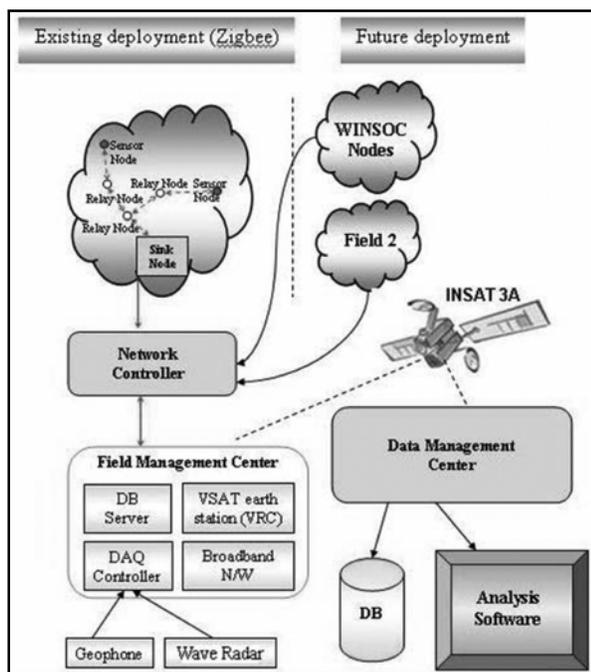


Fig. 3: Wireless Sensor Network Architecture for Erosion Detection

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.

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