Genetic Fuzzy Approach for Prediction of Coastal Erosion

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Abstract - **The applications of Soft Computing contain a wide variety of scenarios. Over the past few years, the application of Soft Computing to solve real life problems. Soft computing is a collection of methodologies, which aim to exploit tolerance for imprecision, uncertainty and partial truth to achieve tractability, robustness and low solution, cost. The focus is to publish the highest quality research in application and convergence of the areas of Fuzzy Logic, Neural Networks, Evolutionary Computing, Rough Sets and other similar techniques to address real world complexities. Genetic Fuzzy System (GFS) are one of the research areas in twenty first century, which provide platform to researchers and scientists with the capability of developing real-time monitoring systems. This paper discusses the development of a GFS to detect coastal erosions, which includes the design, development and implementation of a GFS for real time monitoring, the development of the fuzzy system 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-genetic fuzzy system; genetic algorithm; coastal erosion; genetic programming

I. INTRODUCTION

India has a long coastline of 7517 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 [1].

Environmental disasters are largely unpredictable and occur within very short spans of time. Therefore technology has to be developed to capture relevant data with minimum monitoring delay.

GFS technology has the capability of quick capturing, processing, and transmission of critical data in real-time with high resolution.

We aim to use the GFS 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', 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 erosion detection system using a GFS 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 II describes Research Background and Related Work. In Section III, we describe Genetic programming. Section IV Mamdani Fuzzy Model. Section V Conclusion and Future Work.

II. RESEARCH BACKGROUND AND RELATED WORK

The research background and relevant technologies includes: (1) the definition of erosion, (2) Background on Genetic Algorithm

A. Definition of Coastal Erosion

What is Coastal Erosion?

The landward displacement of the shoreline caused by the forces of waves and currents is termed as ***coastal erosion*** [3].

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

Human intervention causes

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

B. Background on Genetic Algorithm

Genetic Algorithms (GA) is a searching technique used in computing to find true/approximate solutions to optimization and search problem. Genetic Algorithm are a particular class of evolutionary algorithm that use techniques inspired by evolutionary biology such as inheritance, mutation, selection and crossover. GAs has been widely studied, experimented and applied in many fields in engineering world.

Who can benefit from GA?

Nearly everyone can gain benefits from GAs. GAs are useful and efficient when

- The search space is large, complex and poorly understood.
- No mathematical analysis is available
- Traditional search method fails.

Pseudo-Code Algorithm

1. Choose initial population.
2. Evaluate the fitness of each individual to reproduce.
3. Repeat
   (a) Select best-ranking individuals to reproduce.
   (b) Breed new generation through crossover and mutation (genetic operations) and give birth to offspring
4. until termination condition

The common termination conditions are: -

(a) A solution is found that satisfies minimum criteria.
(b) Fixed number of generation reached.
(c) Allocated budget (computation time/money) reached.
(d) Highest ranking solutions fitness is reached.

III. GENETIC PROGRAMMING PARADISM

Genetic programming is a branch of genetic algorithm. The main difference between genetic programming and genetic algorithm is the representation of the solution. Genetic programming creates computer programs in LISP or scheme computer languages as the solution. Genetic algorithms create a string of numbers that represent the solution.

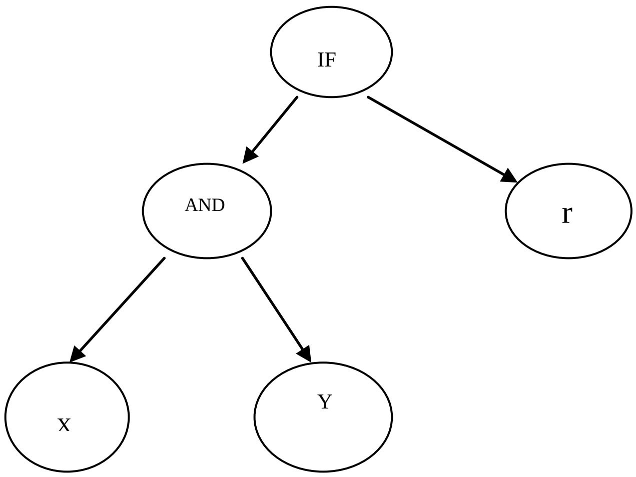
Genetic programming uses four steps to solve problems:

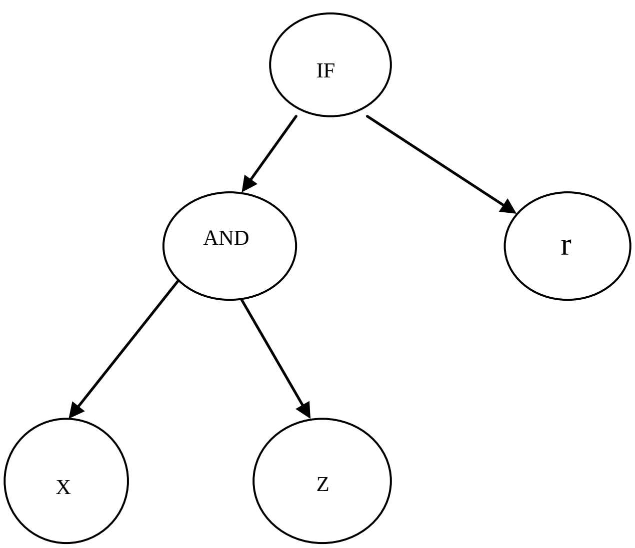
1. Generate an initial population of random compositions of the functions and terminals of the problem.
2. Execute each program in the population and assign it a fitness value according to how well it solves the problem.
3. Create a new population of computer programs.
   (a) Copy the best existing programs
   (b) Create new computer programs by mutation.
   (c) Create new computer programs by crossover (sexual reproduction).
4. The best computer program that appeared in any generation, the best-so-far solution, is designated as the result of genetic programming [Koza 1992].

In our proposed system, we choose the cross over operation by choosing parents to produce children.

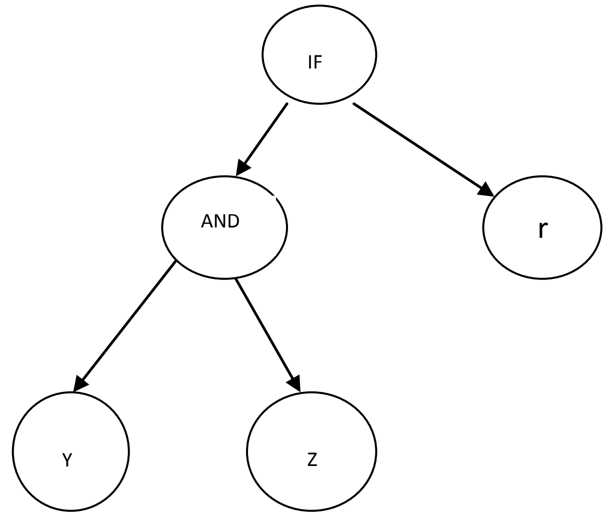
The variable x, y and z are used for the input for fuzzy inference system and the variable r is used for the output for fuzzy inference system.

Parents





Children



The following two parental LISP S-expressions:

(IF(AND(x y))

(r))

(IF(AND(x z))

(r))

The children resulting from crossover is shown below:

(IF(AND(y z))

(r))

IV. 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

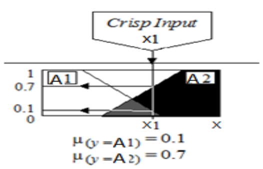
The most commonly used fuzzy inference technique is the so-called **Mamdani** method. In 1975, Professor Ebrahim Mamdani of London University built one of the first fuzzy systems to control a steam engine and boiler combination. He applied a set of fuzzy rules supplied by experienced human operators.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

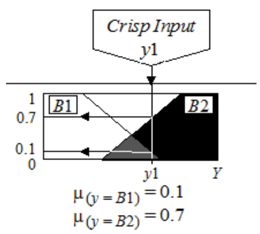
1. Fuzzification of the input variables
2. Rule evaluation (inference)
3. Aggregation of the rule outputs
4. Defuzzification.

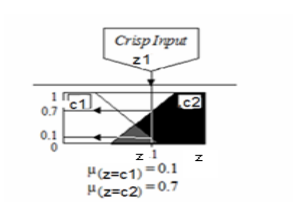
Step 1: Fuzzification

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 [2] 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.
<u>Rule: 2</u> 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:
$\mu_{A\cap B}(x) = \min\, [\mu_A(x), \mu_B(x)]$
<u>Rule: 1</u> IF x is A2 (0.7) AND y is B2 (0.7)
THEN r is O2 (0.7)
<u>Rule: 2</u> 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.

V. 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 GFS based coastal erosion detection system. In the future, this work will be extended to a full deployment by using the lessons learned from the existing system. In the future, we plan to experiment with this method, including a simulation and implementation, to evaluate its performance and usability.

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