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A comprehensive survey on oceanography parameters for developing ocean wave displacement prediction system

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ABSTRACT

Earth is widely covered by ocean. There are many calamities observed as a result of various unpredicted behaviour of ocean wave movements, and Landscaping under ocean along with response to weather change. These dynamic and drastic behaviours of oceans can be measured by various parameters like. The paper describes in depth learning of various concerned parameters which cover impact of parameters individually, different and co-related with each other. Disaster prediction requires analyzing the history and future of ocean parameters, which is a motivationfor forecasting parameters accurately and efficiently. The paper also discusses various approaches for forecasting future ocean parameters proposed by various researches and predicting one dimensional wave displacement. The various approaches that have been discussed in this paper are: Artificial Neural network, Data Assimilation methods, Genetic Algorithm, Statistical methods, Super ensemble methods and mathematical concepts like partial derivation and Fourier series transformations.

Keywords: Oceanography, oceanography parameters, ocean waves, Artificial Neural Networks, Genetic Algorithms, Statistical methods, Super ensemble methods, Partial Derivation and Fourier series.

INTRODUCTION

Earth has seventy percent of water on its surface that is called Oceans. To predict natural calamities the oceanography parametersplays an important role. All the parameters are elaborated in terms of their measurement unit, Applications, Co-relations and Dependencies on each other. The disasters can be predicted by giving input of different parameters that are co-related with each other and serves the new forecasting measurements that can be assumed as nearby approximation from the actual measurements. There are hazards related with oceans namely Floods, Tsunami, Hurricanes, Typhoons, storms, etc. Hazards and Disasters are due the uncertainty and climatic change which affects the parameters. Warning systems and forecasting systems fails to calculate the disaster due to the limitation of the mathematical model and equations fails to give the nearby approximation from previous observations. The survey mainly relies on prediction of ocean waves and waves displacement. Ocean wave prediction encounters the predictions of wave-height, wave-period and wind Speed. The wave-height describes the height of the wave from the surface of the ocean, while wave-period is the distance between two waves through a stationary point. Wave periods can be measure from wave height and Wind Speed algorithms used for ocean wave prediction

The algorithms listed here are specifically having their ability to forecast and make predictions.

Data assimilation (DA): DA has been particularly successful in weather forecasting. They have been using optimal Interpolation method, ad-joint method, and Kalman Filter method. It uses velocity, temperature, Salinity for ocean observing system. It emphasis's on hidden Markov chain model. A Kalman filter comes into existence to control the noisy systems.

Artificial neural network (ANN): ANN is the field of artificial intelligence composes of set of neurons and works as a human brain for information processing system. ANN is now a day's used for coastal and wide ocean areas in oceanography it give very precise result as compared to Kalmanfilter. Feed- Forward network, Back-propagation network and Recurrent neural networks are popular training algorithms of neural networks used in forecasting and making predictions of oceanography parameters.

Genetic Algorithms (GA): It is generally used to solve optimization techniques. They are preferably used for forecasting space time variability of sea. It is used reduces the complexity of non-linear and local optimatization problems. It is preferably used to measure the ocean surface parameters. The problem in GA remains in defining the fitness function; many possible outputs is generated from that one optimal output is selected. The accuracy of generated combinations depend upon the fitness function that is been defined.

Statistical Methods(SM): Statistical methods generally use Regression, Time analysis, Gamma and Erlang Distribution. It involvespure mathematical equations. The more precise equation reduces root mean square error up to 9.

Super-ensemble Methods (ESM): ESM is used for calculating average of the forecasting models and hind cast models. Different models observations are combined into one single model. There are many different methods in super ensemble as under:

Ensemble Mean
Unbiased Ensemble Mean
Linear Combination
Unbiased Linear combination
Fourier series transformation and Partial derivation (FSPD)

The application of partial derivation is specifically used for developing curve equations. In the paper we have used it to develop a mathematical model which will predict the wave displacement of the ocean waves. The equations are formed with partial derivation and it is in the terms of series, as wave equations are always formulized in the terms of series. The significance of using partial derivation and Fourier series is that it reduces complexity while generating mathematical model and the series defined is up to infinity, the will enhance the prediction system's accuracy. The major related mathematical concepts are also discussed here like partial derivation and Fourier series; as major concern of the paper is with respect to ocean wave displacement.

Current State of Art: The literature survey is based on domain consequence, ocean parameter assessment, Natural calamities and hazards, ample analysis of oceanography techniques and challenges encountered for wave predictions.

Oceanography sphere of influence Analysis: Oceanographic researches are working on techniques available to forecast the disasters and give the accurate results. Wireless Sensors are deployed under the oceans at certain distances and reading from the sensors is taken from the systems. Sensor has advantage of long term availability and time constraint to measure vast areas of the oceans. Altimeter data is also used via statistical models to compute the sea depth and temperature for now cast and prediction in deep water.

Study and investigation of oceanography parameters: Ocean waves are disturbances in the ocean that transmit energy from one place to another. Waves are caused through friction and pressure. There are different waves called tsunami waves occurred through earthquakes, internal waves which occur due to water masses.Tides are also the type of waves. It is generally measured through microwaves radiometer and satellite altimeters.

Ocean-optics is a technologyand a global leader in miniature spectroscopy, optical sensing and bio photonics technologies. Ocean pressure increases with ocean depth. The greater will go under the deep sea the force of pressure will be increased. Pressure increases nearly linearly related to depth. The equation is as under:

P = da *g a * hwc

Where da is average of depth density, ga the gravitational force (acceleration), and hwc is the height of the water column. Ocean Currents plays important role for heat and energy transportation. Deep ocean circulation affects different parameters like temperature and salinity, variations in water masses, shorelines, surface topography, tides, etc. Currents are measured through Altimeter. Ocean winds combined with other atmospheric forces are all responsible for the movement of water masses in the ocean, and are thus responsible for ocean currents. It is measured through microwaves radiometer; microwaves scatter meters, SAR (synthetic Aparture Radar), Altimeters.

Radar is remote sensing sensor which is usually used to measure the ocean waves form satellite. Sea surface temperature (SST) is the referred as temperature of the ocean. To measure density it is necessary to measure the ocean temperature and it is equally important for prediction system to know the temperature of the ocean.The Sea surface temperature varies between -1.8Ctemperature at which sea water freezes, and +30C near/below the Equator. It is measured by satellite through Infrared radiometersand Microwave radiometers.

Atmospheric water vaporis generated due to the increasing amount of heat in the oceans that is warmth the water the greater the evaporation.Atmospheric electricity is the pattern of electrical charges in the ocean's atmosphere. Atmospheric Electricity can generate the true energy which is used to supply limitless renewable energy from the electricity. Electricity in atmosphere is generated through the thunderstorm caused in the weather.

Geodetic and Gravityforces of the earth are different everywhere under the oceans. The change in gravitational force can lead to change inoceanparameters.

Salinity / Density have impact on ocean atmosphere; with the temperature the salinity also plays the main role in determining the ocean density. Salinity is mainly used tomeasure the amount of salt in the oceans, thus the density of water in the Deep Ocean is easily derived. Through microwave radiometer the salinity is measured from

Satellite. The salinity is measured through ppt (per parts thousands) and denoted by s. To calculate the density of the ocean is as follows:

Density = water temperature + ocean water salinity

Sea Ice is crucial to measure, monitor and forecast. It can be measured through satellite microwave radiometer, Microwave scatter meters, Infrared sensors, SAR sensors and Altimeter. The ice model is also provided by ocean model to calculate the parameters like thickness, velocity, concentration and drift.

Sea surface topography refers to the land under the ocean which is not equally flat the different highs and lows of the land variations are called ocean/sea surface topography. It defines the height of the ocean above the geoid; geoid is the shape of the ocean when all the currents and tides are not in movements. This is usually measured through microwaveradiometers and altimeters.

Soils are composed of different types known as pelagic sediments or marine sediments. Pelagic sediment is fine-grained sediment which will take the particles of the ocean away from the land. The parameters that affect the soils are: distance from land and water depth which affects their dilution and preservation of biogenic particles.

Impact of natural calamities in oceans: There are many hazards and disasters that occur in the ocean. All the natural calamities are related to the fourteen parameters. One of the hazards on which the detailed survey has been carried out is Tsunami which occurred in 2004 and our forecasting method fails to predict that huge waves.

Tsunami is a major concern in the domain of natural disasters.To accurately forecast tsunami the attributes which are closely related to it must be identified.From the mentioned attributes, ocean-pressure, ocean-depthand ocean-density are closely related to forecast tsunami. Dart, GPSbuoy, Codar, satellite-altimeter, satellite-scattrometer, acoustic are the currently known technologies which can forecast tsunami. From the Comparison given in DART technology seems the most promising among all. DART is using Tsunameters to measure and gives 80% of accurate result.

Techniques for oceanography and their ample analysis with respect to accuracy and efficiency: Oceanography algorithm's computation depends upon the mathematical model design. The oceanography algorithms works on the following three techniques: Data-Assimilation techniques encounter major difficulties with respect to computational reasons: memory size of the system and high computing costs. The kalman filter comprises of predict and update equations. The equations are defined as under:

Predict (i) $Xse(t|t-1) = Fsem(t)\ Xse(t-1|t-1) + Btut$

(ii) $P\ svm(t|t-1) = Fstm(t)Psvm(t-1|\ t-1)Fstm(t)+ Qpvm(t)$

Update (i) $X\ se(t|t) = X\ se(t|t-1) + Kgt\ (Ymv(t) – Hmm(t)Xse(t|t-1))$

(ii)$Kgt= P\ svm(t|t-1)H\ mm(t)\ (H\ mm(t)P\ svm(t|t-1)\ Hmm(t) + Errt)-1$

(iii) $P\ svm(t|t-1) = (I - KtHt)\ P\ svm(t|t-1)$

Where,

Xse = State estimation, Fstm = State transition matrix, u = Control variables, B = Control matrix
Psvm = State variance matrix, Qpvm = Process variance matrix ,Ymv = Measurement Variables
Hmm = Measurement matrix, Kg = Kalman gain
Err = errors from measurement.

Artificial neural network is used to predict the significant wave height accurately. ANN has also indulged its significance in predicting ocean periods accurately for short term predictions. ANN has an advantage of taking less time to train the data using several training algorithms like Back-propagation algorithm, Conjugate Gradient algorithm, Cascade Co-relation algorithm, Gauss Newton algorithm, Steepest Descent method etc. There are two main strategies which should be fulfilled while designing architecture of ANN:

Number of hidden layers should be equals to 1.The hidden layer present in architecture should be mean of the neurons present in input layer and output layer of the architecture. Genetic algorithm is known as search and optimization technique. It is used reduces the complexity of non-linear and local optimization problems. The main advantage of GA is that it selects the accurate output among the several combinations and it takes comparatively less time in computations. The Complexity rises when there is a question of designing fitness function in GA. The computation and results depends upon the fitness function that is designed. The selection procedure includes some usual methods specified as under:

Roulette Wheel selection
Deterministic Sampling
Stochastic Remainder Sampling
Stochastic Remainder selection with replacement
Stochastic remainder selection without replacement

Stochastic universal selection: Super-ensemble methods have equations and notations of the equations are as follows: i refers model index, k is the index of time, M is the number of the models, Nl is the number of time iterations during learning period, Nt is the testing period which shows the number of time index. The data is described by z and at the same time model values is described by x at the same location. The prediction at learning period is Hind cast, while prediction at testing period is Forecast.

Ensemble Mean (EM) takes the average value of both the models Hind cast and forecast.

$$H_k^{EM} = \frac{1}{M}\sum_{i=1}^{M}(x_{k,i}), \qquad k = 1, \dots, N_l \qquad \dots(1)$$

$$F_k^{EM} = \frac{1}{M}\sum_{i=1}^{M} x_{k,i}, k = N_l + 1, .., N_l + N_t \dots(2)$$

Unbiased Ensemble Mean removes bias that is present in both the models by adding anomalies in the models.

$$H_k^{UEM} = \bar{z} + \frac{1}{M}\sum_{i=1}^{M} x`_{k,i}, \qquad k = 1, \dots, N_l \qquad \dots(3)$$

$$F_k^{UEM} = \bar{z} + \frac{1}{M}\sum_{i=1}^{M} x`_{k,i}, k = N_l + 1, \dots, N_l + N_t \dots(4)$$

$\bar{z} = \frac{1}{N_l}\sum_{k=1}^{N_l} z_k$ And $x`_{k,i} = x_{k,i} - \bar{x}_i$ with $\bar{x}_i = \frac{1}{N_l}\sum_{k=1}^{N_l} x_{k,i}$

Linear Combination This technique is the improved version of EM and it consists of weights (wi), depending on model performance with respect to learning period.

$$\begin{bmatrix} x_{1,1} & \cdots & x_{1,M} \\ \vdots & x_{k,i} & \vdots \\ x_{N_l,1} & \cdots & x_{N_l,M} \end{bmatrix}\begin{bmatrix} w_1 \\ \vdots \\ w_M \end{bmatrix} = \begin{bmatrix} z_1 \\ \vdots \\ z_{N_l} \end{bmatrix}$$

$$H_k^{LC} = \sum_{i=1}^{M} x_{k,i} w_i, k = 1, \dots, N_l \qquad \dots(5)$$

$$F_k^{LC} = \sum_{i=1}^{M} x_{k,i} w_i, k = N_l + 1, \dots, N_l + N_t \dots(6)$$

Unbiased Linear combination slightly defers from LC it include weights and one more additional term that is (WM+1) which is beneficial for bias correction. $\begin{bmatrix} x_{1,1} & \cdots & x_{1,M} & 1 \\ \vdots & x_{k,i} & \vdots & \vdots \\ x_{N_l,1} & \cdots & x_{N_l,M} & 1 \end{bmatrix}\begin{bmatrix} w_1 \\ \vdots \\ w_{M+1} \end{bmatrix} = \begin{bmatrix} z_1 \\ \vdots \\ z_{N_l} \end{bmatrix}$

Partial Derivation and Fourier series transformation is used to form curve equations. The equations of wave displacement made with the help of partial derivation and Fourier series includes following things:

Boundary condition means end is fixed at x=0; other end is fixed at x=l

Initial condition has velocity is zero; given initial position. Nature of curve means what type of curve does ocean wave forms e.g. Parabola, Hyperbola, sin wave, cosine wave, etc. Velocity wind speed is velocity. Wave length is horizontal length of the wave. Wave height is vertical length of the wave. Tension of the surface water refers to stretching of two waves in opposite direction. Ocean density remains constant. It is calculated with water temperature and ocean water salinity.

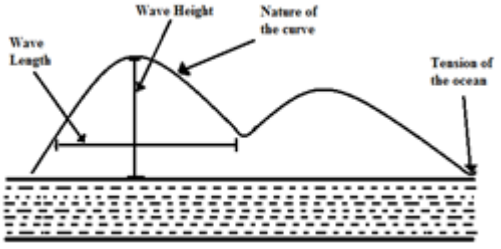

Figure.1.Ocean Wave Displacement

Comparison matrix of oceanography techniques: The table has compared complex factors which have to be keeping in mind while designing the prediction system. The mathematical model should satisfy each feature that is mentioned to acquire the fair results.

Table.1.Feature comparison matrix

Features	Artificial neural network	Genetic algorithm	Kalman filter	Statistical methods
Accuracy in long term forecasting	Average	Good	Poor	Poor
Accuracy in short term forecasting	Good	Good	Average	Average
Execution time	Average	Good	moderate	Average
Assumption boundary value	-	-	Yes	Yes
Simplification of non-linear data	Good	Good	Average	Average
Removes noises from the data	-	-	Good	Poor
Needs continuous data	Yes	Yes	Yes	Yes
Solve complex non-linear functions	Good	Good	Poor	Poor
Reduces root mean square error.	Poor	Good	Poor	Poor

Challenges encountered for ocean wave predictions Challenges that are encountered by researchers for prediction of ocean waves are as under: Previously observed data should be complete and accurate, the incomplete data can lead us errors in future measurements. Non-linear functionality is usually seen in previously observed data and they are not linear they forms non-linear relationship and increases complexity. Quadratic Relationship discovers the relation of one variable to another by function involving constant terms and terms of 1st order and higher. Random behavior and non-linear characteristics of wave increases complexity in mathematical description.

Proposal: The survey has been carried out with the goal to develop a prediction system. Techniques are elaborated in depth with their relevance according to their own strengths and weakness. The forecasting system relies on two dimensional ocean wave displacements. It has good impact to take precaution measure when disaster likes tsunami occurs. It helps to predict that a single wave in the ocean, consumes what amount of time to get flat. According to the state of the art mentioned in the section III mathematical model is most suitable for this kind of applications especially, the partial derivation and Fourier series transformation. Study concludes that Mathematical model based on these tools can be used for efficient prediction in such applications and we propose the same.

CONCLUSION

The paper serves the comprehensive study of oceanography parameters with respect to their measurement units, Applications, Co-relations and Dependencies. The survey also adds the comparative analysis of the techniques which are widely used in oceanography domain for prediction purpose. The comparison of the techniques is mainly based upon feature comparison as well as technical comparison, with their merits and demerits. From survey conclusion that has been made is when natural calamities occurs like tsunami, the predictions system fails to predict the nearby actual measurements which leads to errors. This is due to the flaws present in the technique which is adopted. The mathematical model is quite suitable to generate an efficient technique over the machine learning techniques. The research emphasises more on wave displacements is the another aspect that has been caught during the survey , major prediction/forecasting system are able to predict the initial height or the maximum height of the wave but here the goal is to predict a wave height displacement(WHD). The amount of time wave takes to get flat again in the ocean refers to WHD. This prediction may help to predict the giant waves.A prediction system's mathematical model which has combination of Fourier series transformations and partial derivation is suggested because it reduces the complexity which is faced by machine learning techniques and formations of equation is in the form of series which is up to infinity which leads to good accuracy result and we propose the same.

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