Mobile Object-Tracking Approach using a Combination of Fuzzy Logic and Neural Networks

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Abstract- Ability to locate a specific object in a dynamic environment has several practical applications including security surveillance, navigation and search and rescue operations. The objective of this paper is to develop an object-tracking algorithm using a combination of fuzzy logic and neural networks. The aim is to originate an algorithm that matches the history locations of an object and predicts its location when it goes offline. Determining the location of an object on specific trajectory becomes difficult if the mobile object stopped reporting its location and goes offline. Therefore, in this analytical article, a proposed approach relies on estimations from sensor data of historical movement patterns and geometric models, is fed into special Neural Network to get best accurate present or future object locations. Fuzzy logic application is used to overcome the challenge of imprecision in data. Although this approach is complex; but it can be one of the ways to be applied on large area applications with acceptable accuracy (80%) as shown by experiments.

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MOBILEOBJECTTRACKINGAPPROACHUSINGACOMBINATIONOFFUZZYLOGICANDNEURANETWORKS

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Abstract Ability to locate a specific object in a dynamic environment has several practical applications including security surveillance, navigation and search and rescue operations. The objective of this paper is to develop an object-tracking algorithm using a combination of fuzzy logic and neural networks. The aim is to originate an algorithm that matches the history locations of an object and predicts its location when it goes offline. Determining the location of an object on specific trajectory becomes difficult if the mobile object stopped reporting its location and goes offline. Therefore, in this analytical article, a proposed approach relies on estimations from sensor data of historical movement patterns and geometric models, is fed into special Neural Network to get best accurate present or future object locations. Fuzzy logic application is used to overcome the challenge of imprecision in data. Although this approach is complex; but it can be one of the ways to be applied on large area applications with acceptable accuracy (80%) as shown by experiments.

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I. Introduction

Multivariate Prediction methods and algorithms usually predicts variable value depending on pattern of time series variables, for instance: In continuous time series, variable x will instantly reports its value at time t and denoted as x(t). In other hand, In discrete time series, x will periodically reports its value in time interval t.

A variable is a value or a number that changes in increased or decreased pattern over time. There are two mainly categories of variables, independent variable and dependent variable. The independent variable and dependent variable are differing in an experiment. The independent variable is a variable that is varied or manipulated in the experiments by researchers; it refers to what is the influence during the experiment. The dependent variable is the variable that is simply measured by the researchers; it is the response that is measured. The dependent variable responses to the independent variable. It is called dependent because it depends on the independent variable. We cannot have a dependent variable without an independent variable. From these types, within the context of this article; we are interested in how location of a mobile object coordinates affects moving rate. The independent variable would be the coordinates and the dependent variable would be the speed. We can directly monitor the first and measure how they affect the speed of a mobile object. It is possible to forecast various kinds of data, in general, time series shows the changing of a value in time. The value can be impacted by also other factors rather only time. Time series represents discrete historical values and from a continuous function it can be obtained using sampling[1].

Neural networks involves using historical data and applying the neural network algorithm to predict possible future data. In this light, historical positions recorded prior to the loss of the object will be fed into the network to determine potential location in the present/future. Specifically, the backward propagation neural network model that uses historical data and applies artificial intelligence to predict likely future location of objects.

Neural network technique is particularly suitable in location prediction due to its reliance on minimal historical data to draw valuable inference. The model does not require additional data, making it less cumbersome than geometric and other models. It applies the historical data collected in a specified period and applies artificial intelligence to predict future coordinates of object location. However, as Kapitanova et al in [2] explains, applying backward propagation techniques requires heavy computation requirements and is inferior to artificial neural network models due to its low learning coefficient. In addition, the backward propagation model needs to be modified for every application.

There exist different artificial intelligence and mathematical approaches, approaches, which have been researching movement prediction of Mobile Objects(MO). Among these Markov chains, Bayesian networks, and neural networks. This paper presents and ANN-based approach. Some of the existing ANN-based approaches will be adopted and applied.

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II. Related Work

To predict or forecast a future situation; learning techniques Neural Networks are obvious solution. The challenge is to construct a model using the intelligent hidden relations and transfer these techniques to work with the desired problem information.

Mozer [3] focused on Home Environments Controls by studying the environment and the actions taken by people to attempt to predict their next actions, by learning the anticipation needs. Mozer [4] uses as a predictor a feed-forward neural network with one hidden layer for anticipating the next action. In [5] , the authors have proposed user pattern learning approach neural networks to reduce location update signaling cost by increasing the intelligence of the location procedure. This approach associates to each user a list of cells where mobile is likely to be with a given probability in each time interval. The list is ranked between the most likely and the least likely place where a user may be found. When a call arrives for a mobile, it is paged sequentially in each location within the list. When a user moves between location areas in the list, no location updates are needed. However ,this will demand the storing of all possible locations of an object , which leads to huge storage mass of data in case of many objects not to mention the processing time of scanning these locations frequently. In [6], Pakyan et al, formulated a predictive trajectory model based on piecewise segments with stochastic transition and observation noises. Empirically they found that the second-order Markov model outperforms the first order Markov model. Over the range of look-ahead length from one to ten seconds, Methods were complicated and no NN was used. In [7] NN was implemented for people tracking between restricted rooms , they extracted from the presented previous results, acceptable prediction accuracy obtained using a simplified prediction process. Comparing the dynamic predictor with the static trained dynamic predictor, showing that the pre trained dynamic predictors are more efficient than the dynamic predictors. The structure of their proposed NN is extended in this article to movements of object(s) moving on the segments of trajectories. Buizza et al. [8] transformed some prediction algorithms used in branch prediction techniques of current high-performance micro-processors to handle context prediction. He proposed various context prediction techniques based on previous behavior patterns, in order to anticipate a person's next movement. The evaluation was performed by simulating the predictors with behavior patterns of people walking through a building as workload. Their simulation results show that the context predictors perform well but exhibit differences in training and retraining speed and in their ability to learn complex patterns. Petzold et al. compared these predictors with the Prediction by Partial Matching (PPM) method, and they evaluated the predictors by movement sequences of real persons within an office building reaching up to 59% accuracy in next location prediction without pre-training and, respectively, up to 98% with pre-training.

III. The Neural Prediction Approach for Location Prediction

In order to predict future mobile objects locations and trajectories, Different models can be used to capture all information about the movements of objects on linear edges of road networks, as an example is using Cellular Automation Model (CA) which was introduced in this context in [9]. Simply, The input data for the neural network can be three-dimensional coordinates on a Cartesian plane, velocity of movement and the segment of the trajectory of movement. The output of the neural networks is used to calculate the mean absolute error of the predicted value. The system should be tested using maximum observation data to determine the ideal observations to minimize mean absolute errors [10-12]. The following is an illustration of the basic working of Neural network model.

We chose a multi-layer perceptron with one hidden layer (see Fig. 1) and back-propagation learning algorithm. The input pattern to serve as input layer will consist only of the location of the mobile object and specific edges (segments); the historical pattern of movement then is simply and easily can be used to derive the velocity and direction of movement, simplifying the input layer will save computing cost, which is of particular interest for mobile (energy restrictions) or fast moving (real_time restrictions) applications. The first step of constructing the input and

the output of the NN is to divide the MO trajectory into segments[13]

IV. MODELLING TRAJECTORY AS SEGMENTS

A moving object trajectory is a series of straight trajectory segments which can be generated, with perturbation of noise[13], any trajectory segment, is an element in a set where the next segment is following the previous one constructing a network of moving segments. As shown in Teble 1. This piecewise segment model will enhance the modelling of

coordinates to capture precisely the movement during the reporting position intervals. The trajectory is modelled by joining together multiple segments, where one segment is only dependent on the location and speed of previous segment. Segments related to the road network are only a fraction of the complete Trajectories, Trajectory can be Highway, Cycle way, Track type, Junction. These four Trajectories can have a lot of different values. However, only key-value pairs from Table 1 (only one tag specific for certain group is listed) are used for road networks[14].

Table 1 : Different segments of road networks

Key	Value	Element	Description	Map display	Photo
highway	motorway		A restricted access major divided highway, normally with 2 or more running lanes plus emergency hard shoulder. Equivalent to the Freeway, Autobahn, etc...		
cycleway	lane		A lane is a route that lies within the roadway.		
tracktype	grade1		Solid. Usually a paved or heavily compacted hardcore surface.		
junction	roundabout		Roundabout. This automatically implies oneway=yes, the oneway direction is defined by the sequential ordering of nodes within the Way.		

In order to predict future mobile objects trajectories, We modelled the movements of objects on linear edges using Cellular Automation Model (CA). The movement patterns (on edges) are represented by one dimensional possible locations (cells) , which can be either empty or occupied by objects .

V. DERIVING THE DATA SET FOR THE NEURAL NETWORK

The movement pattern M is recorded periodically in time stamp T by: location p; the direction (angel) and the velocity of the movement v. these parameters of movement were used to simulate mobile objects movements on selected road edges , and the resulted locations and segments were fed as training data to the NN by calculating future trajectories of MO on movement patterns on networks or random plain.

Precisely, if a mobile object moves continuously and periodically reports its location , then Mp1 represents the distance in terms of the number of cells travelled on particular segment (d, r1) of the Mobile Movement (MM) during period of time unit T1 ; Mp2 is the distance is travelled on particular segment during period of time unit T2, then T3 and so constructing periodically (every Time sized windows) pattern on specific trajectory . For example : $Mp=\{Mp1,Mp2,…, Mpn\}$ and $Mp1=(10,1)$ means the desired object was located at distance 10 on trajectory segment 1, $Mp2=(70,1)$ means: the object location is 70 cells on segment 1 if the time interval is 30 seconds then the implicitly indication of average velocity of 2.0 unit/second.

Dividing the set of Mp movements onto subsets, the first subset will be used as input in the training mode while the rest subset will be the desired

output. Applying this procedure with the generated data sets in the analytical simulation represents the trained and output sets. The architecture of the NN is adopted from[7].

VI. The Neural Network Architecture

Multi-layer perceptron with multi-hidden layers using activation function and back-propagation learning algorithm was used to construct the neural network. This model has two inputs (location and segment). And has two output neurons [7], figure 1.

a) The hidden layer

1. Create network and feed-forward with inputs,

$MP_i = Mp$, $Mp + 1$, $Mp + 2$ hidden units and Mpo output units.

2. Initialize all network weights

$$W_{i,j}^1 \quad , \qquad i = \overline{1, Mp},$$

$$j = \overline{1 + Mp_i} \ and \ W_{i,j}^2 \ , \qquad i = \overline{1 + Mp}, j = \overline{1, Mpo} \ \in \left[{-2}/{Mp}, \ \ {2}/{Mp} \right]$$

3. while $E(\overline{W}) - {1}/{2} \sum_{k \ in \ Mpo} (t_k - o_k)^2 \leq T \ (threshold) \ do$

- Input the instance $\overline{X}$ to the network and compute the output $\overline{O}$.

$$\overline{O} = \overline{X}. \overline{W^1}. \overline{W^2}$$

- For each network output unit k , $k - \overline{n1, Mpo}$
calculate its error term δ_k

$$. \ \delta_k - O_k(1 - O_k)(t_k - O_k)$$

- For each hidden unit h , $h - 1, MP_i$
calculate its error term

$$\delta_h = O_h(1 - O_h) \sum_{k \ \epsilon \ MPO} W_{k,h}^2 . \ \delta_k$$

- Update each network weight $W_{i,j}$

$$W_{i,j} = W_{i,j} + \Delta W_{i,j}$$

$$\Delta W_{i,j} = \alpha - \ \delta_i - X_{i,j} \ where \ \alpha \ is \ the \ learning \ step$$

The weights will be randomly initialized in the interval $\left[\frac{-2}{Mp}, \frac{2}{Mp}\right]$, where Mp is the number of neurons in the input layer. For better results we will codify the input data with -1 and 1 and we'll use the following activation function:

$$F(X) = \frac{2}{(1 + e^{-x})} - 1$$

We will vary the number of neurons in the hidden layer (Mp cells). We will try first Mp, Mp + 1, Mp + 2 where Mp is the number of neurons in the input layer as in, then by experiments we find the best configuration.

b) The neural network's training

For the training/learning process we used the well-known Back-Propagation Algorithm from [15] showed in figure 1, and adapted as below :
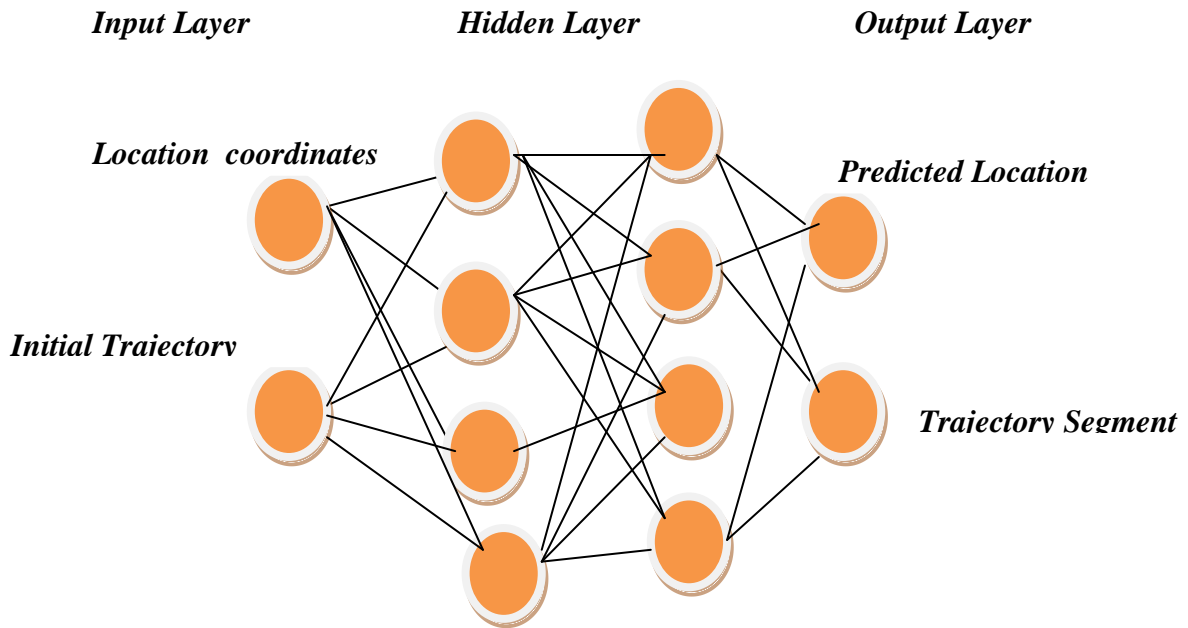
Input Layer   **Hidden Layer**   **Output Layer**

Location coordinates

Initial Traiectory

Predicted Location

Traiectory Segment

Figure 1 : The neural network's structure

VII. The Simulator and the Experimental Results

To evaluate the proposed approach, ANN methodologies (Multi Layer Perceptorn) are adopted. Simulation was developed on MAT LAB simulation environment. The proposed techniques was simulated on Pentium Core Due Processor 3 GHz CPU, 2 GB based RAM and 300 GB storage capacity based Personal Computer. Using the mathematical relationship, the model (MLP) was applied to predict the location management of the cellular network. we generated test sets of 70 randomly sampled locations and 20 trajectories segments , as was done in [6]. For each pattern in the test sets, 70 predictions were generated using the proposed NN model. The Experiment results is shown in figure 2. Cumulative distribution function plots of NN prediction patterns compared to the ground simulated   trajectories. Repeating the experience with dynamic training, shows that the NN make predictions closer to the analytical simulated locations.
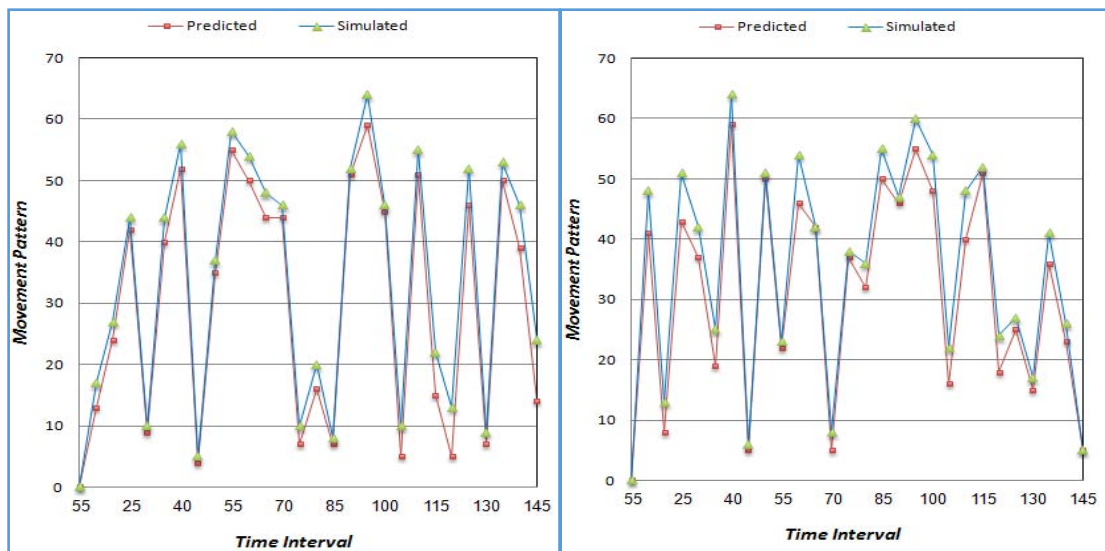
Figure 2 : Evaluation on randomly generated dataset

As to evaluation of accuracy the predictor is fed with a pattern sequence in every time stamp and predicts the next movement. The time intervals was divided into   predefined size. The accuracy measure shown in the chart is then calculated for each interval as follows[16]:

Accuracy = Number of correct prediction / Time interval size

Thus the accuracy is the number of correct predictions over the number of time steps, that is, over the total number predictions in that window. The number of time intervals is varied for comparison ease. Figure 4. shows charts of accuracy over time with dynamic training.

VIII. Using the Fuzzy Logic

Neural network models are efficient when historical data is accurate and precise. However, in large-scale object location assignments, it is often impossible to collect precise coordinates along the object's trajectory. This calls for application of fuzzy logic to overcome the challenge of imprecision in data[17]. Fuzzy logic can tolerate input of unreliable and imprecise data. It is also more intuitive compared to ordinary probability theory besides being easier to use. However, it requires more memory to store the rule-base especially when there are several variables[11] .

The rule base consist of IF (condition), Then (consequence) statements. The objective of the detection algorithm is to reduce incidences of false object detection. Fuzzy logic can accommodate data from several sensors and can augment them with the rule-base to minimize such false detections over time. A simple object detection rule would be as follows.

IF *Time 1*(first input location, Segment) AND*Time 2* (second input location,segment), And *Velocity* is (first reading location differences), THEN Object is (widely defined location).

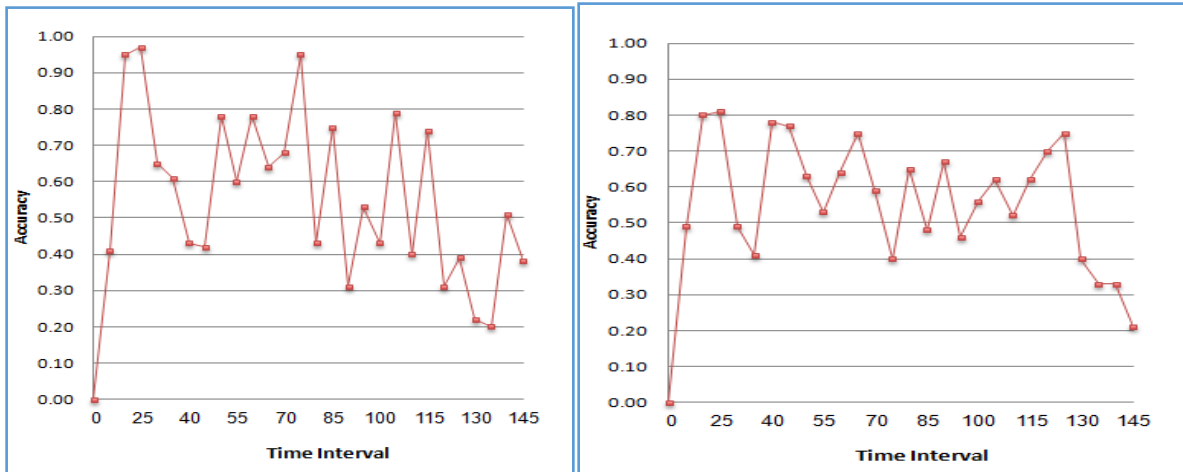Fig. 4 shows charts of accuracy over time with dynamic training.

Figure 3 : The predictive Accuracy of the NN model is measured by the number of correct predictions over the number of time resulting in less accuracy for large window time intervals

IX. Conclusion

Multi-layer perceptron with multi-hidden layers Neural Network for locating mobile objects was constructed, the movement patterns of the mobile objects were simplified and derived from the movement coordinates, direction, velocity and time. This approach relies on estimations from sensor data of historical movement patterns and geometric models, the resulted data is used to dynamic training of special Neural Network producing accurate predicted mobile objects locations up to 80%. Fuzzy logic application is used to overcome the challenge of imprecision in data.

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