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Development of agent based model for predicting emergency response time☆

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Summary Determining the time to reach any incident location by an emergency service is a very important aspect for emergency management. In most of the developing countries road network is considered as a main infrastructure for transporting emergency services. Therefore in order to predict the response time consideration must be given to the characteristics of road segments and driving behaviour of emergency vehicle drivers. In this paper real time driving data by Fire emergency service of Allahabad city is collected using GPS logger HOLUX M1000C. The spatial trajectories collected from GPS logger are analysed in GIS along with road network, population density and landuse data to determine the driver's route deciding behaviour. Based on the integrated analysis the Fire Emergency Vehicle Agent is designed. The Agent based model is simulated to determine the response time which is subsequently compared with the real response time.
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Introduction

In relation to emergency management process the estimation of response time plays a very crucial role. Response time is the time required by the emergency services to reach the incident point after getting incident information. The situations where road network is the medium of transportation of emergency resources, prediction of response time depends upon the quality of roads, traffic congestion and speed profile of various road segments. These factors affect the route selection behaviour of drivers. In most of the prediction models previous datasets are used for developing an approximation of real system. In the present research the dataset of route selection, vehicle speed and the time to reach a fire incident location is collected in real time using GPS Logger for Fire Emergency Vehicles of Allahabad City. The GPS trajectories collected are investigated along with the road network and attributes in spatial proximity, i.e. Landuse and population density to generate a weighted graph of road network. The shortest path algorithm in the resulted road network simulates the driver's behaviour. This computational method is then suitably framed for developing an agent based model. In agent based modelling the components of a system are

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modelled as autonomous computing entities known as agents. Here a GIS based Agent model is developed where the driver's behaviour is incorporated in FEV agents. During simulation the FEV agents moves from fire station to fire incident location and thus response time is determined.

Route selection behaviour

Route taken by the drivers and driving properties like max speed, average speed and acceleration are important aspect of modelling the driver's behaviour. Many models have been previously proposed, popularly known as Route Choice models. Route Choice model tries to determine the route to be taken from a set of alternative routes between a particular source and destination based on the utility function. In Galland et al. (2014) an agent based model is developed to simulate the driving properties of the drivers, i.e. max speed, acceleration, deceleration based on the condition of road. In order to model the Driver's route selection and driving behaviour real driving dataset is collected using GPS logger HOLUX M1000C. The GPS trajectories collected contains a sequence of GPS points with an interval of 1 second having attributes latitude, longitude, speed and time. The GPS trajectories are pre-processed and *Map Matched* with the road network data (*shapefile format*) to provide information about the road segments selected by the drivers and average speed on the segment while moving from fire station to fire incident location (Bandyopadhyay and Singh, 2014a).

A computing model to represent the route selection behaviour of Fire Emergency Vehicles is provided in (Bandyopadhyay and Singh, 2016). Here we are summarizing the work of (Bandyopadhyay and Singh, 2016), the results are included in the present work. The route selection of the Fire Vehicle drivers is based on the physical characteristics of road segments and endogenous congestion on the road segments. The physical characteristics include length and width whereas the endogenous congestion is determined by the landuse and population density of the proximity of road segment. The road links selected by FEV drivers previously is analysed in GIS along with attributes width, length, landuse and population density to assign weightage to the values of attributes.

$$Sw_i = \alpha_1 \times w_{i\text{Length}} + \alpha_2 \times w_{i\text{Width}} + \alpha_3 \times w_{i\text{PopulationDensity}} + \alpha_4 \times w_{i\text{LandUse}}$$

w_{ij} Weight of attribute j of i road segment.
Sw_i Weight of road segment i.

The values of $\alpha_1, \ldots, \alpha_4$ are determined by using an iterative process in which the routes generated by Dijkstra's algorithm is compared with the actual routes. The model proposed in Bandyopadhyay and Singh (2016) has a matching percentage of more than 80% with $\alpha_1 = 1.5$, $\alpha_2 = 1$, $\alpha_3 = 0.5$ and $\alpha_4 = 2$. The shortest Path Algorithm on the generated weighted road network provides the required route that approximately represents the driver's route selection behaviour (Fig. 1).

The endogenous congestion in a road segment certainly affects the vehicle speed. The congestion is due to regular activity in the proximity, width and population density (Litman, 2011; Shiftan, 2008). The Road segments are classified into different classes based on attributes landuse, population density and width and sufficiency of samples as shown in Table 1. The different classes are assigned mean speed and standard deviation based on the processed collected GPS data.

Agent based modelling

In agent based modelling heterogeous components of a system is represented as autonomous computing entities called Agents. Each Agent constitutes two components properties and behaviour. A detailed description of Agent properties and behaviour is provided in Bandyopadhyay and Singh (2014b), Birkin et al. (2012). Each Agent interacts with entities in its perceiving environment according to the behaviour rules. The complete Fire Emergency Response model constitutes Fire Incident, Fire Station, Fire Emergency Vehicle and Road Agent. The route selection behaviour and driving speed on various road segments are modelled in Fire Emergency Vehicles and Road Agents.

For FEV agent the perceiving environment consist of all the Road segments. When the FEV agent receives dispatch message from Fire Station agent, the FEV agent decides the route based on Dijkstra's algorithm. The road segment agents are weighted as described in earlier section. As par the attributes of road segment agent, each road agent is assigned a speed randomly within a range based on mean speed and standard deviation using Gaussian distribution.

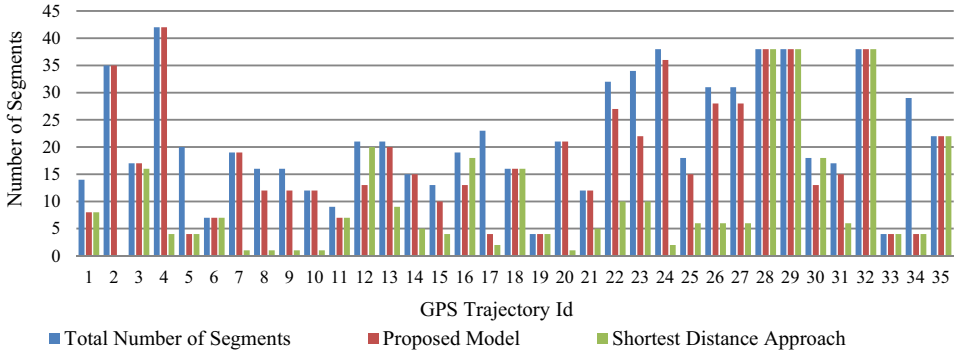

Figure 1 Comparison of proposed model with actual routes selected and shortest distance approach (Bandyopadhyay and Singh, 2016).

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