Optimisation of Emergency Medical Dispatch through Simulation

Research Student: Marcus Poulton, Department of Computer Science and Information Systems, Supervisors: Professor George Roussos, Dr. David Weston

ABSTRACT

Our research is focused on finding new approaches of ambulance deployment through the use of discrete event simulation, using London Ambulance as a case study. Historically, research in this area has focused on a strategic, off-line approaches rather than tactical, on-line approaches to ambulance deployment.

We ask:

- **Can an emulator accurately represent an ambulance system?**
- **Using novel dispatch models, can an emulator improve on system performance?**
- **Can the historic GPS data be used to accurately predict emergency journey time?**

BACKGROUND

We propose a simulation model that can be used to model the ambulance redeployment and dispatch process accurately. To improve accuracy of the model we explicitly take into consideration time-dependent elements, such as travel-time, on-scene time and at-hospital time. We also propose a new combined redeployment and dispatch model and show that resource arrival times can be improved over an extended period of time.

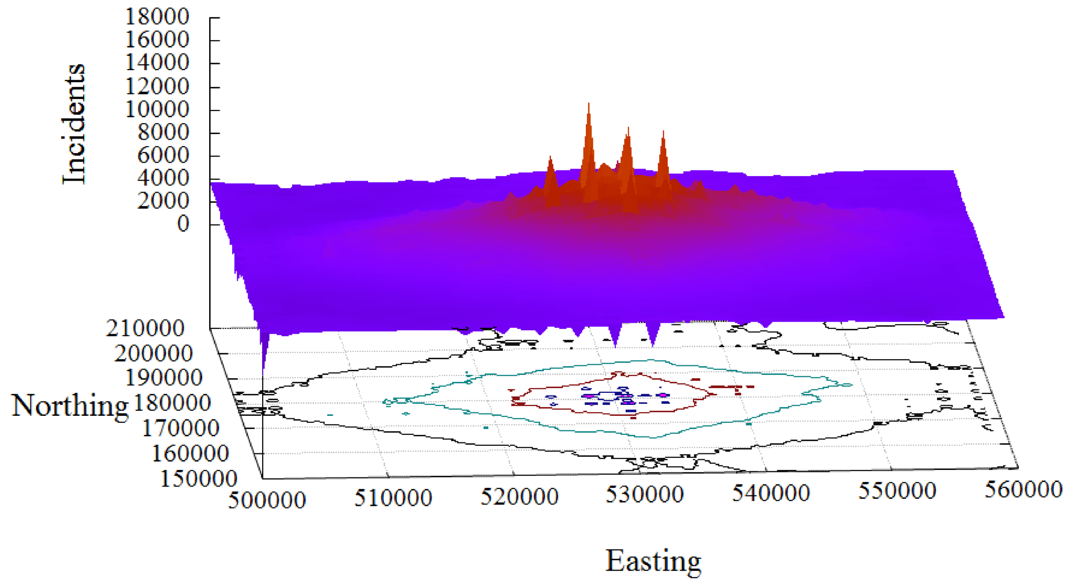


Fig. 1: The Dynamic City – Understanding where emergencies occur

Fig. 1 shows the number of emergency incidents in London during the last 10 years. We turn this data into hourly forecasts.

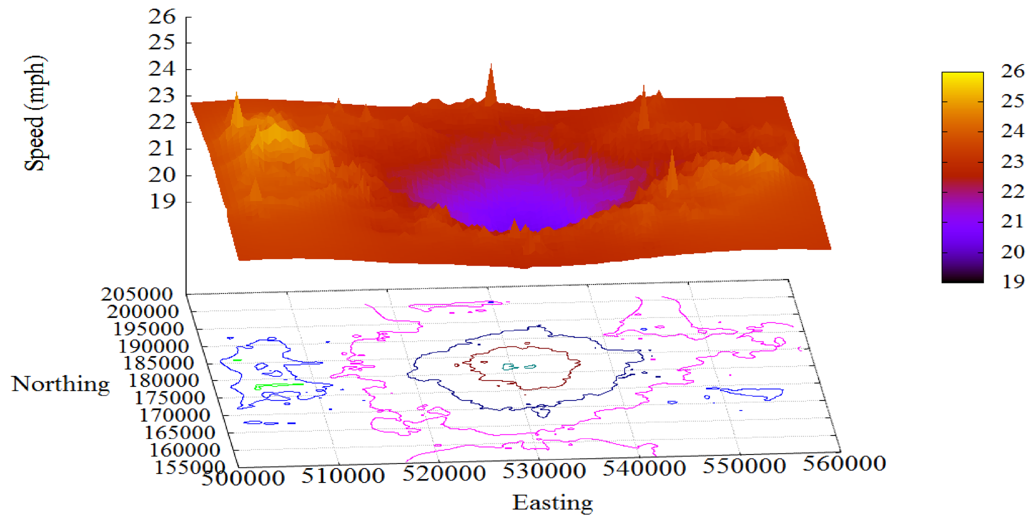


Fig. 2: The Dynamic City – Understanding emergency vehicle road speeds

Predicting how long it takes an ambulance to get from A-to-B in London is essential for our research. Fig. 2 shows typical speeds at 9am. Speeds in the centre of London drop dramatically. Suburban areas see a less drastic effect.

METHODS

Augmenting Road Speeds

The first task in our research is to build a simulator that implements accurate movement of ambulances. Our simulated ambulances must travel along the road network at speeds similar to real ambulances. This requires accurate mining of speeds from existing GPS data. We can't simply snap GPS positions to nearest roads as road segments are missing or incorrectly identified (Fig. 3). We trial two map-matching algorithms methods to overcome this limitation a) Road Constrained Particle Filter, and, b) Hidden Markov Model with Viterbi (HMM/V). So far, the HMM/V algorithm has proved successful in mining over 500,000 ambulance journeys.

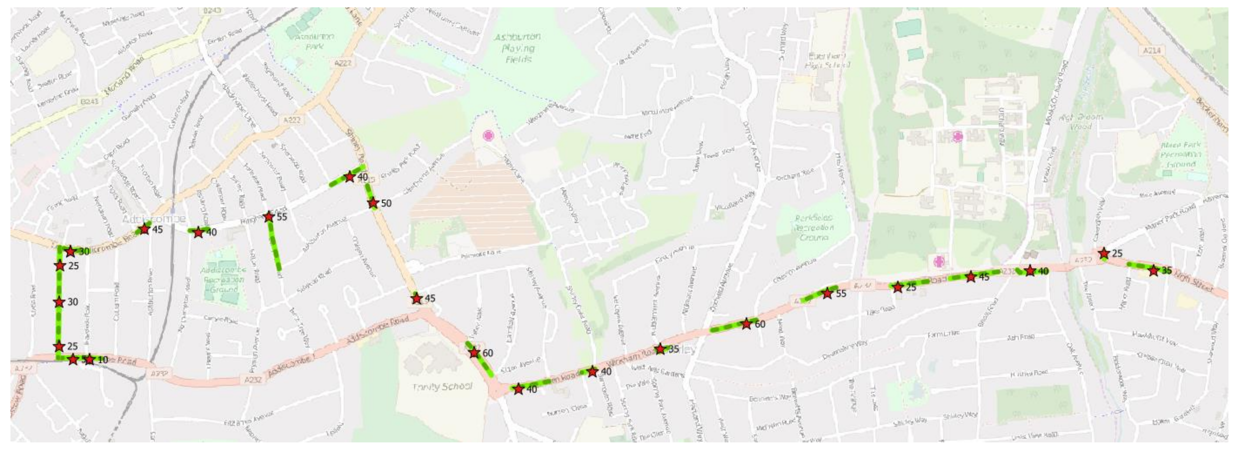
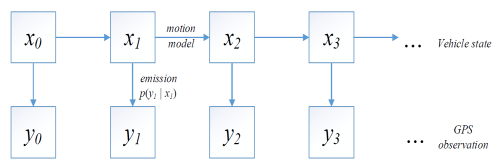


Fig 3. Sample route using simple nearest road snapping. Some roads are incorrectly matched and many road segments that the vehicle passed along have no fix.

Road-constrained Particle Filter

Particle filtering is a Monte Carlo sampling method for performing inference in an evolving state-space model. The filter attempts to sequentially estimate the probability density of internal hidden states given noisy or partial observations using many particles.



In our case, each internal hidden state is a motion vector of a vehicle on a road network at any given time. A single particle is used to represent a hidden state and a probability of being in that state. Particle filters typically use thousands of particles to represent the state distribution at any one time. The use of particles in this case is useful when the distribution of unobserved states cannot easily be represented and require non-linear methods. The particles collectively form what is termed the *posterior distribution*, which is a distribution that is formed after relevant information, such as the GPS fix, is taken into account. The output of the particle filter is an estimate route that the ambulance may have taken,

Hidden Markov Model with Viterbi

The HMM/V takes GPS fixes as input and generates an estimated road route. The HMM contains a matrix of weighted candidate road positions using a custom emission probability density function. Transition (Exponential) probabilities determine likelihood of moving from one candidate to the next.

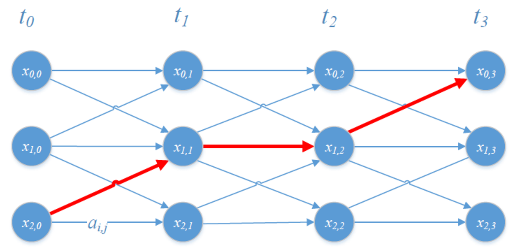


Fig 4. Viterbi algorithm finds the best path through the HMM

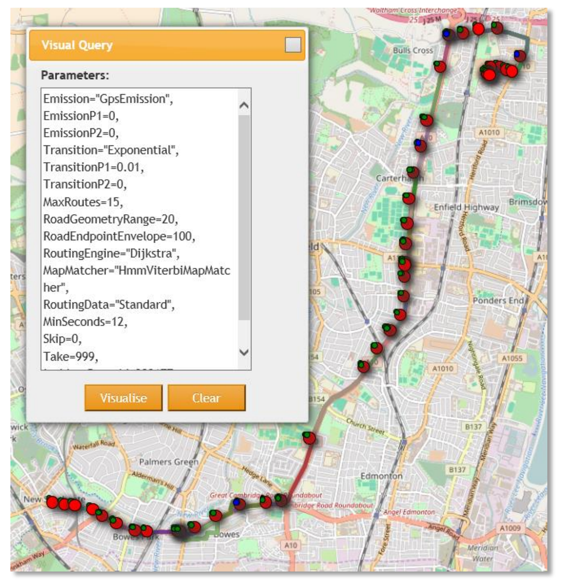


Fig 5. Example road track from GPS data using HMM/V

A Viterbi path is a dynamic algorithm for finding the most likely sequence of hidden states through the HMM. Given a HMM with state space S, initial probabilities π_i of being in state i and transition probabilities $a_{i,j}$ of transitioning from state i to j. We observe outputs $y_1..y_t$ in the form of GPS fixes. The Viterbi path is the most likely state sequence $x_1..x_t$ as depicted in Fig 4 by the red line. Our efforts have concentrated on establishing suitable emission and transition parameters (amongst others) for the successful generation of estimated road routes from GPS fixes.

AIMS AND OBJECTIVES

In initial aim of the project is to build a robust road routing engine that would act as a solid foundation for the ambulance simulator. The routing engine will be used to accurately simulate ambulance movements across London and also provide necessary vehicle coverage calculations for the novel dispatch algorithms. We have recently managed to analyse and extract road speed information from over 500,000 historic routes taken by emergency vehicles. A web-based application has been developed to make the running of experiments a lot easier (an example of its output is depicted in Fig. 5) and has helped significantly in diagnosing and developing the map matching algorithms. The current stage of work is the building and evaluation of road speed models for the accurate prediction of routing paths and arrival times. The process will be repeated once we have received more up-to-date data from the LAS. Further analysis is required on the performance of the routing engine to verify its accuracy. I intend to publish a paper on this aspect of the research.

Work will start on the simulation when the road routing engine work has completed. The simulation code will be brought forward from previous research work and implemented in the web application. The dispatch algorithms will then be developed and run in the simulation environment and compared with historic performance.

Publications

M. Poulton and G. Roussos "Towards smarter metropolitan emergency response" in *2013 IEEE 24th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC)*, pp. 2576-2580, Sept. 2013