Multi-Agent Systems in Rail Freight

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Abstract

Supply chains are increasingly pressured to deliver products quickly and cheaply whilst reducing costs, energy and emissions. It has became important for the logistics industry to take advantage of the latest algorithms to find the best solution for their needs.

Advances in technology - specifically processing power - gives researchers and businesses the power to process huge amounts of data. Multi and many-objective algorithms combined with these more powerful computers allows the most efficient solutions for supply chains to be discovered without the laborious work of calculating it manually.

The proposed research will bring together these algorithms, Agent-Based Modelling and Graph databases (Big Data) to create a unique simulation based in Northern England.

Introduction

Supply Chains transport goods around the globe, with the aim to transport those goods as efficiently as possible, making strategic decisions about where to locate warehouses, factories and other assets. Customers want their items to arrive quickly as they are used to faster means of content delivery methods which has been made possible thanks to the Internet.

Supply chains have needed to evolve over time due to consumerism and globalisation. Initially the logistics industry had the simple aim of getting a product from one location to another in the most cost effective way. The logistics industry has had to make improvements to allow businesses to better organise their stock levels more efficiently, deliver products quicker and other various requirements.

Also, as consumers have expected goods to arrive quicker, companies have had make use of multiobjective algorithms to take account of more parameters to make their supply chains more efficient. With climate change, modern supply chains also have to incorporate reductions of energy use and emissions whilst still trying to reduce costs, time, stock levels, etc. This of course, has been made easier with advances in technology and where multi and many objective optimisation comes into play, to find the best balance depending on the specific business' needs [9].

Advances in technology has had a significant impact in increasing global businesses and supply chains. It has allowed more accurate forecasting to predict demand in order to expect what sort of stock levels are needed in a warehouse [4] or where to strategically place assets.

Main Objectives

1. Create as close to realistic simulation of Northern England's rail freight.
2. The ability to plug in real world data as it is received including (but not limited to) train schedules and freight train loads.
3. Reduce costs and emissions in the rail freight industry.

A simulation using various techniques will be used to create as close to realistic simulation of the freight industry based on Northern England with the use of **Graph Database**, **Agent-Based Modelling** and modern **optimisation** techniques.

Agent-Based Modelling

The idea of ABMs first appeared in the 1940s but didnt become popular until the 1990s [2].They became useful for the simulation of complex systems including financial markets, socio-economic systems and transportation. Agents themselves are very simple and primarily perform if-then-else functions but there needs to be a way to manage the number of agents involved [3]. Although the agents individually are very simple, they overall represent a complex system.

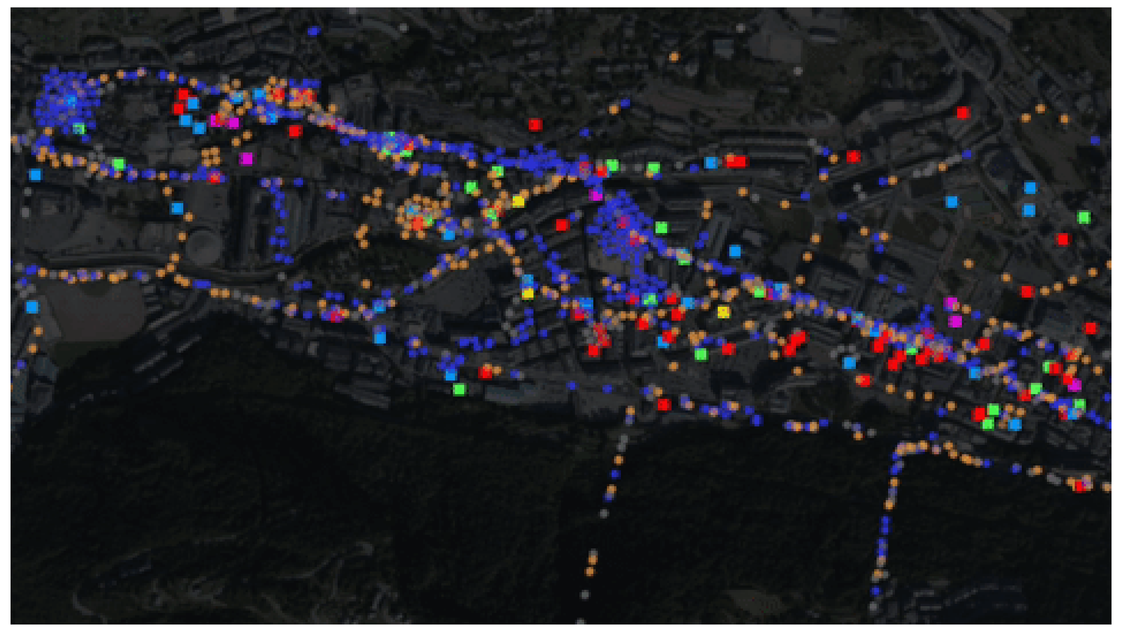

Figure 1: An example of ABMs on roads [10]

Agent-Based Models (ABM) can be seen as the natural extension of the Ising model which has been very successful in the past decades, shedding light on various physical phenomena. Cellular Automata is an example of agents with simple rules creating complex and impressive visualisations.

Multi-Agent Systems (MAS) are becoming predominant within the computer simulation tool-set and involve multiple agents interacting with one another. They are used to solve problems that are too complex for individual agents. They overlap with ABMs due to the many similarities [5].

An agent within this system is a simple train going from a starting location to a destination. Another example of an agent is a supplier or warehouse owner making random transactions.

A more complex agent representing a logistics company will be used to control multiple train agents by having them use the most optimal route.

Graph Databases

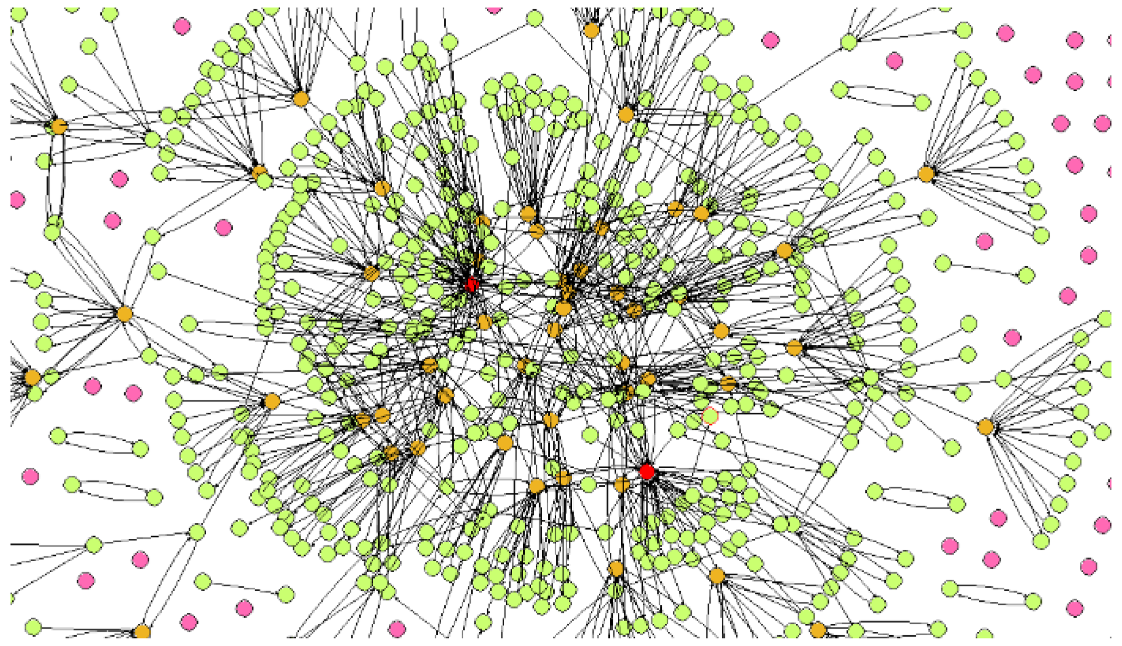

Figure 2: Graph database connections [8]

The quantity of data being collected is growing at a huge rate. More data was created in 2013-15 than in the entirety of human history, with more than 44 trillion gigabytes accumulated by 2020 [6].

In a world where more data is being stored about an individual - i.e. Facebook and Google - it is important to move away from the traditional SQL based databases.

Graph databases consist of two things: nodes and relationships. A node represents an individual item such as person or place whilst a relationship stores how each node is related. Facebook, Google, LinkedIn and PayPal have harnessed the power of graph databases for use with their highly connected data [7].

Graph databases will be used for this research to store the map data as nodes, in particular railway stations, ports, and rail links. Graph databases are designed to handle this sort of data and allow the user to view connections between each node. As more map data is added, performance does not become an issue as it would with SQL databases whilst remaining flexible when changes are needed. An excellent example, showing the performance of a graph database, is to find the shortest route between two points on a map.

Optimisation

Evolutionary Multi-Objective Optimizations first appeared in the 1980s [11] but became popular in the 2000s and new algorithms are proposed every month making it increasing difficult to track new algorithms [1].

The simulation will have the ability to compare popular optimisation algorithms such as IBEA, NSGA-II and SPEA2. The algorithms will be used to find a Pareto-optimal, making sure the best routes and schedule are chosen, optimising the use of freight resources.

A Pareto-optimal is a solution where an improvement to one parameter does not do harm to any others.

Conclusions

In order for supply chains to maintain their position in relation to consumer demand, they have to become more optimised and creative. This research aims to uncover new strategies and methods to improve the efficiency within northern England.

The graph database will be used to store OpenStreetMap information containing the entire UK road, rail and water network. They do, have their limitations so a standard SQL database will be used in conjunction to store simple information such as logistics companies, suppliers and vehicle information.

Optimisation techniques will be used by more complex agents to determine how multiple - more simple - agents (trains) work by determining the best route and schedule to take.

A continuous simulation using the previously outlined technologies will allow searching for new solutions. The simulation will also have the ability to create custom optimisation algorithms to potentially discover new - more efficient - algorithms.

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