Applications of genetic algorithms on fully-autonomous road networks

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My Topic

- Semi-autonomous vehicles are becoming more prevalent
- Roads are becoming more congested with a 78% increase in motor traffic since 1993 [3]
- Fully autonomous vehicle trials have been legal in parts of the US since 2015[1], with the UK set to follow by next year (2021)[8]
- Much of the current research into autonomous vehicle routing focuses on environments where human drivers are still present
- By removing the human element and working on theoretical *fully autonomous road networks* we can make many useful assumptions about the behaviour of other vehicles
- The solution to road congestion is not to build bigger roads, it is to optimise the traffic flows.
- Just 78.2% of journeys on the UK Highway Agencies roads were *on time* in the year ending June 2014 [7]

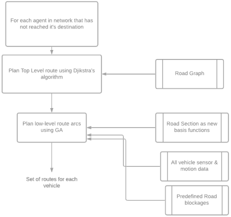

Figure: Abstract Project Topology

- From a technical perspective, there are many things that need to be implemented to make such a system possible.
  - The functional representation of vehicle trajectories
  - The encoding of routes into a real-valued string of genes
  - The decoding of a real-valued string of genes to a route which a vehicle can take
  - The implementation of a function to determine the fitness of an individual route.
  - Implementation of genetic operators: Selection, crossover and mutation.
  - Cleanup operators to make certain any new individuals are valid

My Goal

My goal with this project is to investigate the feasibility of such a system.
To do so I will *programatically* implement an experimental version, making various assumptions about the data available to it.
With my system I hope to be able to run various simulations to determine it's performance in quasi real-world scenarios and conclude as to whether the use of GAs have merit in this area.
Currently the research yields no such results. The feasibility of similar systems have been discussed[4] but never experimentally investigated.

Literature Review

I am currently intending to pursue my research assuming the absence of classical speed lanes as described by Kala and Warwick in [6].
I have chosen to focus on the applications of Genetic Algorithms on the field for 3 reasons:

1. It is a class of optimisation algorithms that I find particularly interesting
2. GAs are *probabilistically optimal and complete*, i.e given infinite time, they will always produce the global optimal solution if such a solution exists[5]
3. It is a class of algorithm that has seen relatively minimal research in my specific sub-area

- Other approaches involve *black box* methodologies, such as the use of Reinforcement and deep inverse reinforcement learning by You et al.[9]
- The downside of such an approach is that it is very difficult to reason and predict the actions of the system with a high degree of certainty. The ability to assure safety of such a critical system is very important and so GAs offer a much more predictable result
- Kala and Warwick [5] proposed a system of two coordinate systems to safely represent points on the road within Cartesian space.
- In a book by Kala [4] he proposes GAs optimise Bézier curves representing the movement arc of a vehicle

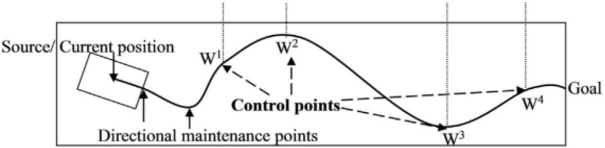

Figure: Bézier curves for route representation from Kala [4]

- A Bézier curve with n control points is said to have a *degree* of $n-1$ (initial point is called P_0 and is not counted in degree)
- A Bézier with a degree of 1 is a straight line between the two control points (the start and end point)
- Further control points *bend* the line into a curve.
- The curve does not necessarily pass through all intermediate control points but it is determined by them.
- Bézier curves are smooth $\implies$ good for representing vehicle routes
- Trivially, they are also continuous so will represent an entire route from $A \rightarrow B$

- By their definition, Bézier curves are parametric. This lends themselves nicely to an parametric optimisation techniques such as GAs.
- We can represent the control points as genes in the genome of each candidate.
- We can represent a curve's fitness as its length within feasible space.

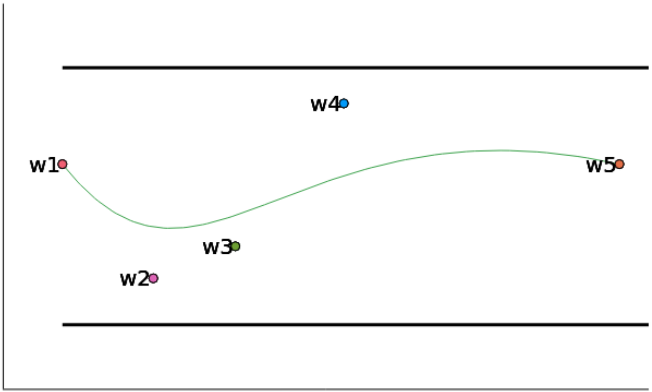

Figure: Example of Bézier curve of degree 4 in road coordinate space, my implementation

Methods

I have started by reading and collating papers, books and articles surrounding GAs and their applications on routing problems.
I have found substantial research into GAs but only a few papers on my sub-area, mainly by Rahul Kala from the Indian Institute of Information Technology.
I have begun implementing various utility functions and types in Julia[2], including:

- Bézier curve functions
- Road, Individual, Phenotype and Genotype types
- Plotting utilities for Roads and candidate solutions
- Population initialisation functions

Still to implement:

- Genetic operators
- Cooperative route planning wrapper

Once a basic GA has been implemented, the stage of variable and operator refinement can begin.

There are many oppertunities for improvement of GAs with a wide variety of crossover and mutation techniques being discussed in literature, each performing differently depending on the search space.

One aim of my report will be to assess and collate the effectiveness of a wide variety of such operators, with the hope of concluding which are best for the task.
GAs can also be augmented via the use of domain-specific heuristics and as such I will investigate this area also

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