Machine Learning based Dispatching for Autonomous, Single Track Cargo Vehicles

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Topic

I seek to develop a machine learning based algorithm to control the dispatching and pathing of autonomous robots, used to carry objects, operating on a physical or virtual rail network in an efficient and optimized fashion.

Applications

There are many applications for such an algorithm that can be reduced to a set of agents and a set of goals all existing within a directed graph network of tracks. Each goal is a triplet consisting of an origin, destination, and constraint condition or priority. Optimized solutions require agent cooperation to varying degrees depending on the application.

Application	**Track Type**	**Cooperation**
Freight Rail	Physical Rail	Forming platoons leads to vastly decreased air resistance which reduces cost even when taking longer paths or delaying departure. Utilizes virtual coupling (F. Flammini)
Warehouse Robots	Line Follower	More dense network, increased priority on maximal utilization, ensure robots spend as much of their travel time carrying payloads as possible to not waste charge.

Campus Delivery Rovers	Virtual Rail	Lower overall utilization, less dense network, platooning can decrease campus disruption, more time sensitive operation, no task can be out prioritized for long periods of time.

All of these vehicle types operate in similar environments; they travel on single track networks and must cooperate and plan accordingly. I believe that an efficient and optimized dispatching algorithm could be utilized in all of these applications with reasonable parity and with immensely valuable payoffs.

Prior Work

Ride Sharing

Upon brief preliminary research, there seems to be a lot of research into rideshare optimization algorithms utilizing machine learning. These applications usually rely on the desire to hold multiple people within the same vehicle who have different beginning and ending destinations. The algorithms seek to plan routes which optimize travel times for individuals and decrease costs for the companies. These dispatching algorithms are already developed and being used by rideshare companies.

Petri Net

Much peripheral work has been done into optimizing scheduling algorithms, Petri Net, for example, is a scheduling algorithm represented by a directed graph of Places and Transitions which can hold tokens. The tokens must be moved in prescribed ways between the Places and Transitions. Petri Net, and other scheduling algorithms, provide valuable background to solving this problem. (Yan-cong Zhou)

Freight Rail

A lot of research has been done into the immense benefits of platooning freight vehicles from an economical and environmental standpoint. This is a key factor in the optimization of this specific task.

Warehouse Automation

Warehouse automation has shown great value to companies for many years which means there is more research in this specific application including prior work utilizing custom simulations which will be very useful for my own research.

Campus Delivery Rovers

Small delivery rovers are only starting to appear more often in the market which makes this a novel path of exploration as well as immensely beneficial to the Campus Rover project.

All of these tasks center around a dispatching algorithm for vehicles which only carry a single payload (as opposed to multiple people with different destinations) but desire economic and environmental improvements brought about by cooperation.

Simulation

To tackle this novel problem I will first need to create an efficient low level simulation to be used for the testing and evaluation of this problem.

Simulation Use

I see two possible utilization paths for this simulation. Either the simulation will be used to generate data which the neural network could quickly train on and then final evaluation could be done using the simulation. This would remove the simulation from the training paradigm.

Or, the simulation could be used in the training paradigm with some type of reinforcement learning as seen in DeepPool. (A. O. Al-Abbasi) More research will need to be done into the feasibility and value of each of these solutions before a decision is made.

Requirements

- This simulation will need to be as accurate as possible, utilizing real data such as drag force reductions for platooning and informed cost metrics.
- This simulation should be customizable for anyone to use in their personal work. I plan to research more related simulations to inform my design and execution; however, the Morgantown People Mover simulation for software testing seems to be solving a very related task and could be very informative. (T. A. Zimniewicz)

I imagine my simulation will feature a custom graph network configurable to represent a rail network. The simulation will likely involve a random spawning of agents and cargo to be moved at different times throughout the day to different locations.

As part of my work with MIT Driverless I developed a small Python simulation to test our object tracking algorithms which is why I am particularly interested in taking on this much more complex simulation task.

I would like to complete the simulation by the end of the first semester and provide the code as part of my final deliverable.

Research and Work

The primary purpose of my first semester will be to create an accurate simulation which can be used to facilitate the discovery of this model. I will begin the semester with a comprehensive survey of the state of research in relation to my topic. This will include studying algorithms that solve related issues (DeepPool for example) and solidifying the real world use cases of my model to pinpoint its exact objective.

Research Questions for First Semester

- Which costs affect companies the most?
- How can autonomous vehicles reduce energy consumption?

Most importantly, a lot of research in the first third of this semester will go into what makes an effective simulation.

- How many agents should be available?
- How big should the track network be?
- What assumptions need to be made in simulation?
- How customizable should the simulation be?
- How will a user or an AI provide input?
- How much will the simulation delay training times?
- What other simulations have been created for similar tasks?

I aim to “complete” this section of research and project scoping between the first third or the first half of this semester which will allow the remainder of the semester to be used to write and test all code necessary for an effective simulation.

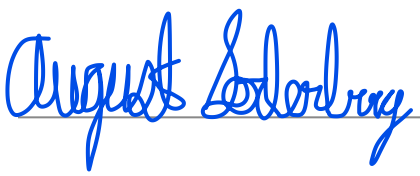
The second semester of work is where the primary machine learning work will begin. As I have seen in my prior work, the first ideas and attempts at developing machine learning models to solve a task usually fail quite often. This is why I am leaving the first half to two thirds of the second semester purely for training and developing a machine learning model to solve this task. Keep in mind that research into what types of models and how they will be trained has been completed in the first semester. I aim to see promising results by the first half or two thirds of the semester which leaves the last third to focus on writing my thesis as well as any finishing touches, small training adjustments, and code cleaning and refactoring that needs to be completed. I think this timeline of deliverables is realistic and achievable.

As a final recap, the first third or half a semester will be a demonstrable research phase with concrete plans and knowledge being developed. The second half will be focused on the creation of a simulation which will be usable by the end of the first semester. The first half to two thirds of the second semester will be to create and train a model which solves the task at hand. The last half or third of the semester will be for paper writing, code cleaning and packaging, and any loose ends that need to be tied up. A timeline has been provided below with deliverables.

Date	Topic	Deliverable
Oct 18, 2021	Research	Document containing specific details of how the simulation will function (almost like a wireframe). Documented research and analysis into all previous research informing my current research. Type of model (or models) I will create to solve this task and explanations of the benefits of them. Full report of cost metrics I will consider when

		creating the simulation; this includes physics calculations, as well as monetary figures for things like costs of delays.
Dec 17, 2021	Simulation	Full feature simulation to be used in training. Code (not polished as small changes will probably be made) will be provided as well as a live demo showing features, a simple algorithm showing baseline performance, and demo of modularity of the simulation.
Apr 4, 2022	Machine Learning Model	Created and trained model with results showing improved performance over baseline. Multiple models trained on different circumstances from simulation. Performance should be >95% of the final result in the paper. This means I am not just starting to see a promising method forward, I actually have solved the task at hand.
May 9, 2022	Paper + Code	Publishable Paper, Clean and polished code for full simulation, clean and polished code for machine learning model, and pretrained model(s) solving the proposed problem.

Submitted by: Accepted by:



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