Fall 2016 ME Graduate Poster

Title: A hierarchical route guidance framework for improving mobility of off-road connected fleets

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Biography

I pursued my under-graduate studies from NIT Bhopal, India and work under Prof. Ameenur Rehman on analysis of fuel spray pattern. After my graduation I had joined VE Commercial Vehicles Ltd. (part of the VOLVO group) and worked for 5 years in engine controls and calibration. I had lead the development of a 4-cylinder light duty Selective Catalytic Reduction (SCR) Euro IV OBDII engine and was the part of the team which developed the first Euro IV commercial vehicle engine in India with Exhaust Gas Recirculation (EGR) and only Diesel Oxidation Catalyst (DOC). I had joined Dr. Vahidi's research group in Clemson University in Fall'2015. Currently I am working on off-road autonomous driving using connected vehicle technology. I am also working on a robot equipped with Inertial Measurement Unit (IMU), camera and ultrasonic sensors, developing algorithms for point cloud terrain mapping and autonomous driving.

Overview:

Improvements in fleet energy efficiency and safety are of paramount importance to the Army. I am working on a novel path-planning algorithm as part of a decision support tool for off-road scenarios. The algorithm incorporates a-priori knowledge of the low resolution soil and elevation information. The proposed hierarchical path-planning algorithm distributes the computational cost to find the optimal path over a large terrain. A dynamic programming (DP) method generates the globally optimal path approximation based on various information like soil condition, elevation, visibility, etc. The optimal cost-to-go from each grid cell to the destination is calculated by back-stepping from the target and stored. A model-predictive algorithm finds the locally optimal path over moving radial horizon using the cost-to-go map and high resolution elevation map. I am also trying to implement the local optimization on a scaled autonomous robot.

Motivation

Since the last decade a lot of research work has been done on autonomous vehicles but most of the research is confined to on-road vehicles. Off-road driving presents significant challenges when compared to on-road [1], [2], [3], [4]. Unlike motion of on-road vehicles which are constrained on the road network, motion of off-road vehicles have more route considerations for the optimization routines. Various algorithms have been proposed for cooperative path planning of unmanned aerial vehicles [9], [10], [11], [12], [13] in recent years. Constraints imposed due to the terrain make the translation of such algorithms for ground vehicles very inefficient. For many critical missions like transportation of military cargo, personnel and mined ore, it is desirable that the vehicles are commandeered real-time by humans. For remote fleet operation, assisting the vehicle operator with updated route guidance can be a critical difference. We are exploring a framework for efficiently creating, updating and sharing route critical information among fleet vehicles and a central server, and using the information to update the prescribed routes.

State of the Art

Efforts have been made for improving the ride quality in off-road driving based on rough-ness of the terrain [5]. Additionally, the path optimization routine needs to efficiently access and handle 3D terrain information. In recent years' considerable effort has been spent on detecting and classifying the terrain [3], [6], [7], [8]. Recent terrain mapping efforts can largely be classified into two approaches; developing a terrain model with obstacle constraints based on vehicle sensors and using high resolution terrain information collected a priori. An opportunity exists to utilize and combine the strength of the two approaches. Algorithms have been proposed for collaborative path finding for autonomous vehicles [14], [15], [16], [17].

Intellectual Merit

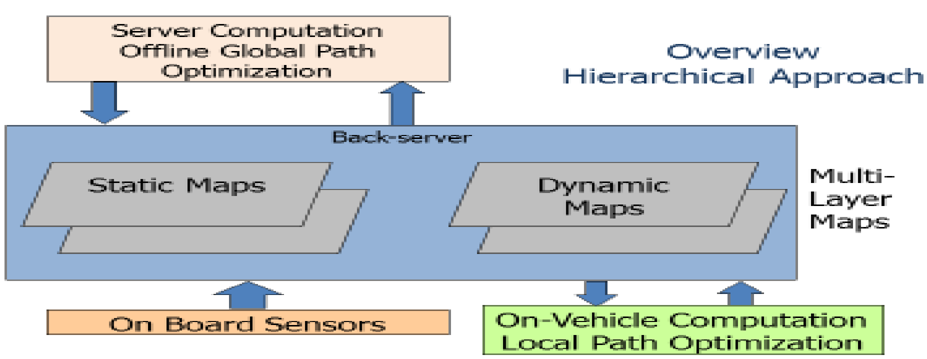
Combing a Dynamic Programming and Model-Predictive-Control approach in improving online computations for path finding using a backend server for sharing information is a novel approach which we are trying to implement in this research. Efficiently creating, updating and sharing route critical information among fleet vehicles and a central server, and using the information to update the prescribed routes in a layer based approach is also another novel area of this research. The work will facilitate off-road autonomous or semi-autonomous driving in the future.

Broader Impact

This research has the potential for improvement in on off-road driving. The future scope of this work is getting GPS directed path for the driver in off-road conditions which is limited to on-road driving currently.

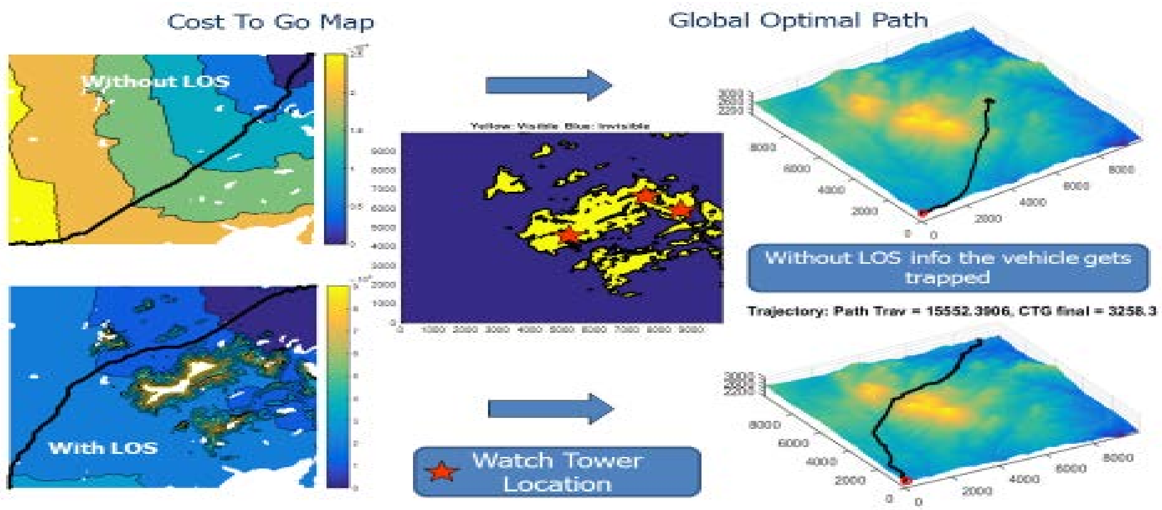
Research Approach

Fundamental Concepts (Dynamic Programming, Model Predictive Control, Vehicle Kinematics and Dynamics, etc.) Experimental plan: We are currently working on a scaled robot which follows the guided path given by the global optimization routine avoiding obstacles while being locally optimal by running an MPC on-board. Our Architecture is shown in the figure:

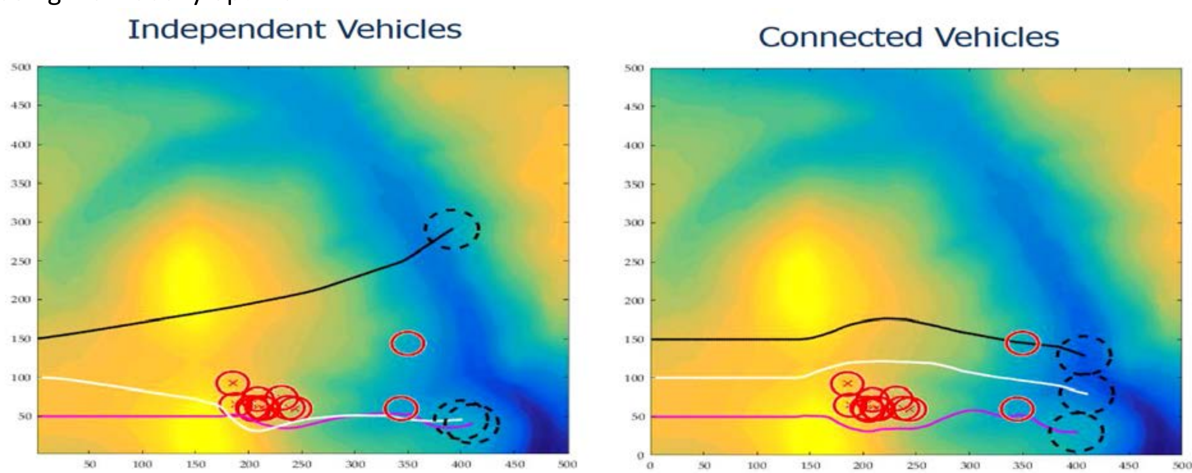


Findings to Date

1.Having a DP + MPC approach prevents the path finding algorithm from being short sighted and being trapped in a local optimal path. Also the layer based approach helps in improving the safety of the fleet.



2. Connected Fleets sharing information in off-road conditions can improve path planning and avoid the fleet from getting scattered (for e.g.: while being attacked the fleet can take precautionary measure but the safety of the fleet is in staying together and be optimal as a group rather than being individually optimal.



Conclusions

Major anticipated results are:

1. To prove that the approach which being globally optimal is optimal at the local level.
2. To prove approach is computationally efficient to be implement on real vehicles and run series of simulated vehicles.

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