

ECE4011/ECE 4012 Project Summary

Project Title	Harris Path-Planning A
Team Members (names and majors)	Jacob Jeong, EE Alvin O'Garro, CmpE Antony Samuel, EE Kartik Sastry, CmpE
Advisor / Section	Prof. Erik Verriest / A05
Semester	Year/Semester Final (ECE4012) - Fall 2018
Project Abstract (250-300 words)	<p>A major challenge for mobile robotic systems is path planning. Harris Corporation, an American technology company and defense contractor, is sponsoring the development of a 3D path planning tool for quick and efficient routing towards a static or potentially dynamic target using airborne LiDAR/Hi-Res 3D point cloud data. Harris is interested in mission planning, Intelligence, Surveillance and Reconnaissance (ISR), area scanning, emergency situation response, and warehouse/material handling applications of this technology.</p> <p>NavX's objective is to develop software that computes the shortest navigable path through austere terrain for an existing mobile robot, the Tactical Unmanned Ground Vehicle (TUGV) to navigate in austere conditions. The software will translate pre-processed LiDAR data into a usable set of waypoints for a mobile robot to navigate on a given terrain (urban, suburban, and wild land environments). The software will collect data from an airborne LiDAR system, generate a discretized representation of its environment, and implement a path-planning algorithm that operates on the selected representation to determine waypoints for the robot. Options for path-planning algorithms include Dijkstra's Algorithm, A* and Dynamic A*.</p> <p>NavX's final product will be software that computes an optimal global path for a mobile robotic system using airborne LiDAR data, and, potentially, static terrain/elevation data in addition. This global path will be transferred in the form of waypoints to a robot on the surface. Another Harris-sponsored design team will use this global path as guidance for local motion planning. In real-time, the TUGV will deviate from and rejoin the global path as necessary to account for unforeseen circumstances.</p>

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List codes and standards that significantly affect your project. Briefly describe how they influenced your design.	<p>LAS Standard: Public, binary file format for storage and exchange of 3-dimensional point cloud data, primarily for LiDAR point cloud data. All pre-processed data from the LiDAR data collection source (helicopter, drone) will be in LAS format. LiDAR LAS files contain data such as (terrain) point classification, pulse intensity, GPS time stamp, number of return pulses, etc. that will be used to determine whether or not the path can pass through the corresponding geographic region.</p> <p>GIFDS (Geographic Information Framework Data Standard): Standard for storage and exchange of geospatial data. Seven categories of GIFDS data are: cadastral data, digital orthoimagery, elevation, geodetic control, government units, hydrography, and transportation. Both LiDAR and non-LiDAR data (to be fused with LiDAR data) will follow GIFDS. This standard will be used for extracting meaningful information from formatted data.</p> <p>GML (Geography Markup Language): XML based open standard for GIS data exchange. This standard will be used for extracting meaningful information from formatted data.</p> <p>IEEE 802.11: PHY and MAC specifications for WLAN communication. For wireless communication between the robot and base station, 2.4 GHz and 5 GHz bands will be used and follow 802.11.</p>										
List at least two significant realistic design constraints that applied to your project. Briefly describe how they affected your design.	<p>1. Base station computing limitations. For prototyping and testing purposes, a base station (a commercially available laptop) will serve as the primary computer for executing global path planning. The memory capacity limitations on this laptop will impose limitations on the spatial resolution of a discrete world representation (if a discrete world representation is chosen). The clock frequency limitations will impose bounds on the computation time of paths and updated paths, which will become relevant when the end-point is moving. Specifications for a typical base station are given below:</p> <table border="1"> <thead> <tr> <th>Base Station Parameter</th><th>Minimum Requirements</th></tr> </thead> <tbody> <tr> <td>Clock Speed</td><td>2.0 GHz</td></tr> <tr> <td>RAM</td><td>8 GB</td></tr> <tr> <td>Disk/Flash</td><td>256 GB</td></tr> <tr> <td>I/O Capability</td><td> <ul style="list-style-type: none"> 802.11n compliant Wireless LAN (Wi-Fi) USB Interface for Serial Communication </td></tr> </tbody> </table> <p>3. Resolution of acquired LiDAR data. Due to the nature of this project (military applications), the LiDAR data provided by our sponsor (Harris Corp.) for prototyping and testing is outdated and unclassified. As a result, the resolution of provided data is lower than that obtained with current LiDAR data acquisition systems. Although the path planning algorithm and program will be designed to accommodate varying data resolution, testing with high resolution LiDAR data will be limited. Furthermore, the global path produced may be more strenuous for the robot to traverse through and obstacles may be missed as resolution gets coarser.</p>	Base Station Parameter	Minimum Requirements	Clock Speed	2.0 GHz	RAM	8 GB	Disk/Flash	256 GB	I/O Capability	<ul style="list-style-type: none"> 802.11n compliant Wireless LAN (Wi-Fi) USB Interface for Serial Communication
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<p>Briefly explain two significant trade-offs considered in your design, including options considered and the solution chosen.</p>	<p>1. Spatial density of data vs computation resources. Data from LAS files (such as pulse intensity and point classification) needs to be transformed into an internal world representation that can be used by the path-planning algorithm. Higher spatial density of the world representation will allow for finer control over the path trajectory, but will increase the time to return path waypoints by nature of the path planning algorithm runtimes. The world representation must not be so dense as to drastically increase the time to calculate a path, as this calculation time may be bounded by</p> <p>2. Path optimality vs computation time. Pre-processed LAS data will be input into a path-planning algorithm to output the best path from one point to another. Higher run times for the path-planning algorithm will be required to create the most efficient path. In contrast, the algorithm must be able to return a path within reasonable computation time, so some path optimality will have to be sacrificed for reasonable computation time.</p>
<p>Briefly describe the computing aspects of your projects, specifically identifying hardware-software tradeoffs, interfaces, and/or interactions.</p> <p><i>Complete if applicable; required if team includes CmpE majors.</i></p>	<p>The primary objective of the path-planning program is to compute the shortest navigable path for the robot to travel from a given start point to a given end point. The scope of our project is developing a computationally efficient representation mechanism and path planning algorithm. Limitations on the optimality of the calculated path include the resolution of the provided LiDAR data and the density of the generated map representation. Both of these constraints are informed by limits to the processing speed and storage space of the base station and the robot's onboard computer. A higher resolution map and a more sophisticated path planning algorithm will allow potential paths to be analyzed more comprehensively, leading to a shorter path.</p> <p>The primary hardware/software tradeoff in the project deals with the world representation and algorithms for its manipulation (which differ from the path planning algorithms). A grid-based (discrete) world representation can be stored as an array of floating point numbers or as a graph. If the world (as is typical) has sparsely located obstacles, the graph model would be dense, and connected in a mesh topology. Adjacency matrix representations are recommended for dense graphs. The choice between the graph or array representation will be dependent upon both the required times for manipulating the data structures, as well as the path planning algorithm selected. Since a significant portion of the time to populate the world representation will be spent in the manipulation algorithms, it is favorable to place bounds on the access times.</p> <p>The number of cells in the grid (or nodes in the graph) grows quadratically with linear increase in the spatial resolution of the cells. Thus, it is necessary to select a suitable cell size to trade-off spatial resolution and memory usage. To mitigate this storage problem, k-d tree structures can be used to encode the array of cells. This decreases the space usage from $O(n^2)$ to $O(n)$. However, the time to access a cell increases from $O(1)$ to $O(\log n)$. Again, it becomes necessary to select the data structure to trade-off responsiveness of the robot with memory usage.</p>

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<p>Leadership Roles (ECE4011 & Forecasted for ECE4012) (NOTE: ECE4012 requires definition of additional leadership roles including: 1. Webmaster 2. Expo coordinator 3. Documentation</p>	<p>Alvin O'Garro – Web Master, Algorithms Lead</p> <p>Jacob Jeong – Expo/Scheduling Coordinator, Data Preprocessing Lead</p> <p>Antony Samuel – Sponsor Liaison, Data Acquisition Lead</p> <p>Kartik Sastry – Project Advisor Liaison, Map Development Lead, Documentation, Group Leader</p>
<p>International Program: Global Issues (Less than one page) (Only teams with one or more International Program participants need to complete this section)</p>	<p>Not Applicable.</p>