**Autonomy**

LATTICE’s architecture and system design impose requirements on the terrain where it is to be successfully deployed. As an example, between every two stakes, there must be a stretch of terrain that does not exceed the minimum ground clearance of the system (else the shuttle would collide with the ground during its movement). More generally, these requirements arise due to set-up rover capabilities (e.g. stake placement tolerance, slope traversal ability) and system parameters (e.g. ground clearance, distance, and angle between stakes). Thus, the autonomy subteam focused on the stake placement problem to (1) Determine whether it is **feasible** to find paths in and out of craters on the lunar south pole meeting system constraints and (2) Find the **optimal** (shortest) path meeting constraints between two points on any topography map.

In order to determine the feasibility of finding paths that meet the system constraints, we used high-resolution elevation maps of lunar south pole sites. Specifically, we chose a region of Shackleton Crater as it is the highest resolution map available and it is an upper bound for distance and steepness. We used a dense sequence of random samples to construct a tree from a given start point outside the rim into the crater. This is basically a *rapidly exploring random tree (RRT)*, and it is able to generate feasible trajectories with simple functions that detail where the tree is able to extend. Note that we are not trying to find the optimal path with this method. In Fig. X, we show 100 paths generated by the RRT algorithm with 100 m cable span and 0.5 m ground clearance. To see how varying the constraints affects path-finding difficulty, in Fig. X we plotted the percentage of successful paths for a given cable span and clearance. In general, we would want longer cable spans (as long as they can be supported by a spool on the set-up robot) to have less stakes and reduce system mass, and a lower ground clearance (as long as paths are still feasible) to simplify tensioning and load requirements in the shuttle and stakes. Preliminary results support the initial choice of 100 m cable spans with 0.5 m ground clearance, but further analysis is pending.

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Fig. X - 100 paths generated from RRT, with 100 m of cable spans and 0.5 m of ground clearance in between. The color-map details relative elevation in (m).

Fig. X - Feasibility percentage as a function of cable span and ground clearance between stakes. It is defined as the number of successful paths found divided by the number of attempts

We approached the generation of optimal paths in a given topography map by constructing a graph and then performing graph search between start and end nodes. Each node in the graph is a potential stake placement, and nodes are connected if a cabled stake placement between them is allowed by the constraints. After building the graph, the shortest path between any start and end node can be found by a graph-search algorithm such as Djikstra’s or A\*. Right now, only the cable distance and ground clearance constraints are being taken into account. We will work on adding more of the identified constraints, taking slopes into account, and on using this code to generate the stake placement for our demonstration.

Additionally, we are currently working on using these results to figure out target requirements that drive design specifications of LATTICE and its subsystems. The plan is to use the feasibility and optimal path analysis in conjunction with system relation equations to identify parameters of the mass optimal system (e.g. optimal distance between cables). Furthermore, we aim to map the topography of Peterman Hill and run this code to verify and optimize demo system scale and path.

In our proposal, we detailed an autonomy plan for the set-up rover. The only change is that instead of deciding the optimal stake placement online, this will be done offline. Informed by analysis and conversations with our mentors, the set-up rover will be tele-operated (with tele-op assists for driving and stake placement). These changes make sense for our operational scenario given the relatively low latency allowing tele-operation of robotic systems on the moon, and the availability of topography maps to determine stake placement beforehand. Beyond work on the placement algorithms and the set-up rover, other future work includes the sensing and control autonomy for shuttle bots as in the proposal.