robotika international

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# DARPA Subterranean Challenge (SubT) Case Study

## SubT Challenge Integration Exercise (STIX)

## Introduction

The Defense Advanced Research Projects Agency (DARPA) seeks to nourish development of innovative technologies that could be leveraged to perform various underground operations autonomously. Specifically, DARPA is interested in systems that could map, navigate and search complex underground environments, both natural and man-made, including mines, caves and underground urban spaces. Underground environments present unique challenges to autonomous robotic platforms due to, among other things, difficult terrain, unstable structures, communication constraints and limited visibility.

## General Purpose Mobility Platform

The Robotika International team has years of experience developing autonomous mobile robotics and focuses on research and development of general purpose autonomous mobility platforms. The goal for such platforms is to be well positioned to solve many different tasks with just limited customization of its hardware and/or software. Robotika International welcomed DARPA's SubT Challenge as a means for validating Robotika's product line by subjecting it to one of the most cutting edge challenges presented to the community of autonomous mobile robotics today.

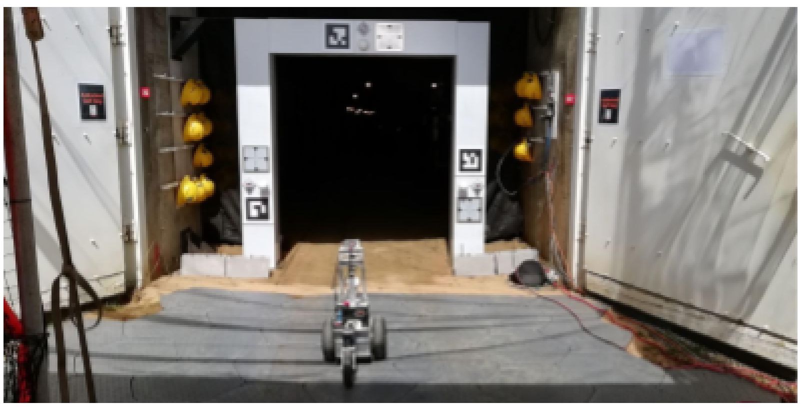
## Operational Constraints - Tasks and Rules

In this competition, DARPA challenged the world's top experts on autonomous robotics to create a mobile robot, or a system of robots, able to navigate in an underground space (e.g., mine shafts, tunnels, caves) without the presence of a human operator for the purpose of seeking and reporting the location of certain artifacts (e.g., survivors/mannequins, backpacks, cell phones, fire extinguishers). This was a challenging scenario for multiple reasons:

constricted space with uneven terrain, man-made and natural debris, equipment, and poor visibility due to dust or smoke. Radio communication inside such spaces is hard to maintain, a compass is unreliable and GPS is obviously not available. Moisture in the environment makes surfaces slippery or muddy.

## Robotika's Approach

Robotika's goal for its autonomous mobile platform is for it to be versatile enough to perform a range of tasks with only limited customization. It is designed to maintain baseline functionality regardless of available sensors, power trains and task-specific equipment, their reliability or accuracy, in any environment and for any task.



Our tricycle robot at the entrance of the test mine tunnel

Given the constraints of this challenge, we selected to use **LIDAR**, an **inertial measurement unit (IMU)** and **wheel odometry** as the sensors used for calculating and tracking the robot's location. While some simpler methods for exploration may not necessarily require maintaining of the robot's location, it is a requirement in this scenario as the robot needs to report the location where the sought-after artifacts were found.

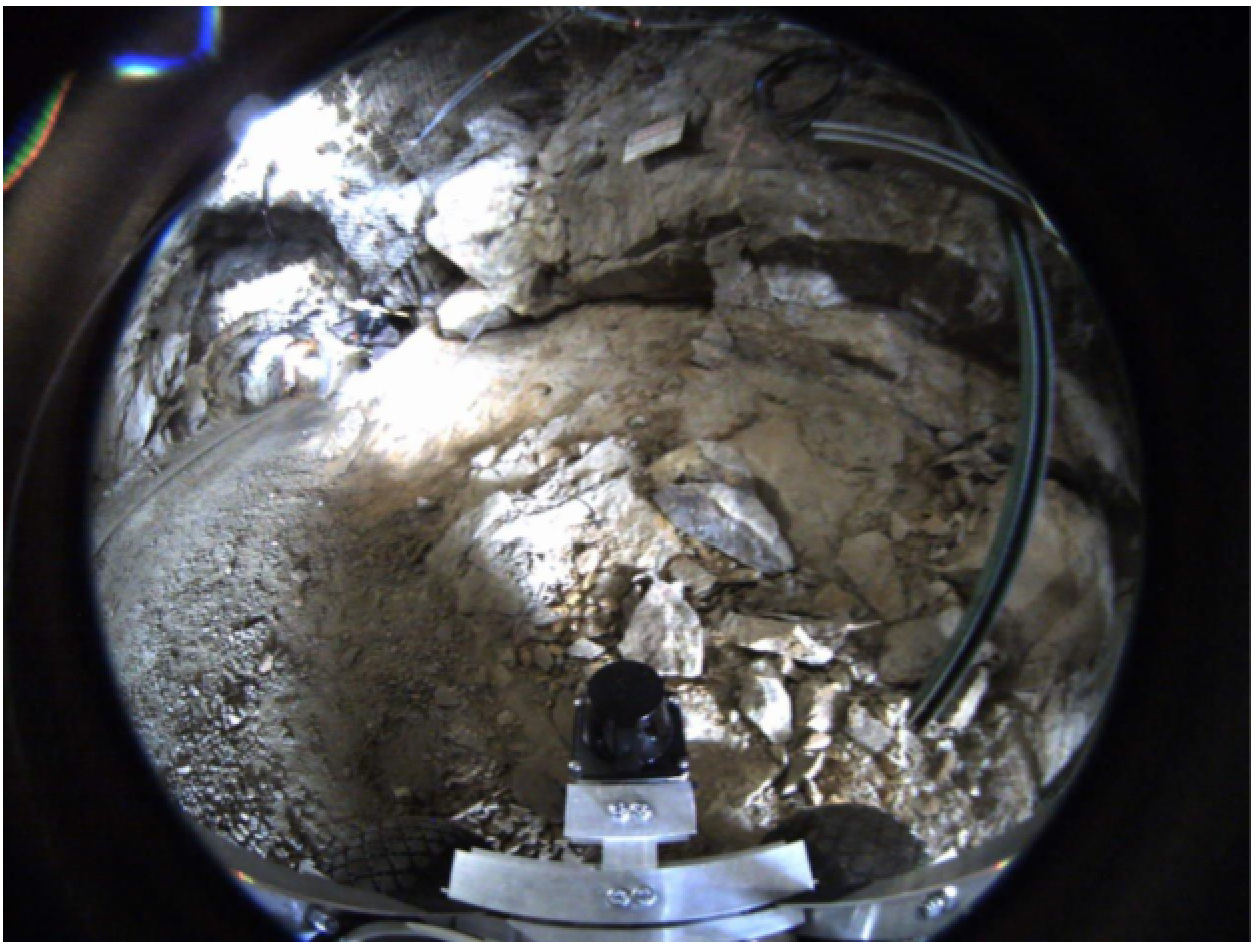
To validate the flexibility of our general purpose platforms, instead of building a task-specific robot from scratch, our submission to SubT followed the model of what we offer commercially, i.e. utilizing our existing platform as a starting point and applying only limited hardware and software customization. This approach enabled us to prepare and field two separate vehicles within a matter of months. Designing and developing a fully custom solution would have taken much more time.

## Customization and Optimization

We fielded two separate vehicles with two distinct chassis. The first vehicle is a tricycle with two larger independently driven wheels up front and a smaller caster wheel in the back. The second vehicle is a four wheel vehicle with two fixed axles, one wheel on each end of each axle. Two wheels on each side are connected by a belt and turn in tandem. Steering is achieved by turning the two sets of wheels at different speeds.

Given the properties of the existing chassis and their hardware and considering the specifics of the environment and the deployment scenario, we have configured and optimized our autonomous navigation engine to work with these constraints and to solve the challenges efficiently.

For example, in normal urban environment, shapes are often rectangular (buildings, doors, etc) with a minimal number of obstacles expected to protrude into the drive path higher off the ground. In contrast, in a mine-like environment, many times the tunnels are rounded, meaning the “floor” near the “walls” is sloping and the surface path on which the robot travels is narrower than the width of the tunnel. Further, objects could be hanging on the walls or ceiling, so something could collide with the upper portion of the robot even if the chassis has a clear driving path.



Robot is examining rubble in its path along the right wall. The main passageway is on the left.

To address these possibilities, we have modified the robot’s envelope in order to navigate this environment safely. Similarly, unlike paved or natural surface trails, which are typically smooth, in this environment the driving surface can contain obstacles that would be difficult to traverse for most platforms: train tracks (possibly partially buried/covered), grills and vents, loose rubble, sand, mud, rocks, etc. In a more open environment, it would be possible to avoid such impediments. Since our goal was to use our existing platform, we didn't have the option to design a custom platform for this specific environment and task -- a modification to the clearance height or steering mechanism, for example. Instead, we have optimized our driving algorithm to perform better in this environment and to navigate around or through such challenging areas more effectively.

## Validation and Testing

As access to a working mine or even a cave is typically limited, we tested our prototype in similar constrained and underground spaces: cellars, utility collectors, or particularly uneven outdoor terrain . After preliminary configuration based on our experiences with these environments, our system performed well during a test in an actual mine. Our simulation tests provided us with valuable learning experiences that we are leveraging to improve our platform even further.

## Event Calibration and Deployment

During the initial testing in the mine environment, we were able to focus on parameters such as driving speed, minimum distance from detected obstacles and multi-robot collaboration strategies, as well as the overall tactics for achieving the highest score (e.g., a few long runs attempting to maximize the explored area vs. frequent returns to base from shorter trips to make sure artifacts actually get reported). Based on the experiences from the trial run, we devised and implemented a strategy for the rated run. This was not a competitive event and served primarily as an integration exercise to test and confirm vehicles working well within the DARPA framework. As such, individual teams' results are not made available and there was no judgement of "good" or "poor" performance. However, we feel that we performed in line with our own expectations, learned a lot and came away with several ideas for the next event in August 2019 and beyond. Our progress and achievements here are sure to benefit our commercial customers.

## Lessons Learned and Future Work

This event exposed us to relatively less understood type of terrain by us and perhaps the autonomous mobile robotics community as well. While we were able to improve the performance of our systems by using some of our existing customization and optimization tools, this experience also showed us where additional configurability could be used. On the hardware side, while we maintain our general purpose platform philosophy, we also see that certain modifications of the chassis could improve the robustness of traversing over the terrain dramatically, which would have utility beyond underground scenarios. We will also be expanding the area that our robots scan with their sensors, as this experience showed us that 360 degree situational awareness is beneficial in not just this type of subterranean environment, but probably many others.

**Robotika International**
info@robotika-intl.com
www.robotika-intl.com
Twitter: RobotikaIntl
Instagram: robotika_intl