Autonomous Exploration of Unknown Rough Terrain with Hexapod Walking Robot

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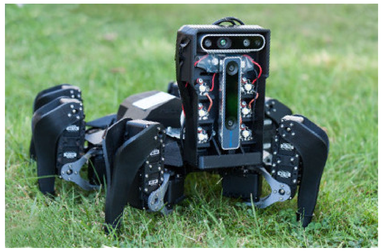
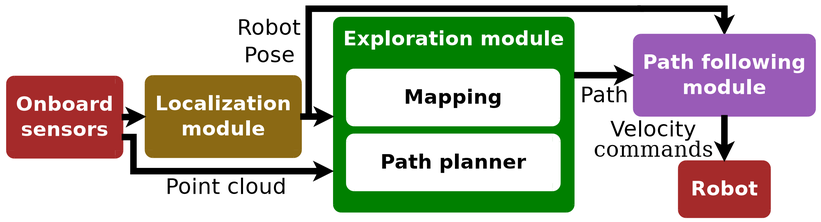
Motivation and Requirements

- Search and rescue in subterranean environments
  - Limited communication
  - No prior map
  - No external localization system
  - Rough terrain
- Requirements
  - Robotic exploration
  - Real-time autonomy
  - Mapping and localization using onboard sensors
  - Deployable on walking robot
    - Limited computational power
    - Limited paid load (1 kg)



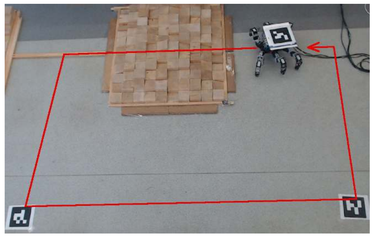
Architecture of the Proposed Solution



- Various **localization** modules were used
  - **Vision-based localization** for walking robot
    - ORB-SLAM2 + RGB-D camera
    - New Embedded localization Intel RealSense T265
  - Localization from **laser range-finder** (LIDAR) for wheeled and tracked robots
- **Mapping** incrementally builds the elevation map using the proposed memory-efficient structure speeded-up by cache technique
- **Exploration module** determines a cost-efficient path to the next selected navigation waypoint to explore not yet seen parts of the environment
- The plan is executed by the **path following module** that steers the robot by velocity commands
- The framework is implemented in C++ using the ROS middleware

Evaluation of Localization Systems

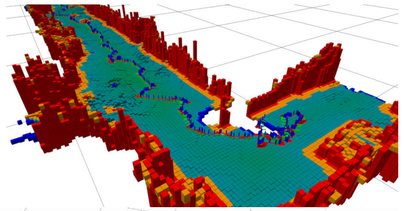
- Existing visual **ORB-SLAM2** with the RGB-D camera
- Embedded localization based on **Intel RealSense T265**
- Experimental laboratory setup with walking robot crawling on flat but also rough terrain

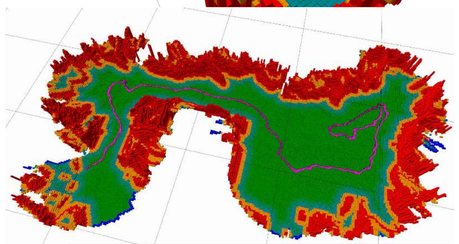


- Based on measured localization errors, Intel RealSense T265 outperformed localization system ORB-SLAM2

Exploration with Hexapod Walking Robot

- **Fully** autonomous exploration in an **indoor** environment and uneven **grass** terrain

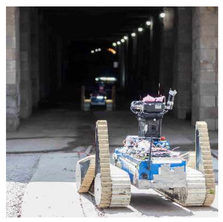




- Exploration setup, time, and traversed distance

Terrain type	Indoor	Grass
Map resolution [cm]	7.5	7.5
Exploration time [min]	28.3	44.3
Traversed distance [m]	49.1	46.0

Exploration with Wheeled, Tracked robots

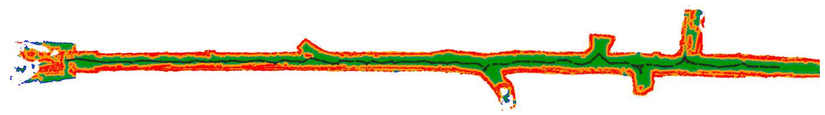


- Deployment with object detection

Deployment in DARPA Subterranean Challenge – Tunnel Circuit

- The proposed solution for autonomous exploration has been deployed on the **walking**, **wheeled** and **tracked robots**

- The exploration framework covered >**200 m** long tunnels, and it is deployable on embedded computers (**Odroid-XU4**)



Contribution

- Autonomous exploration framework deployed on mobile robots of different types (walking, wheeled, and tracked robots)
- The developed framework has been utilized in the research work published in [1], [2] and two more papers are in review
- Deployment in the Tunnel Circuit event of the DARPA Subterranean Challenge (**3rd** place for our team **CTU-CRAS**)

References

[1] M. Prágr, P. Čížek, J. Bayer, and J. Faigl, "Online Incremental Learning of the Terrain Traversal Cost in Autonomous Exploration," in *Robotics: Science and Systems (RSS)*, 2019.

[2] J. Bayer and J. Faigl, "On Autonomous Spatial Exploration with Small Hexapod Walking Robot using Tracking Camera Intel RealSense T265," in *European Conference on Mobile Robots (ECMR)*, 2019.