Three-Dimensional SLAM for an Autonomous Underwater Vehicle  
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### Background
The RoboSub Club of the Palouse builds fully Autonomous Underwater Vehicles (AUV) to compete in the Association for Unmanned Vehicle Systems International (AUVSI) RoboSub competition annually. To aid in identifying objects and interacting with them in 3D space, the team requested a Simultaneous Localization and Mapping (SLAM) system.

### ORB-SLAM2: System Overview
- Feature-based
- Monocular, Stereo, and RGB-D
- Loop closing, relocalization and map
- Three threads running in parallel
  - Tracking
  - Local Mapping
  - Loop Closing

### Fusion
- Node added that labels objects identified by ORB-SLAM with bounding boxes
  - Pairs coordinates with corresponding object label
  - Translates into real-world coordinates
- Utilizes existing object detection system for providing object labels
- Outputs to ROS TF2 for future use by other subsystems

### Goals
1. Implement a SLAM system that generates 3D maps of the AUV’s underwater environment.
2. Create a module that outputs the results of the SLAM system as a usable format for other components of the AUV to utilize.
3. Integrate code coverage into the RoboSub GitLab repository to promote good testing practices.

### Technologies Used

### Map
- Map points
  - 3D position
  - Viewing direction
  - Representative ORB descriptor
  - Viewing distance
- Keyframes
  - Camera pose
  - Camera intrinsics
  - ORB features in the frame

### Place Recognition
- Visual Vocabulary
  - Offline vocabulary of ORB descriptors extracted from a set of images

### Graphs
- Covisibility Graph
  - Node: Keyframe
  - Edge: Share observations of map points
  - Min shared map points: 15

- Essential Graph
  - Spanning tree
  - Subgraph of covisibility graph
  - Min shared map points: 100

### Future Work
- The maps generated by SLAM can be used by other subsystems onboard
  - Navigation can be implemented to steer the submarine
  - The AI can perform path planning to create the most efficient route
- Real-world verification of implemented modules

### Glossary
- **AUV**: Autonomous Underwater Vehicle.
- **SLAM**: Simultaneous Localization and Mapping. Takes input from the cameras and maps points to a 3D space.
- **ROS**: Robot Operating System. Modularized system that allows for cross-system communication between software and hardware components.
- **TF2**: Transform 2. A ROS library for performing coordinate frame transformations.

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