Multi-Robot Systems for Collaborative Exploration and 3D Scene Reconstruction

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OBJECTIVE:

Leverage a multi-robot system for efficient 3D mapping and navigation in dynamic and constrained environments.

Key Capabilities:
Collaborative exploration, efficient mapping, adaptability in narrow or changing spaces, multi sensor collaboration, smart mapping

HARDWARE CONFIGURATION

- **LiDAR Unit:** High-resolution 3D point cloud generation with Intel L515.
- **TOF Camera Unit:** Lightweight 2D depth mapping for accurate feature detection.
- **Locomotion Base:** Designed for testing diverse strategies and interactions with differential drive and PID.

COMMUNICATION AND COORDINATION FRAMEWORK

- **ROS-Based Multi-Master System:** Distributed task management and synchronized transforms for seamless cooperation.
- **Real-Time Communication:** Facilitates coordinated problem-solving and efficient data sharing across robots.

Fig. 1 – Multi Robot System mapping interiors in 3D.

IMPLEMENTATION OVERVIEW

Single-Robot 3D Scene Mapping:
- Data acquisition of LiDAR, TOF Camera and on-board locomotion sensors
- 3D Map Merging

Multi-Robot Coordination & Data Fusion:
- SLAM Framework for 3D scene Reconstruction
- Exploration algorithms for autonomous exploration along with path planning algorithms like RRT.

VISION-BASED 3D SCENE RECONSTRUCTION

Depth Map Fusion: 2D depth maps converted to 3D point clouds, combined with LiDAR point cloud data we can have a feature rich 3D Scene.

Fig. 2 – Intel L515 LiDAR unit

MULTI ROBOT ADVANTAGES

COLLABORATIVE NAVIGATION STRATEGIES

- **Narrow Passage Navigation**
- **Collision Avoidance & Cooperation**
- **Dynamic Problem Solving:** Robots replan paths if obstructions arise, ensuring navigation continuity.

COLLABORATIVE EXPLORATION & MAPPING

Dynamic Goal Allocation: Real-time task assignment through auction-based policies, enabling flexible task switching.
Advanced Path Planning: We can implement refined local path adjustments.

FUTURE WORK

Using Reinforcement Learning (RL) for Dynamic Task Allocation & Mapping:
- **MAPPO for Decentralized Decision-Making**
- **RL for Adaptive Re-Planning:** Enables self-learning of optimal behaviors in variable conditions.
- **RL for Improved Mapping & Trajectory Planning**

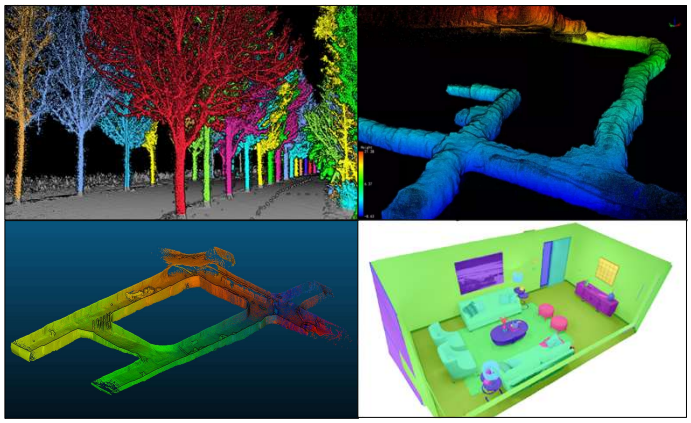

Fig. 3 – Mapping examples for different environments using LiDAR and camera data implementation for feature rich data

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