

# Map Building via RTABMap and *Guidance*

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# Overview

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- 3 Processing Algorithms

# Problem Statement

**Statement:** Given a set of sensors, produce a metrically accurate 3-D map of the world while estimating observation location and motion in that map.

# Sensor Suite

- *Inertial* 6DOF inertial data is available with calibration parameters
- *Depth* Dense metric depth imagery is available with a pinhole camera model
- *Visual* Imagery is available with a pinhole camera model

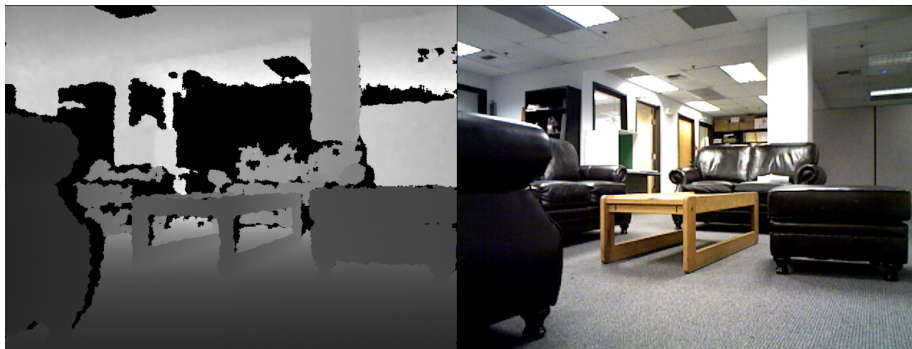


Figure: Sample RGB-D Image Pair

# Data Flow Block Diagrams

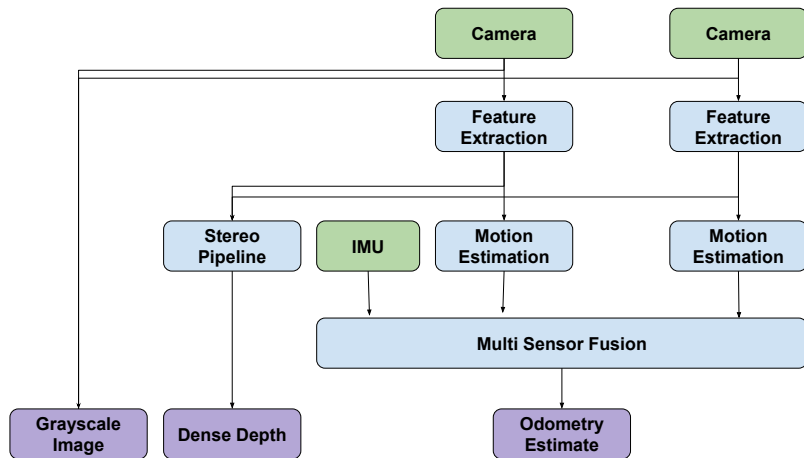


Figure: *Guidance* System Diagram

# Data Flow Block Diagrams

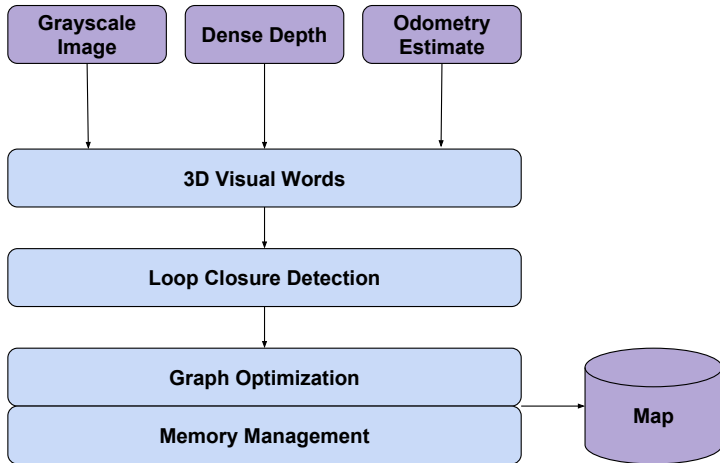


Figure: *RTABMap* Mapping System Diagram

## Guidance Sensor Detail: Camera

- Five stereo pairs, each rectified to pinhole model with available pinhole parameters (10 total cameras)
- QVGA (320x240) resolution in grayscale
- Global shutter
- Auto exposure
- External 20Hz frame rate, synchronized among all cameras

# Guidance Sensor Detail: IMU

- Five Invensense MPU 6050
- Integrated MEMS gyros + accelerometers
- External 20Hz update rate, synchronized to images

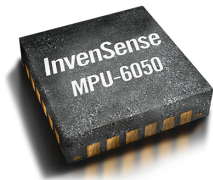


Figure: *Invensense* IMU



- Independently run on each image (10 total)
- **FAST**: Features from Accelerated Segment Test
- Relies on corner detection to identify feature
- Characterized by a **BRIEF** descriptor: Binary Robust Independent Elementary Features
- Optimized for memory-constrained applications

# Guidance Processing: Motion Estimation

- Uses both  $2D \rightarrow 3D$  and  $3D \rightarrow 2D$  estimation
- Monocular estimation based on least squares fit utilizing epipolar constraints and camera calibration parameters
- Stereo estimation utilizes 3D triangulation from stereo calibration parameters
- Seamless switching between mono/stereo motion sources

# Guidance Processing: Stereo pipeline

- Uses a sliding block matching algorithm
- Computes a dense depth maps for two pairs most aligned in the overall direction of travel
- External 20Hz frame rate of depth map

- Based on metric scale EKF of Kneip, Weiss, and Siegwart
- Relies on short-term integration of gyro measurements between successive samples
- Incorporates both stereo and mono motion estimates
- External 10Hz data rate

- **SURF** detector: Speeded Up Robust Features
- Faster than **SIFT**: Scale Invariant Feature Transform
- Not patent encumbered
- Capable of GPU acceleration via OpenCV OpenCL support
- *Interest points*: Cascaded pyramid using Difference of Gaussians (vs Laplacian of Gaussians for SIFT)
- *Local description*: Based on Haar wavelet response (includes an orientation of the feature for rotation invariance)
- Visual Words combine a SURF feature descriptor with a 3D position

# RTABMap Processing: Pose Graph Optimization

- SLAM problem represented as a graph: nodes are poses, links are rigid transformations
- Solve by finding minimum residual of estimated poses and estimated transformations that explain measurements
- Optimization only runs using working memory constraints for speed
- Able to run using complete constraints offline for maximum map quality

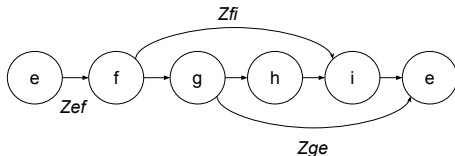


Figure: Pose Graph Representation Showing Rigid Constraints and Loop Closures

# RTABMap Processing: Loop Closure Detection

- Evaluated by comparing extracted visual words of every  $N^{th}$  frame against saved visual word dictionary
- Creates additional pose graph transformation constraints to limit effect of visual drift
- Rigid transformation estimated using RANSAC over matched visual words

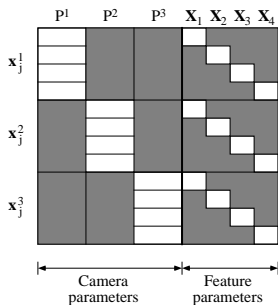


Figure: Pose Graph Sparse Jacobian

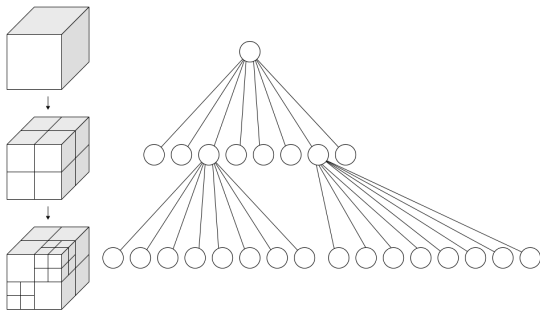
# RTABMap Processing: Memory Management

- Three levels of storage of visual words: short-term, working, and long-term
- New data percolate towards long-term memory
- Movement of data is determined by similarity ratio; highly similar images are not stored
- Trades off map quality for online execution of graph optimization over working memory



# RTABMap Processing: Map Generation

- Map is stored as an OctoMap
- Eight-connected map storing three states: {unknown, empty, known}
- Prepared by projecting depth point clouds from graph optimization into world coordinates



**Figure:** Octree Occupancy Volume Representation