Astrobee Mapping and Localization

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JAXA Kibo Robotic Programming Challenge Student Seminar

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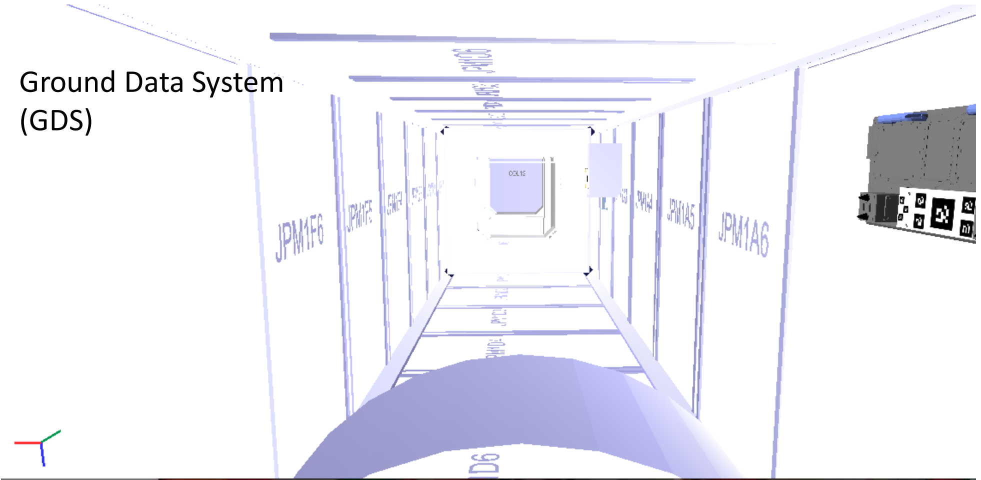
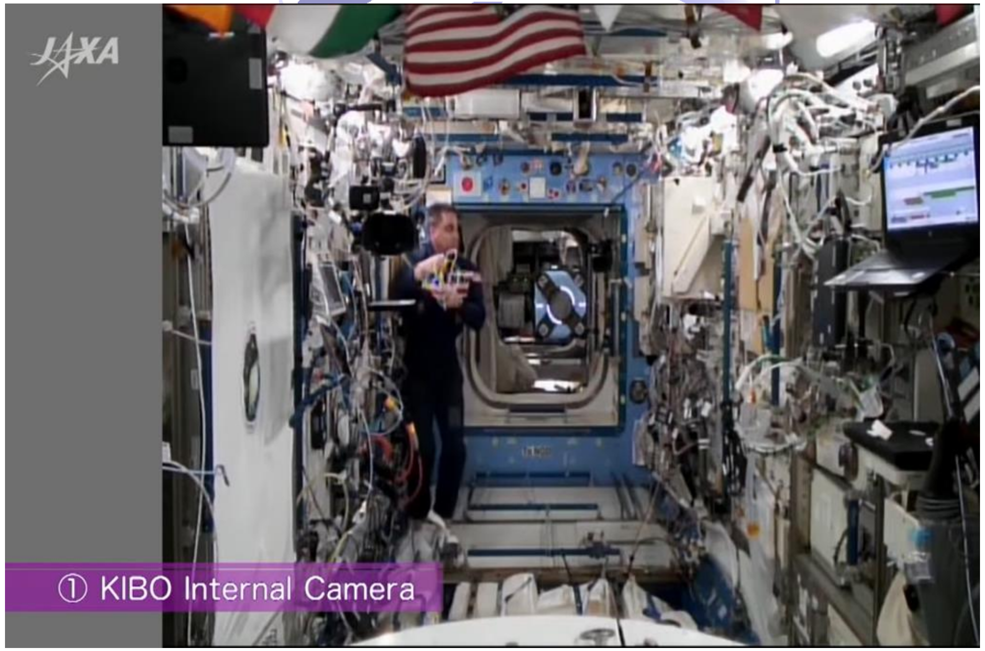
Japanese Experimental Module (JEM)

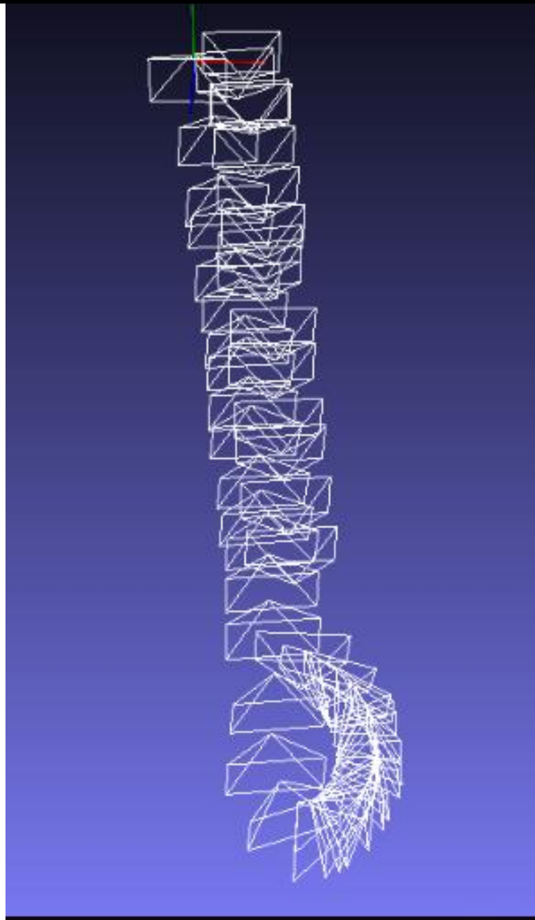
- "Kibo" is Japan's 1st manned experiment facility. Largest experiment module on the International Space Station (ISS).
- It consists of two experiment facilities, the Pressurized Module (PM) and the Exposed Facility (EF).
- PM is 11.2 meters long and 4.4 meters in diameter, atmospheric pressure is maintained to 1 atm.
- Scientific experiments using the microgravity environment and cosmic radiation are being carried out on the experiment racks in the PM.
- Kibo may temporarily be used for Cargo Transfer Bags (CTBs) storage purposes.
- 3D simulated environment helps plan ideal Astrobee trajectories and missions.





Astrobee Mapping

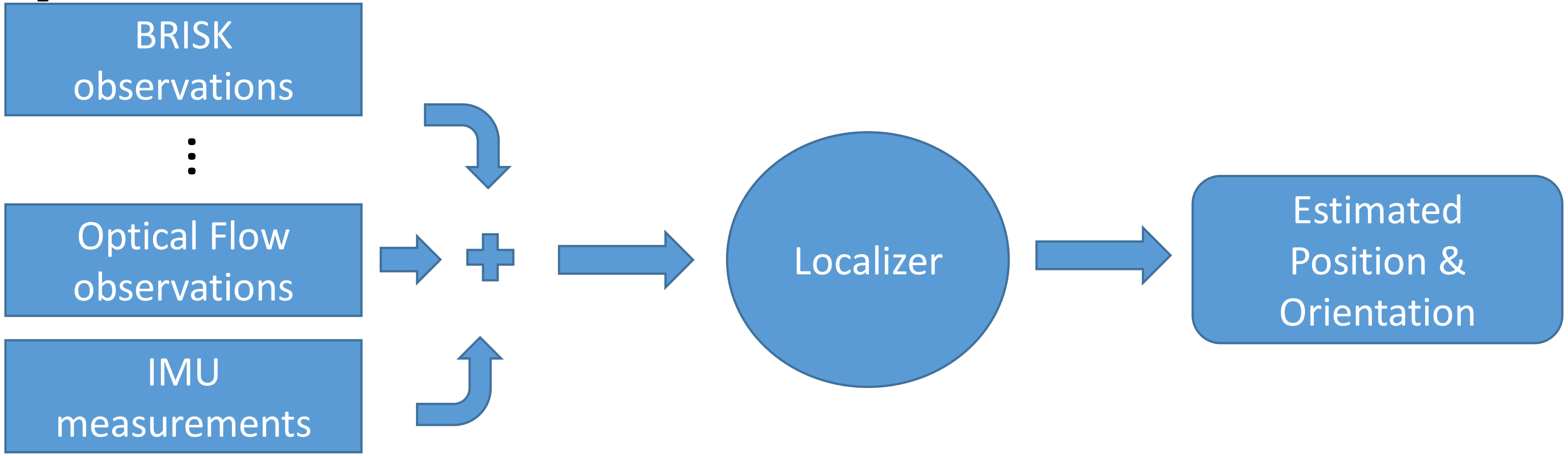
- Process
  - Map is built offline, separate from localization.
  - Astronaut moves Astrobee inside JEM to collect initial set of images.
  - Visual features are detected and matched across a collection of these images.
  - Features’ 3D positions are jointly optimized using structure from motion (SfM) similar to [1].
  - Later on, new images can be acquired autonomously by Astrobee.
- Environmental changes adversely affect mapping and localization: lighting, objects.



[1] S. Agarwal, Y. Furukawa, N. Snavely, I. Simon, B. Curless, S. M. Seitz, and R. Szeliski, “Building Rome in a day,” Communications of the ACM, vol. 54, no. 10, pp. 105–112, 2011.

Astrobee Localization

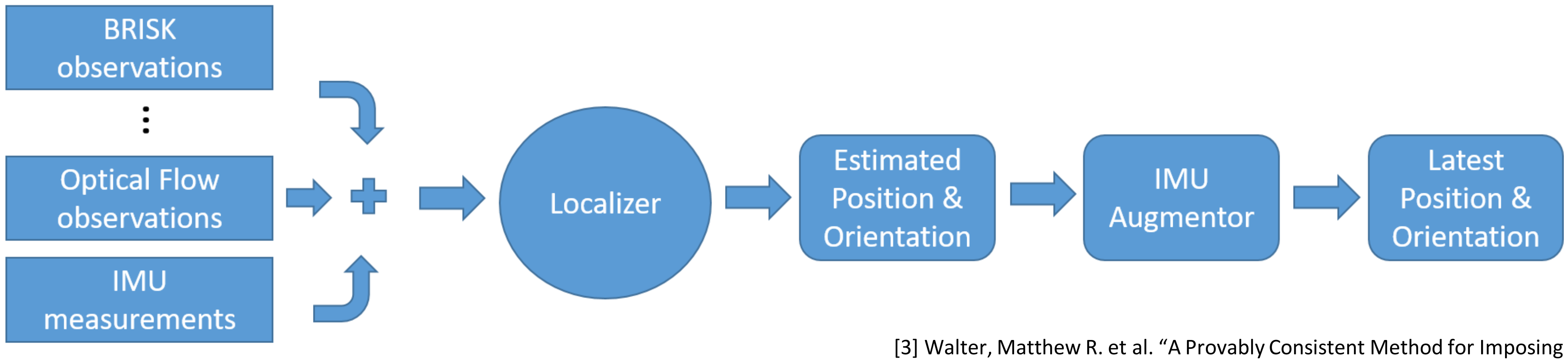
- The localizer matches specific “sparse” BRISK features between NavCam images and the map.
- The localizer also utilizes IMU information and “optical flow” features.
- The previous localizer fuses measurements using an Extended Kalman Filter. [2]



[2] Mourikis AI, Roumeliotis SI. “A multi-state constraint Kalman filter for vision-aided inertial navigation.

Astrobee Localization

- The improved localization is a graph-based algorithm which uses a sliding window approach to be computationally efficient. [Soussan, Kumar, Coltin, Smith]
- Graphs are more computationally expensive, but do multiple iterations of optimization to more accurately calculate localization estimate [3]
  - EKF can be thought of as doing a single iteration which is faster and more efficient but more error prone
  - Graph optimizes a history of poses and other estimates to improve accuracy



[3] Walter, Matthew R. et al. "A Provably Consistent Method for Imposing Sparsity in Feature-Based SLAM Information Filters."

Astrobee Mapping & Localization

- Challenges
  - Tracking of SSLA light settings.
  - Account for differences between simulated and real-world in mission planning.
  - Account for unforeseen changes in environment not captured in map.
  - Account for areas where the environment has surfaces with no detectable features

Feedback to students

- Most errors due to unhandled exceptions, i.e. “what if” scenarios
  - Simulation vs real-world
- Position tolerance violations (PTV)
  - Key factors: map (sparse mapping), localization, tolerance, Keep-in/out zones
  - The ISS is a complex, challenging, and constantly changing environment, the robot can sometimes think is out of its planned path (due to sporadic errors in feature recognition and pose resolution), but PTVs ensure the robot gets to its original destination.
  - Astrobee team is already working in solving sparse mapping outliers
- Most teams had problems reading QR codes and AR tags for different reasons.
- Some implemented maneuvers that, under real-life conditions, barely missed the codes from their Field-of-View (FOV)
- Some teams used Region-of-Interest (ROI) in their recognition procedures, this, although an interesting approach, limited their ability to adapt.
- Implementing adaptable and robust software (e.g. adjust ROI, increase or change FOV, handle more unexpected cases) is key to increasing chances of success.