Monocular ORB-SLAM3 on MBot: Challenges and Performance in Real Environments

MICHIGAN ENGINEERING
UNIVERSITY OF MICHIGAN

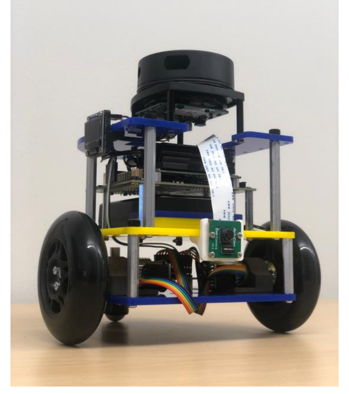
Po-Hsun Chang, Yu-I Chang, Jheng-Yi Lin

Abstract

This project explores the implementation of ORB-SLAM3[1] on the MBot Classic[2] robot using a monocular camera. We collected indoor RGB datasets in EuRoC[3] format to ensure compatibility with the SLAM system. Two custom environments—a rectangular loop and a complex maze—were designed to test loop closure and pose estimation accuracy. While ORB-SLAM3 successfully captured the overall path structure, the monocular configuration exhibited notable scale drift and struggled during pure rotational motion. These results emphasize the limitations of monocular SLAM and the critical role of loop closure and inertial sensing for improved robustness.

Data Acquisition

- **Data Stream:** RGB images, IMU, and timestamps via custom LCM messages
- **Rate:** Image 10 Hz, IMU 25 Hz, Time 100 Hz
- **Resolution:** 480 x 240 pixels
- **Image Message (msg_img_t):**
  - utime: Timestamp
  - img_name: Frame ID (timestamp)
  - data_size: Image size (bytes)
  - img_data: PNG-compressed image



Algorithm 1 Camera Image Capture and Publishing

```
Initialize: camera, LCM, subscription to MBOT_TIMESYNC
publish_rate ← 100 Hz
while camera is active do
    if last_timestamp is undefined then
        sleep(1 ms)                    ▷ Wait for first sync
        continue
    end if
    frame ← capture_and_process_camera()
    bytes ← compress_to_PNG(frame)
    msg.utime ← last_timestamp
    msg.img_name ← string(last_timestamp)
    msg.data_size ← length(bytes)
    msg.img_data ← bytes
    publish(MBOT_IMG_CHANNEL, msg)
    sleep(1/publish_rate − elapsed)
end while
```

Framework

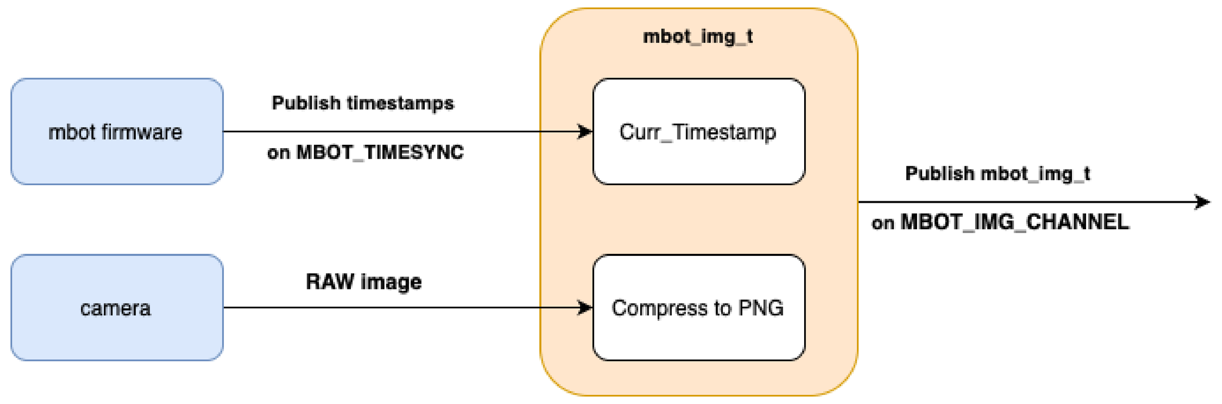


Fig. 1. Data Acquisition Pipeline:

The MBot firmware (lcm serial server) publishes synchronized timestamp on the MBOT_TIMESYNC channel, which the mbot_image_publisher subscribe to and uses to update its internal timestamp. The publisher captures camera frames, compresses them to PNG format, and packages the image data along with the latest timestamp into a mbot_img_t LCM message. The message is then published on MBOT_IMG_CHANNEL, feeding the later ORB-SLAM3 framework SLAM processing.

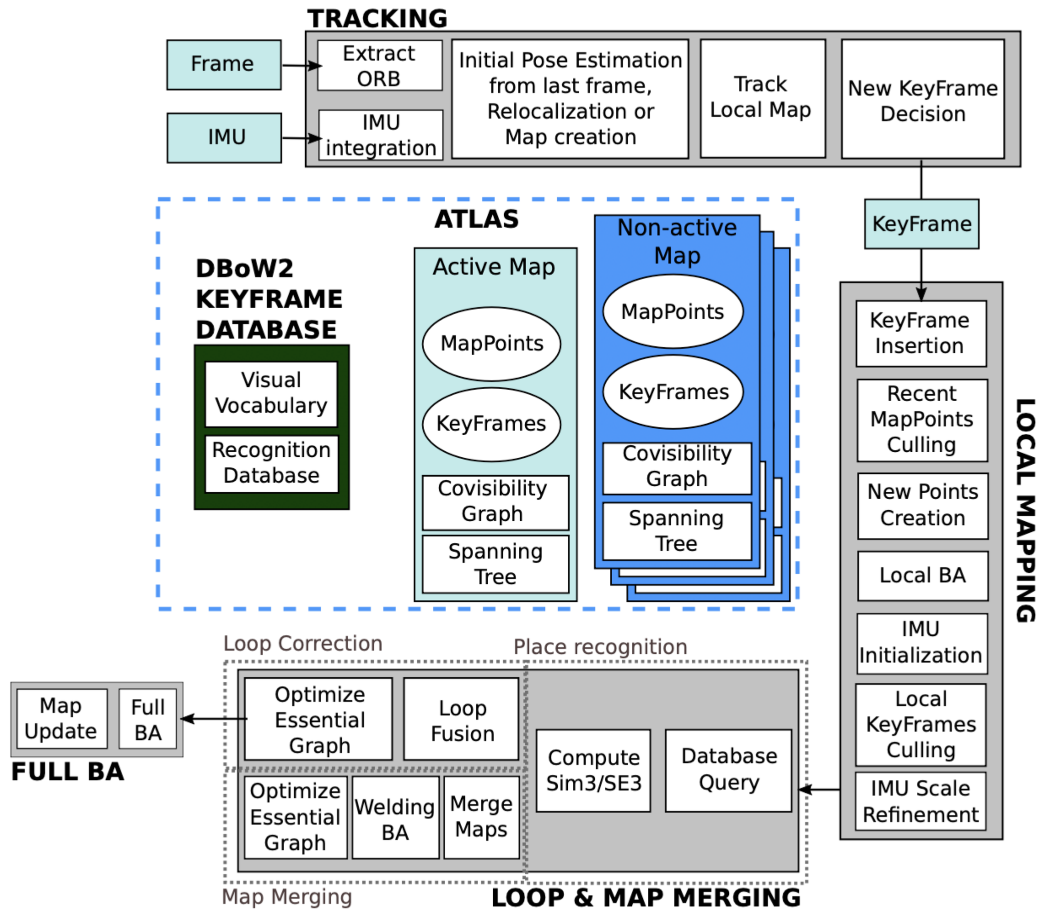


Fig. 2. Internal structure of ORB-SLAM3 Framework

The Tracking thread detects and matches ORB features in each frame, uses IMU preintegration for motion prediction, and computes the camera pose in real time. Simultaneously, the Local Mapping thread promotes new keyframes, prunes redundant ones, and refines both poses and landmarks through local bundle adjustment—merging visual and inertial constraints once the IMU is initialized. Meanwhile, the Loop & Map Merging thread continuously queries the Place Recognition database, verifies matches with a high-recall geometric check, and either closes loops or fuses separate maps into one. After any loop closure or map merge, a global optimization propagates corrections throughout the map.

Experiment

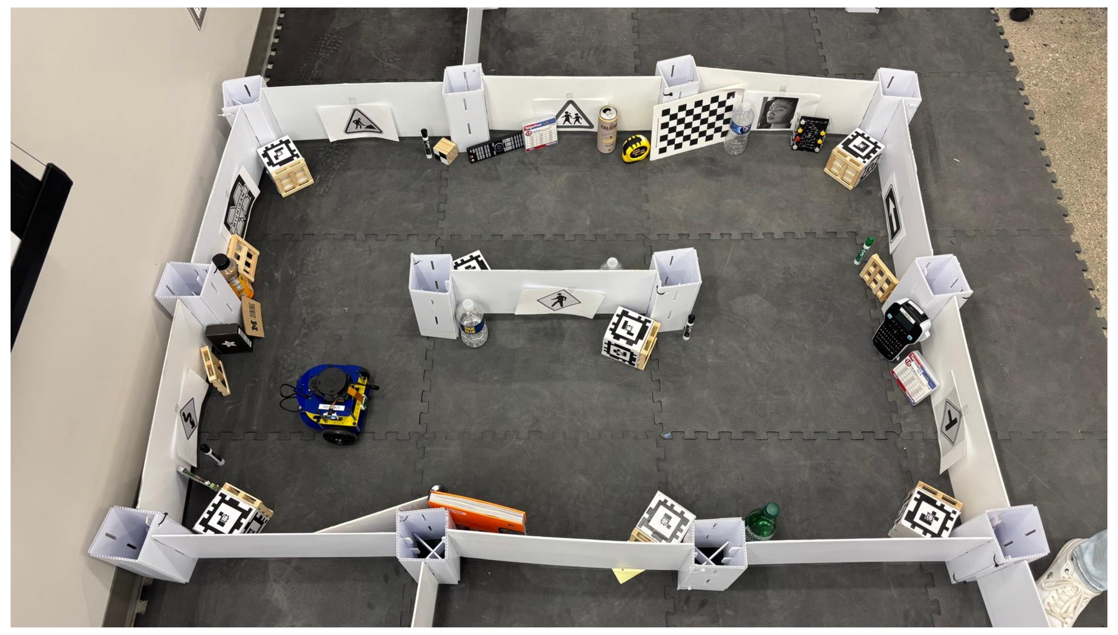
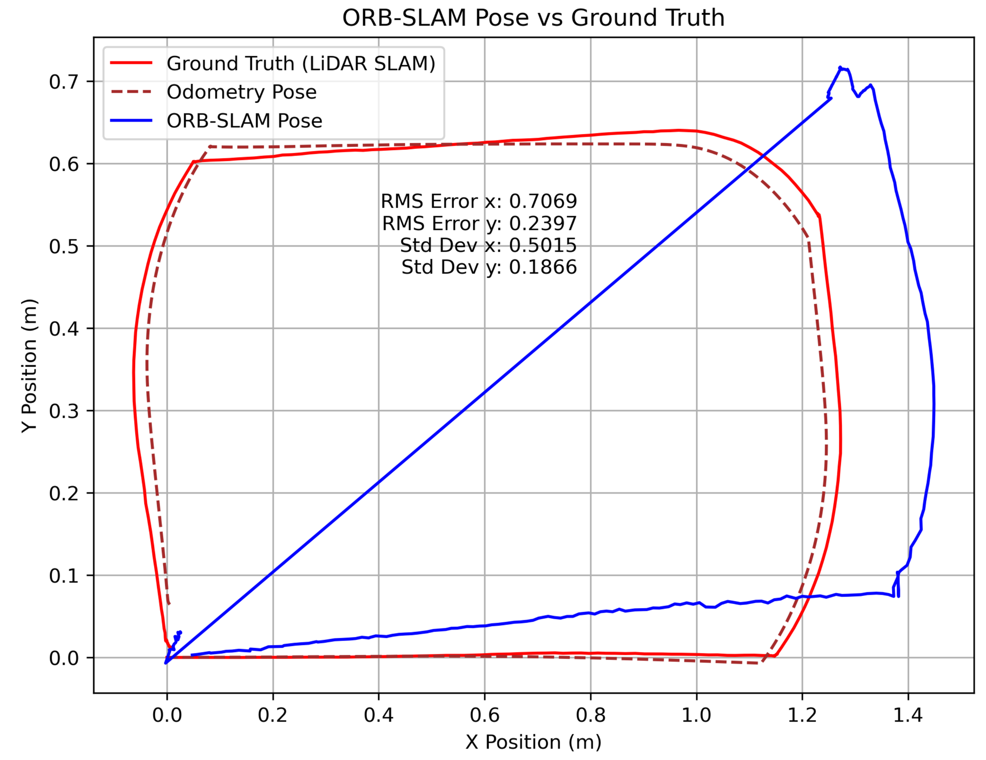


Fig. 3. / Fig. 4. ORB-SLAM3 Result in Closed Loop Environment



Conclusion

- ORB-SLAM3 with a monocular camera captures the overall route structure, but struggles with accurate distance estimation.
- Pose estimation is unreliable during **pure rotational motion** due to the inability to triangulate new map points without translation.
- **Loop closure** is essential in monocular SLAM to correct drift and ensure relocalization.
- Improving sensor quality and update rates is a potential future direction for better SLAM accuracy and responsiveness.

Reference

[1] C. Campos, R. Elvira, J. J. G. Rodríguez, J. M. M. Montiel and J. D. Tardós, "ORB-SLAM3: An Accurate Open-Source Library for Visual, Visual–Inertial, and Multimap SLAM," in IEEE Transactions on Robotics, vol. 37, no. 6, pp. 1874-1890, Dec. 2021, doi: 10.1109/TRO.2021.3075644.
[2] University of Michigan, "MBot Classic," [Online]: https://mbot.robotics.umich.edu/docs/hardware/classic/
[3] M. Burri, J. Nikolic, P. Gohl, T. Schneider, J. Rehder, S. Omari, M. Achtelik, and R. Siegwart, "The EuRoC micro aerial vehicle datasets," \textit{Int. J. Robot. Res.}, vol. 35, no. 10, pp. 1157–1163, 2016. [Online]. Available: https://projects.asl.ethz.ch/datasets/doku.php?id=kmavvisualinertialdatasets