Graph-based Thermal-Inertial SLAM with Probabilistic Neural Networks

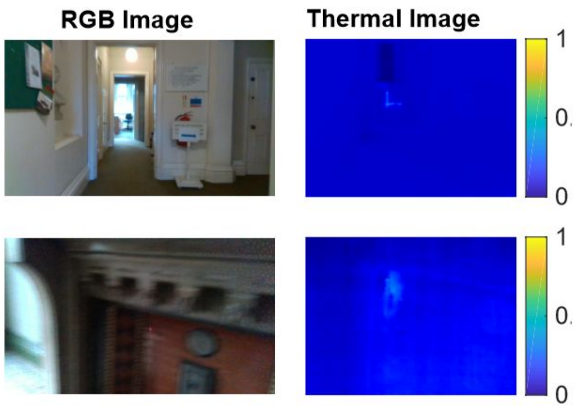
Dr. M. Risqi Utama Saputra
Cyber-physical Systems Group
Department of Computer Science
University of Oxford

Background

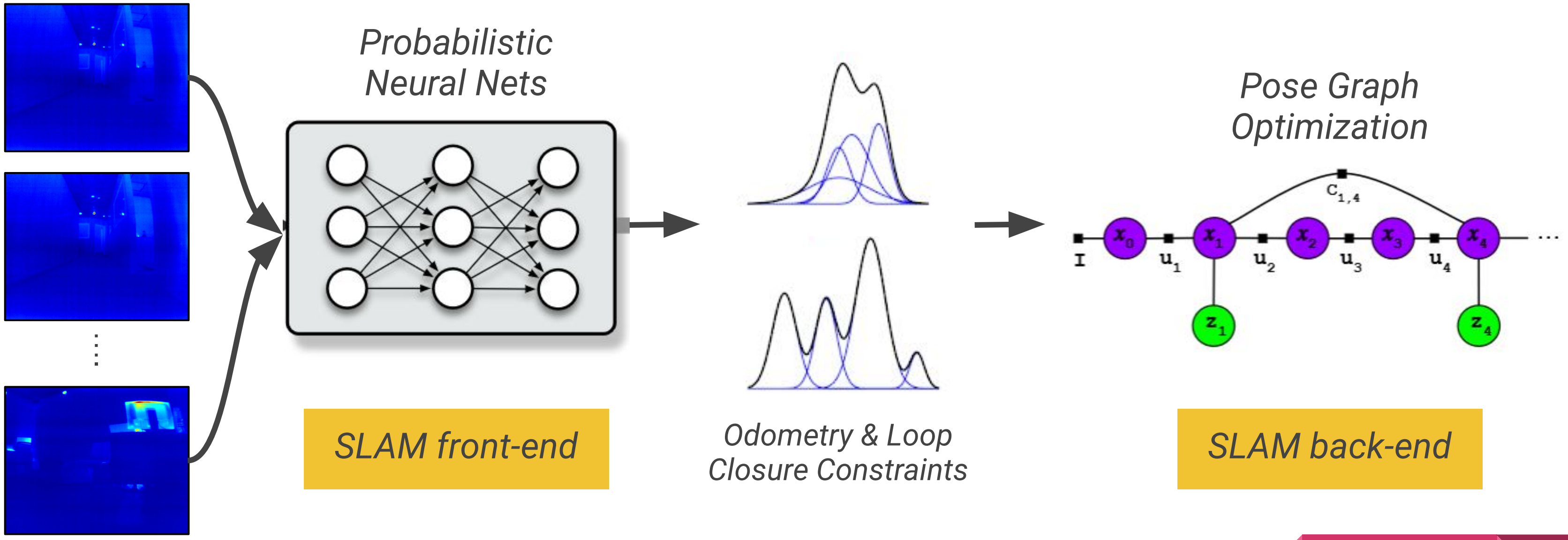
- Existing Simultaneous Localisation and Mapping (SLAM) system based on RGB-D/Lidar cannot operate in visually-denied environments
- Thermal cameras are not affected by illumination condition

Challenges

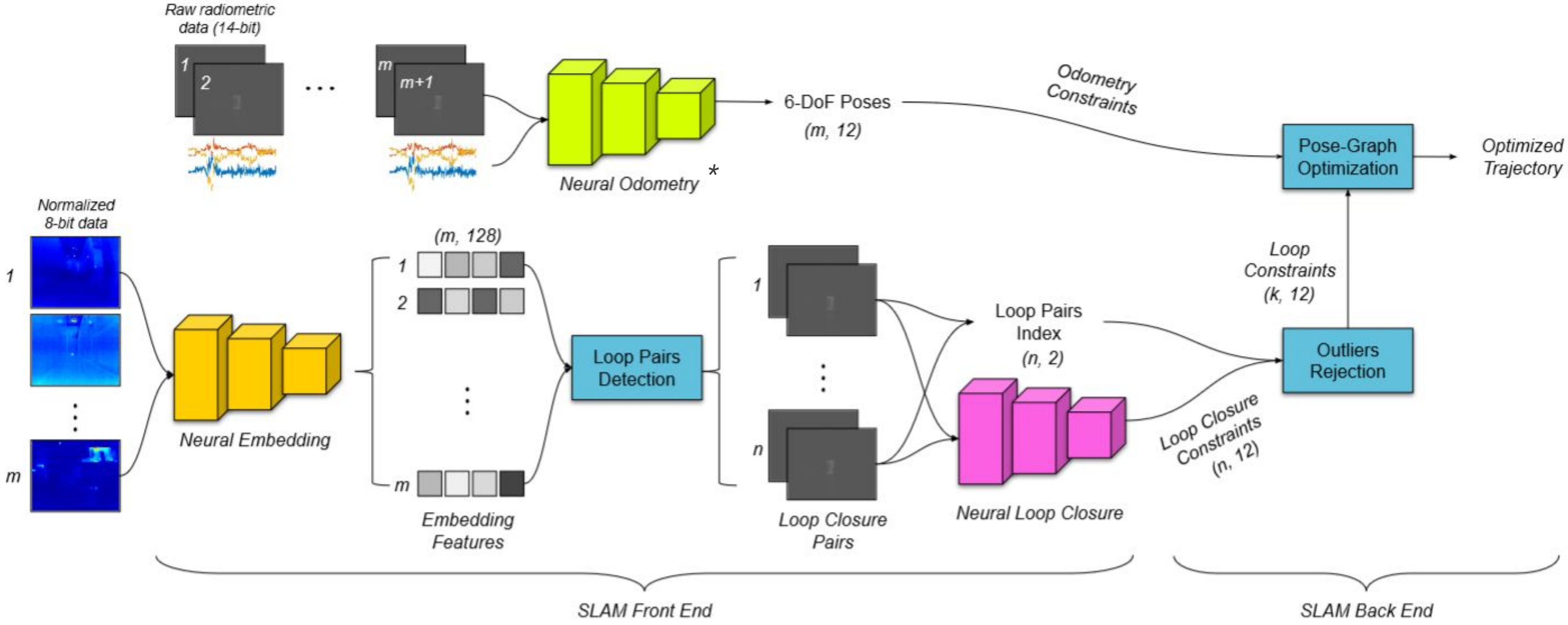
- Challenges of using thermal cameras:
  - Capture the temperature profile of the scene instead of appearances
  - Lack robust visual features (no texture, low contrast, etc.)
  - Periodically suspend camera operation to perform Non-Uniformity Correction (NUC)
- Research questions:
  - How to encode/abstract thermal data to maximally aid graph optimization in thermal SLAM?



Method

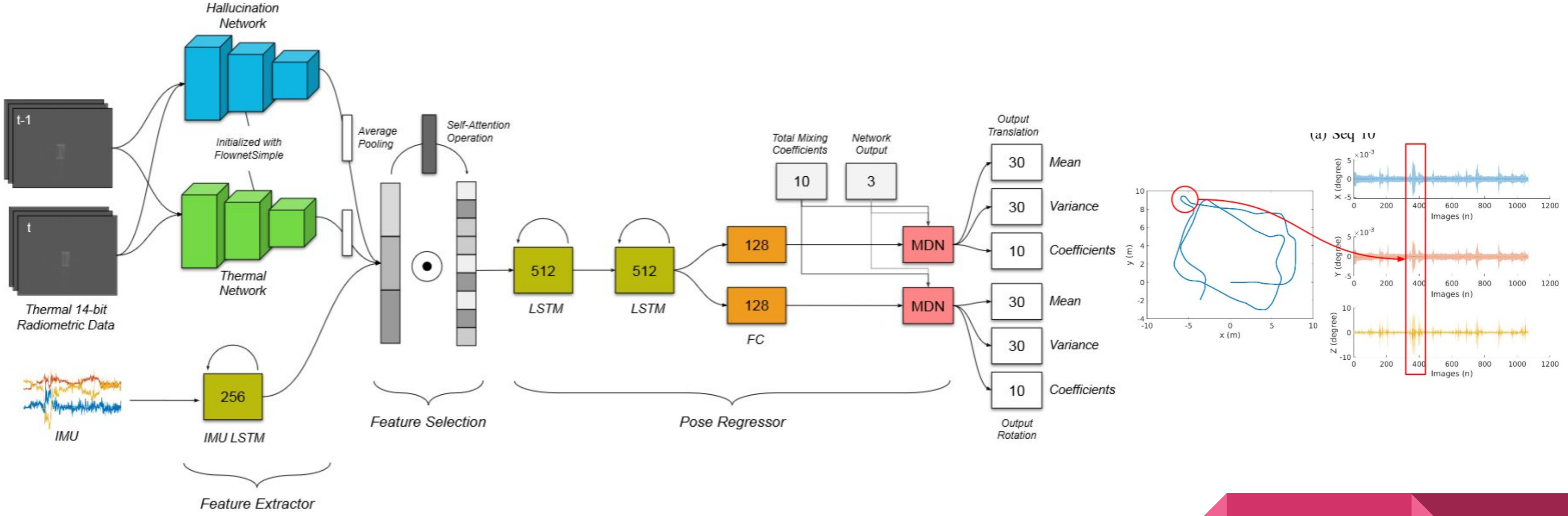

Probabilistic Neural Nets
SLAM front-end
Odometry & Loop Closure Constraints
Pose Graph Optimization
SLAM back-end
I
x_0
u_1
x_1
u_2
x_2
u_3
x_3
u_4
x_4
$c_{1,4}$
z_1
z_4

TI-SLAM



*M. R. U. Saputra, et. al., (2020), "DeepTIO: A Deep Thermal-Inertial Odometry with Visual Hallucination", IEEE RAL.

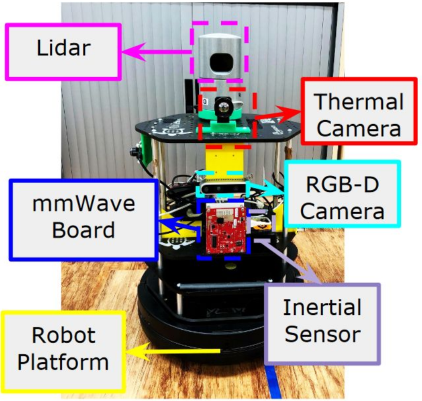
Probabilistic Networks



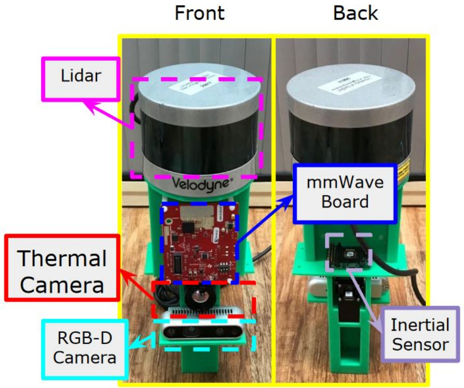
The network estimates the parameters of Mixture Density Networks (mean, variance, & mixing coefficients)

Dataset

- We collected ground robot and handheld data in indoor environments, both for benign and adverse visibility.
- Sensors:
    - Thermal
    - mmWave Radar
    - Lidar
    - RGB-D
    - IMU
- Trajectory length: 8km.



Ground robot

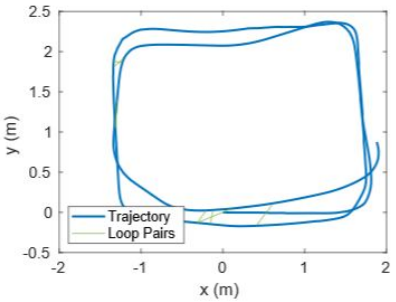


Handheld

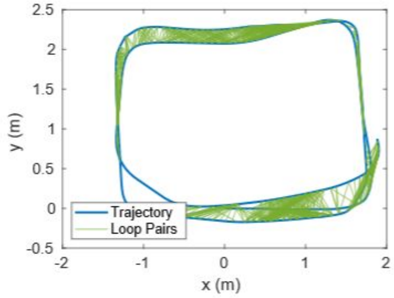
Loop Closure Detection on Thermal

UNIVERSITY OF OXFORD

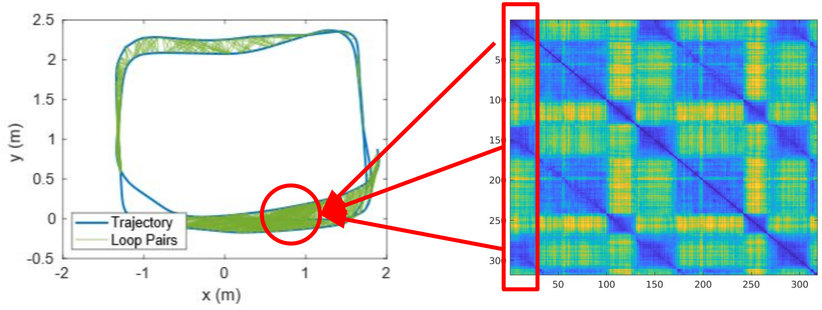
- Our model produce similar performance to NetVLAD with a far smaller embedding size (0.4%)



BoTW on Thermal



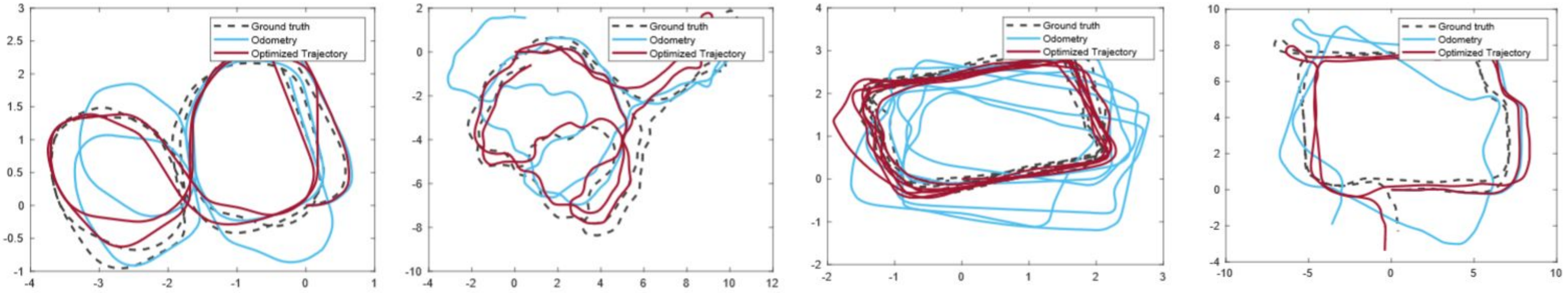
NetVLAD on Thermal



Our model

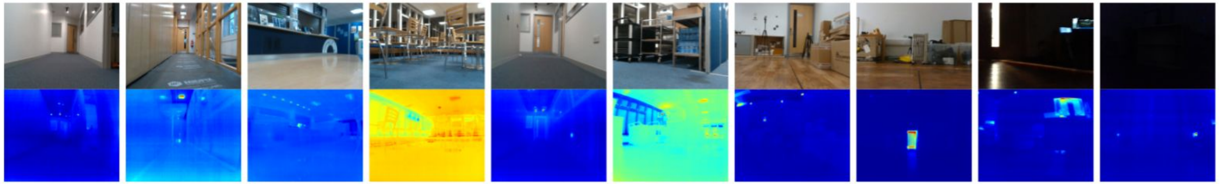
Test on Ground Robot Data

SLAM Results:



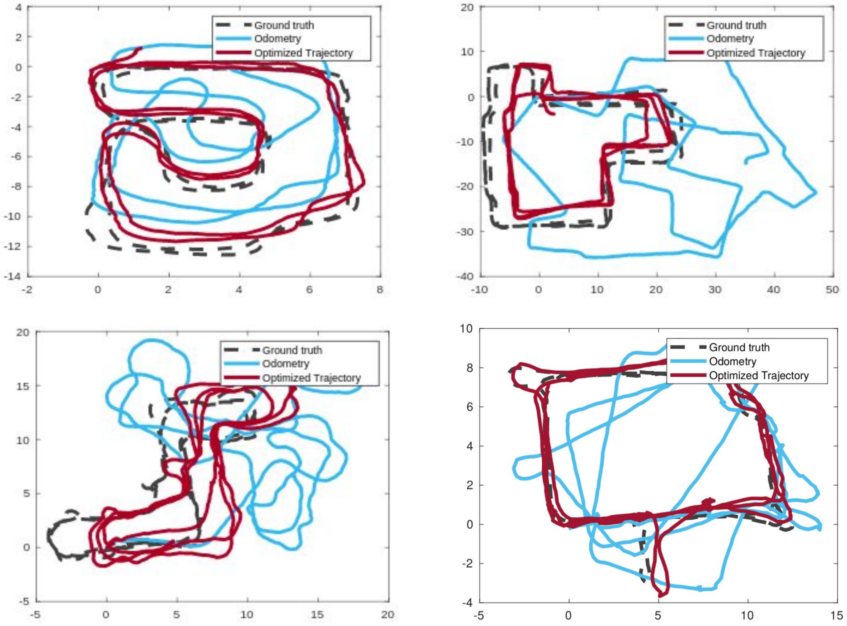
Mean Absolute Trajectory Errors (ATE): 0.281m

Sample Images:



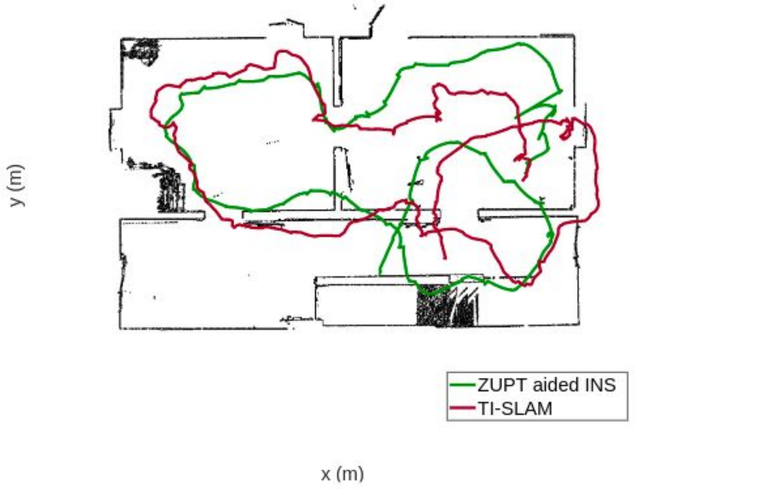
Test on Handheld Data

Oxford Buildings (Benign and Darkness)



Mean Absolute Trajectory Errors (ATE): 1.334m

Firefighter Training Facility in Washington (Smoke-filled)



Possible Future Directions

- Global localization (or scale correction) with LoRa trilateration/fingerprinting
- Collaborative localization and mapping between human and robots
- Realtime SLAM
- Semantic SLAM