EVALUATION OF INDOOR LOCALIZATION METHODOLOGIES: A COMPARATIVE STUDY OF TRILATERATION, LSTM, AND RANDOM FOREST REGRESSION

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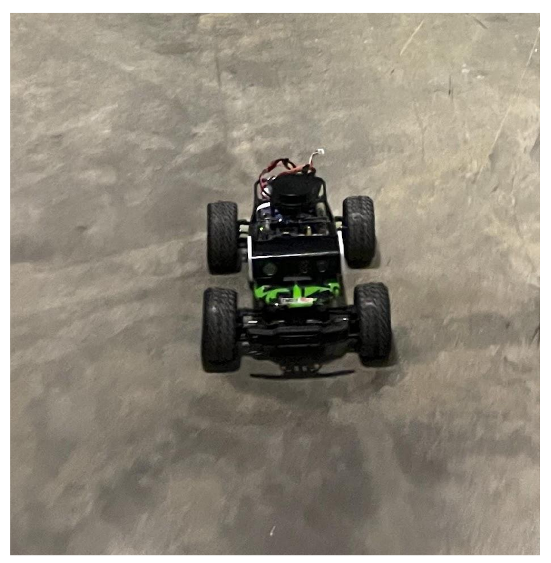
INDOOR LOCALIZATION METHODOLOGIES

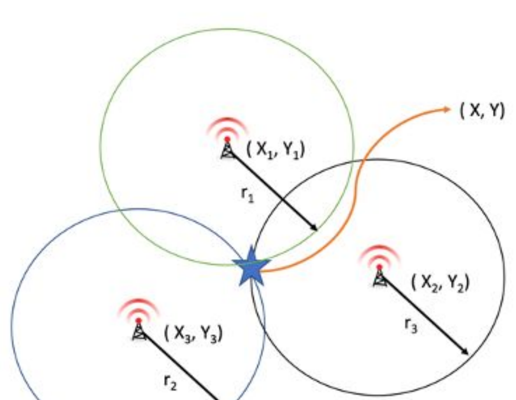
- Comparison of Methods of indoor localization using WiFi & LoRa Received Signal Strength Indication (RSSI)
- Two Machine learning based Methods:
  - Random Forest Regression
  - Long Short-Term Memory (LSTM)
- One Classical Localization Method:
  - Trilateration



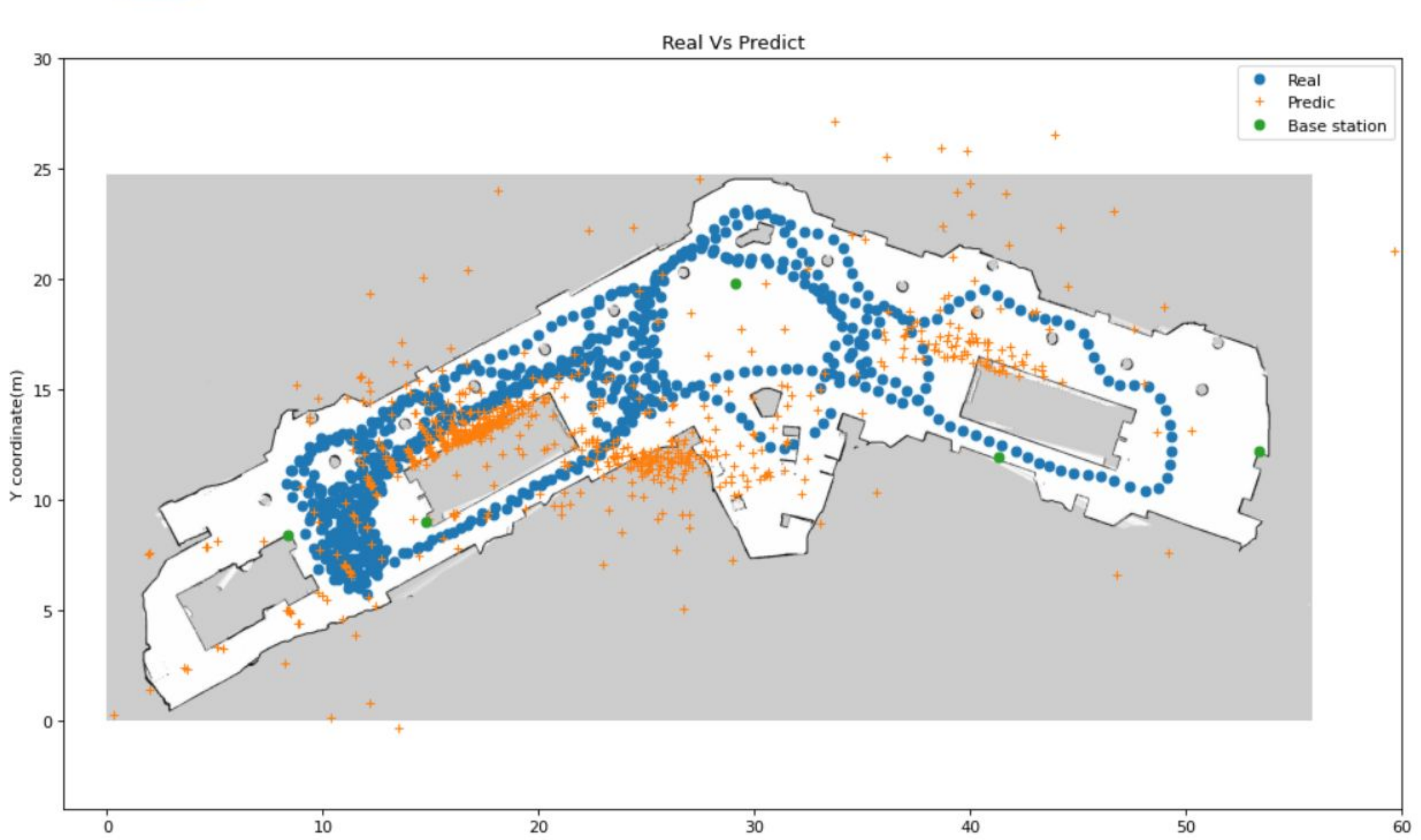
- The ML methods used "Finger Printing" of a Radio Map created by the RSSI values from 89 WiFi access points at known Locations throughout the ECE basement
  - An automated data collection robot was built on a MUSHR car platform to collect radio map
- The Trilateration method used LoRa hotspots at known locations in the ECE basement and calculated distance based on Wave Propagation Equations

LOCALIZATION WITH TRILATERATION

Visual Representation of Trilateration.

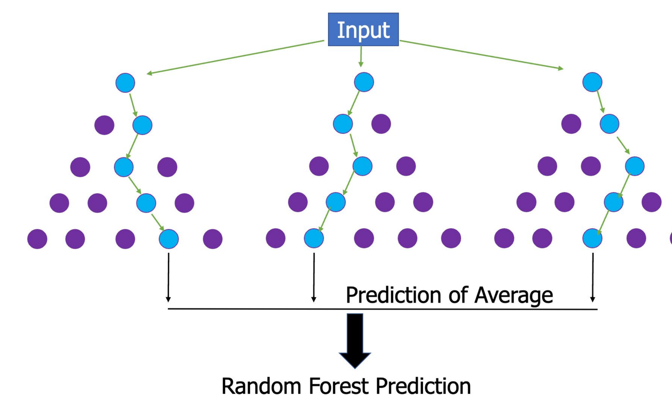


- A major advantage of the trilateration technique is its ease of setup and use, as it does not require training data or a "database"
- Trilateration is not as computationally intensive as some other techniques.
- Information about antenna gain and path loss is required for accurate position estimation
- Trilateration is subject to multipath errors

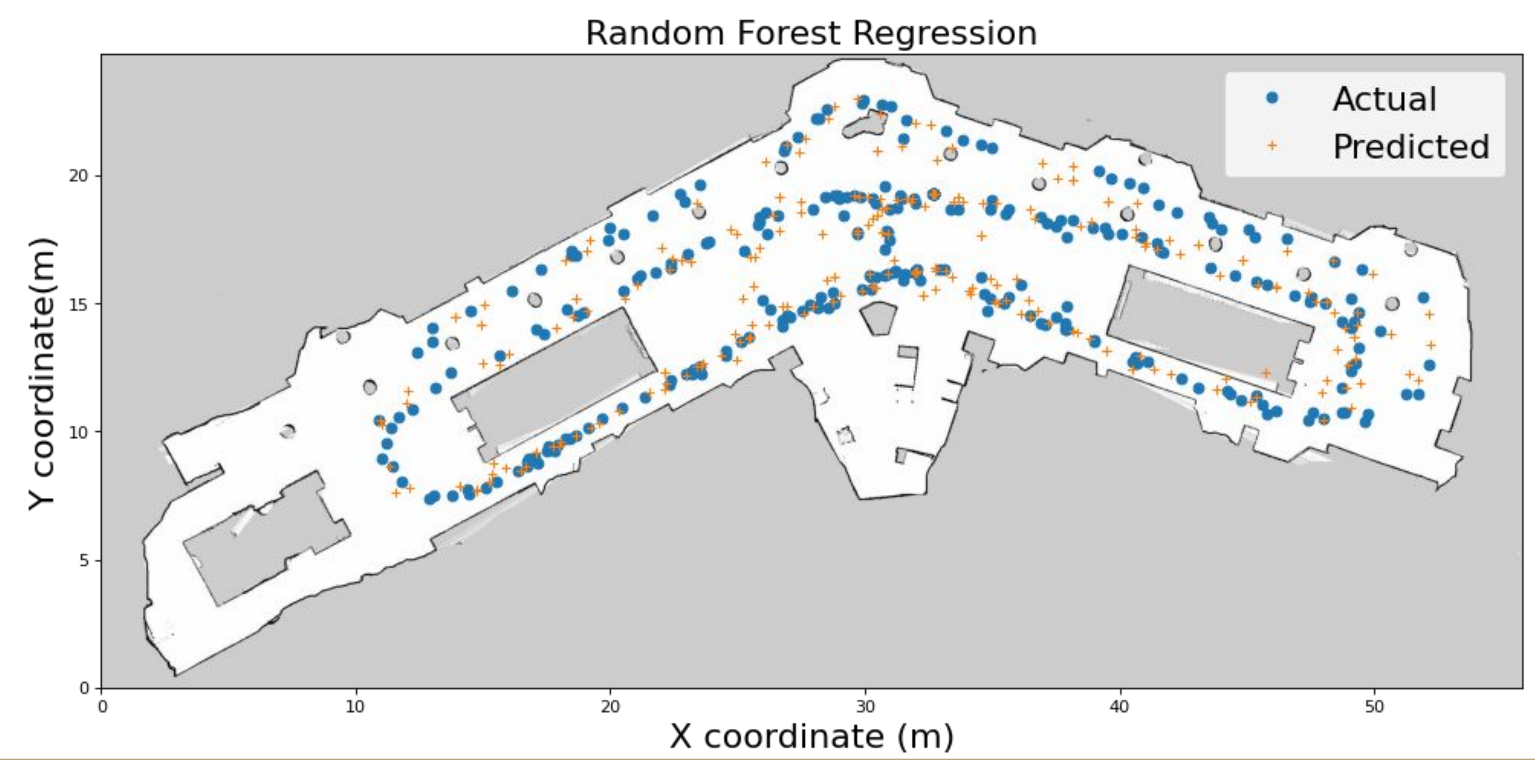


LOCALIZATION WITH RANDOM FOREST REGRESSION

Random Forest is a machine learning method that constructs multiple decision trees on randomly selected data subsets to improve prediction accuracy while reducing overfitting, requiring a large dataset and computational resources for training.

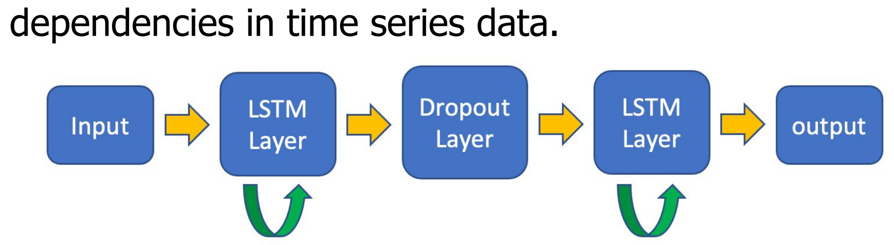


Benefits:
- Tolerant of missing data, multiple features, and outliers
- Less prone to overfitting and easier to interpret

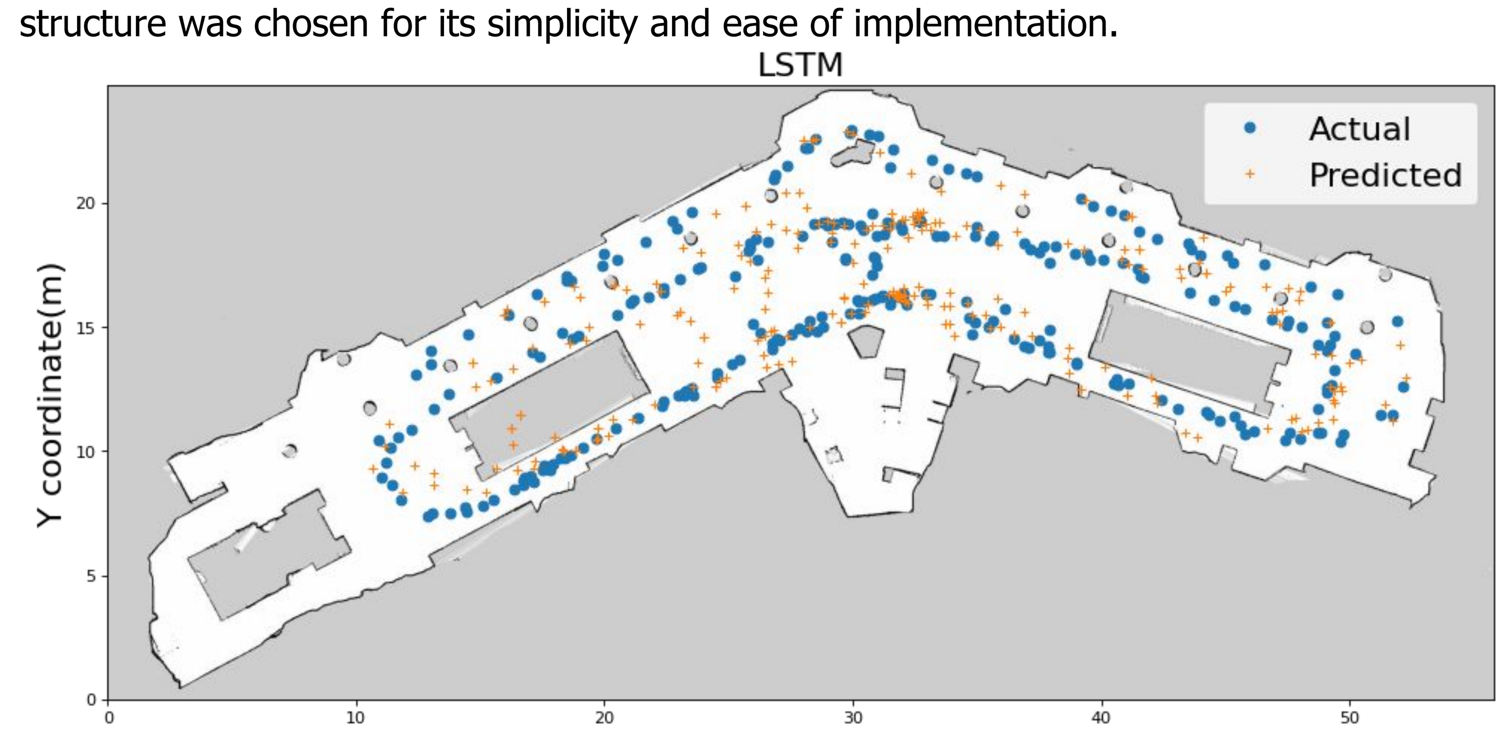


LOCALIZATION WITH LSTM

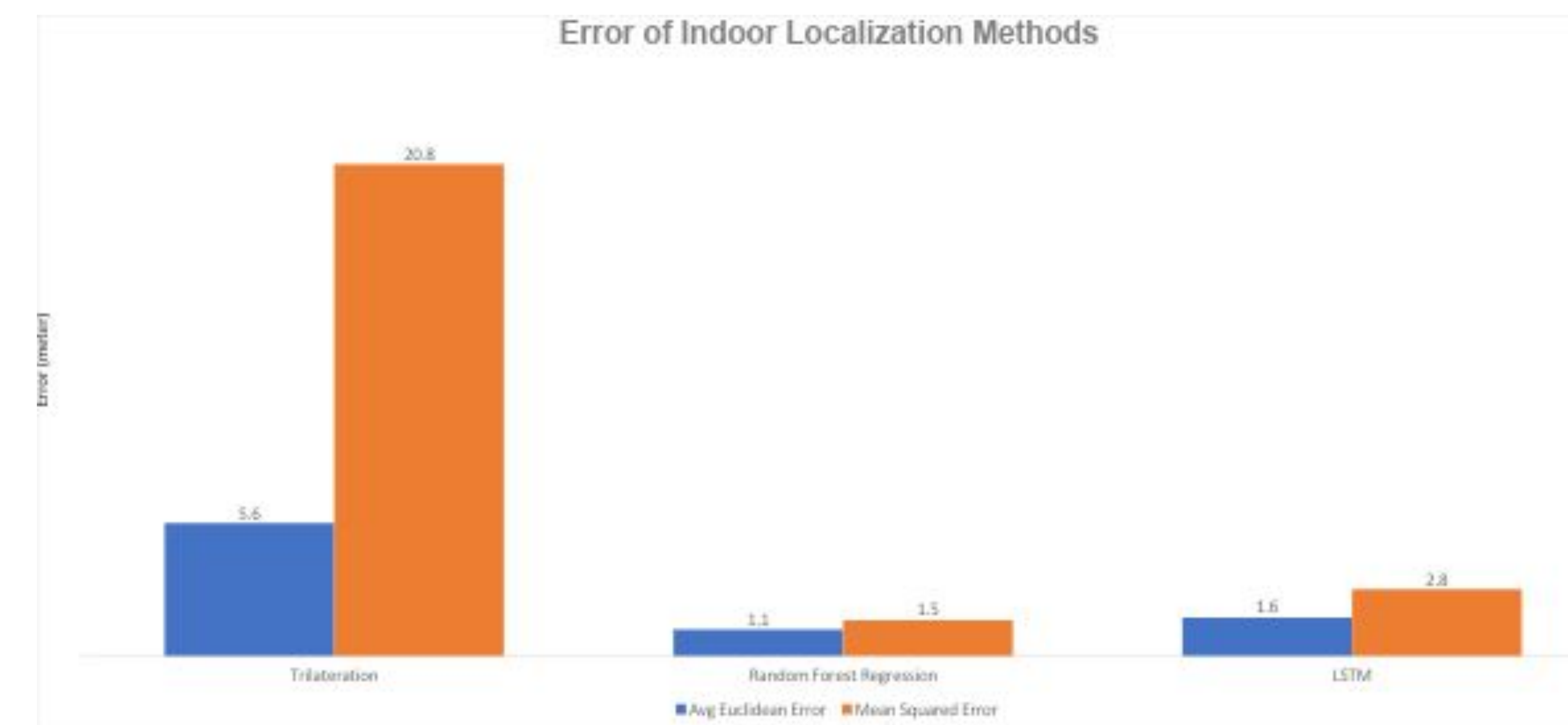
Long Short-Term Memory (LSTM) is a machine learning method that is well-suited for modeling long-term dependencies in time series data.



For this research methodology, the proposed model features two LSTM layers after the input layer and employs a single drop-out layer in between the two LSTM layers to prevent overfitting. This structure was chosen for its simplicity and ease of implementation.



COMPARING LOCALIZATION RESULTS



Average Euclidean Error (meters) and Mean Squared Error (MSE) to evaluate the accuracy performance of the models utilized.

- The ML-based methods outperformed the trilateration method. Random Forest Regression proved to have the smallest MSE (1.6 m) and Average Euclidean Error (1.1 m).
- The disadvantage of the ML-based methods (Random Forest Regression and LSTM), is the user needs to collect Wi-Fi RSSI data in the environment and train the ML model
- The disadvantage of Trilateration is that the absolute location of the routers needs to be known as well as hardware characteristics for path loss calculation.
- Random Forest Regression was quicker to train than LSTM and the learned model consumed less memory

Random Forest Regression proved to be the most effective method of the three. Our future work will evaluate real-time performance on an embedded system and explore sensor fusion methods to improve accuracy. Random Forest Regression shows the most promise for future development based on its performance and computational cost.

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References

1. Srinivasa, S.S.; Lancaster, P.; Michalove, J.; Schmittle, M.; Summers, C.; Rockett, M.; Smith, J.R.; Choudhury, S.; Mavrogiannis, C.; Sadeghi, F. MuSHR: A Low-Cost, Open-Source Robotic Racecar for Education and Research 2019.
2. The University of Washington MuSHR: The UW Open Racecar Project Available online: https://prl-mushr.github.io (accessed on 15 January 2023).
3. Ho, T.K. Random Decision Forests. In Proceedings of the Proceedings of 3rd International Conference on Document Analysis and Recognition; IEEE: Montreal, QC, Canada, August 1995; Vol. 1, pp. 278–282 vol.1.
4. LoRa PHY | Semtech Available online: https://www.semtech.com/lora/what-is-lora (accessed on 15 January 2023).
5. UW Department of Electrical & Computer Engineering Available online: https://www.ece.uw.edu/ (accessed on 19 January 2023).
6. Yoo, J. Multiple Fingerprinting Localization by an Artificial Neural Network. Sensors 2022, 22, 7505, doi:10.3390/s22197505.
7. Hochreiter, S.; Schmidhuber, J. Long Short-Term Memory. *Neural Comput.* 1997, *9*, 1735–1780, doi:10.1162/neco.1997.9.8.1735.
8. Institute of Smart Systems and Artificial Intelligence A Tutorial on WiFi-Based Indoor Localization Available online: https://github.com/IS2AI/tutorial_indoor_localization_WiFine (accessed on 24 January 2023).

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