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XXXIII Cycle

Neural network-based indoor localization using capacitive sensors

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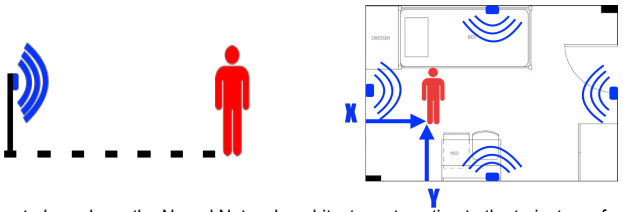
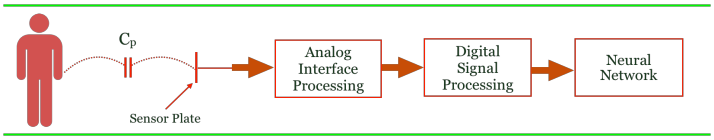
Research context and motivation

- Capacitors are commonly used as sensors for short distances, e.g. in touch screens and mechanical vibration measurements. They provide good accuracy and are passive devices
- Accurate tag-less Indoor localization is important for several application such as assisted living and health monitoring
- Capacitive sensors can be used for indoor localization in loading mode, where a metal plate acts as one side of capacitor and the person acts as the second capacitor plate. This makes this localization technique tag-less as compared to many other available localization techniques
- In this study we use long-range capacitive sensors for indoor person localization. With capacitive sensors using 16cm x 16cm plates we achieved sensing ranges of about 1.5m



- Our study explores the Neural Network architectures to estimate the trajectory of a person in a room of 3m x 3m. We used 4 capacitive sensors, attached to the room walls and achieved the trajectory estimation with RMSE of 26 cm, using signal conditioning followed by an autoregressive Neural Network.



Addressed research questions/problems

- Viability of single plate capacitors for indoor person localization
- Viability of neural networks to convert sensor data (i.e. oscillator frequency) into trajectory
- Challenges
  - Steep (more than quadratic) decrease of sensitivity as distance increases
  - High electric and electrostatic noise from environment
  - Drift mostly because of changes of static charge in the environment

Novel contributions

Extended range – high sensitivity, low noise for measurements over distances 10–20X sensor size (single plate)

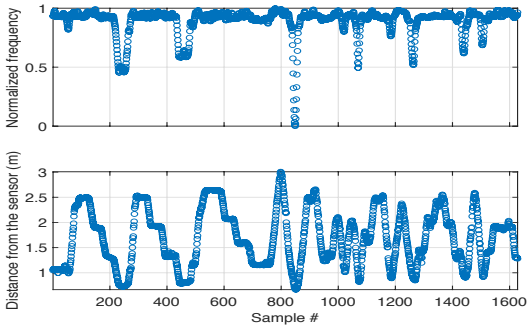
- Differentiate between human movements and changes in environmental conditions (drift)
- Use of Neural Networks to infer human movement and trajectory from the oscillator frequency variations

List of attended classes

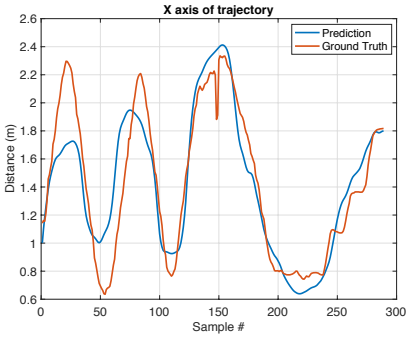
- 01SHCRV – Unsupervised neural networks (9/4/2018, 6 credits)
- 01SCSIU – Machine learning for pattern recognition (28/5/2018, 4 credits)
- 01MNFIU – Parallel and distributed computing (27/6/2018, 5 credits)
- 01QSCIU – Reconfigurable computing (15/6/2018, 4 credits)
- 01SGURV – Intellectual Property Rights, Technology Transfer and Hi-Tech Entrepreneurship (22/3/2018, 6 credits)
- External Training Activity – Innovation for Change (25/5/2018, 30 hours)
- External Training Activity – Intelligent Cars on Digital Roads – Frontiers in Machine Intelligence (3/8/2018, 38 hours)
- External Training Activity – Neural Networks and Deep Learning
- External Training Activity – Improving Deep Neural Networks: Hyperparameter tuning, Regularization and Optimization
- External Training Activity – Structuring Machine Learning Projects
- External Training Activity – Convolutional Neural Networks
- External Training Activity – Sequence Models

Adopted methodologies

- Data from four capacitive sensors labelled with X and Y coordinates of room using ultrasonic sensors
- Extensive NN architectural exploration, leading to the best results from an Autoregressive Neural Network with three hidden layers (64 neurons, 32 neurons, 8 neurons with dropout regularization).
- NN trained on various sizes of input window, LP and median filter parameters to obtain the best combination of hyper-parameters.



- Strong non-linear dependence between sensor output and the distance to person
- Noise limited correlation between sensor data and distance of person from the sensor



- The resulting RMSE was about 26 cm, which is perfectly suitable to track, for example, the movement of an elderly person within an apartment

Future work

- Training and testing of Neural Networks on data acquired in separate environments
- Use of more and more realistic settings for our experiments, for example tracking a person performing normal daily activities within a room or tracking a person across multiple rooms, or tracking multiple people

Submitted and published works

- Tariq, O.B., Shan, J., Floros, G., Lavagno, L., Lazarescu, M.T., Sotiriou, C., Casu, M., Rafiq, M.T., "Physical Aware High-Level Synthesis", Design, Automation and Test in Europe Conference, submitted
- Tariq, O. B., Lazarescu, M. T., & Lavagno, L. (2019, September). Neural network-based indoor tag-less localization using capacitive sensors. In Proceedings of the 2019 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2019 ACM International Symposium on Wearable Computers (pp. 9-12). ACM.
- Tariq, O. B., Lazarescu, M. T., Iqbal, J., & Lavagno, L. (2017). Performance of Machine Learning Classifiers for Indoor Person Localization With Capacitive Sensors. *IEEE Access*, *5*, 12913-12926.
- Ramezani Akhmareh, A., Lazarescu, M. T., Bin Tariq, O., & Lavagno, L. (2016). A tagless indoor localization system based on capacitive sensing technology. *Sensors*, *16*(9), 1448.
- Iqbal, J., Lazarescu, M. T., Tariq, O. B., Arif, A., & Lavagno, L. (2018). Capacitive Sensor for Tagless Remote Human Identification Using Body Frequency Absorption Signatures. *IEEE Transactions on Instrumentation and Measurement*, *67*(4), 789-797.