CS724A: Sensing, Communications and Networking for Smart Wireless Devices

Academic Year: 2023-2024 Semester: I

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Lectures: Wednesdays and Fridays from 10:30-12:00 (in RM 101).

Course description: The course will cover different types of sensing, communication and networking techniques for current/future smart devices. The primary objective of this course is to help students build foundations for developing real-world sensing technologies and solutions. The course will start with some mathematical concepts and then how to apply them in solving real-life problems. Key topics of this course include GPS, indoor localization techniques, motion tracking, applications of different sensing modalities, low power wireless protocols etc.

Prerequisites: The course is mostly self-contained, so it does not have any formal prerequisites. However, some familiarity with linear algebra and programming (preferably Python or Matlab) is expected.

Grading: Here is the grading schema

Assignments	20%
Midterm	40%
Final project and related presentation/viva	30%
Paper presentation	10%

Tentative topics: A tentative list of topics are as follows.

1. **Introduction, overview and motivation:** Technology, scope, applications of wireless sensing and sensor networks.
2. **Indoor/outdoor localization of smart devices:** GPS localization, indoor localization challenges, RSSI based localization, fingerprinting based approaches, Time-of-flight (ToF), Time difference of arrival (TDoA), ToF based localization and clock synchronization issues.

3. **Signal processing and its sensing related applications**: Time domain to frequency domain conversion, DFT basics and spectrogram, Beamforming basics and applications, Beam rotation, Angle-of-arrival (AoA) based localization.
4. **Sensing and event detection:** Notion of event detection accuracy using inaccurate sensors, concepts of true/false positive/negative and confusion matrix, event detection as hypothesis testing, Neyman-Pearson lemma, understanding Receiver Operating Characteristics (ROC) curve and its implications.
5. **IMU sensor and motion sensing:** Understanding inertial measurement unit (accelerometer, gyroscope, magnetometer), sensor fusion, applications of IMUs for motion tracking, gesture detection, activity tracking, motion tracking using Kalman filter.
6. **Audio sensing and classification:** Mel scale and Mel filter banks, logarithmic perception of frequency, Mel spectrogram, Mel Frequency Cepstrum Coefficients (MFCC) and audio classification.
7. **Device-free sensing:** Wireless signals and communication channels for sensing, applications like human presence detection, device free gesture tracking, digital agriculture, contactless liquid sensing etc.
8. **Dynamic time warping and applications:** Basics of pattern matching, dynamic time warping, applications like posture detection, hand movement tracking etc.
9. **Security and privacy of sensing devices:** Information leakage from sensing devices, Bayesian inference, guessing typing patterns from IMU data, hacking speakers with inaudible acoustics etc.
10. **MAC in sensor networks:** Introduction to sensor networks and use cases, synchronous vs asynchronous MAC, low-power MAC, specific examples including IEEE 802.15.4.
11. **Routing in sensor networks:** Routing challenges in low-power sensor networks, energy aware routing, geographic routing, attribute based routing etc., routing and adaptations in rechargeable sensor networks.

References: There will not be any dedicated textbook for this course. Students are expected to read research papers and online materials/tutorials, which will be provided with the corresponding lectures.