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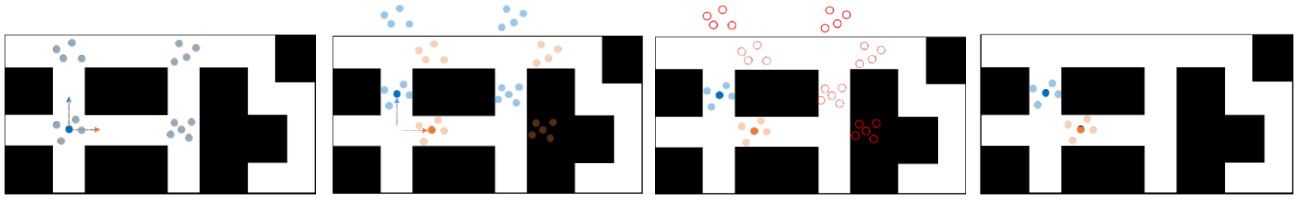
M2M-Tracking: Encounter-based Collaborative Localization using M2M-sisted Particle Filter

1. Project Description

This project targets the development of Encounter-based Collaborative Tracking algorithm (ECT), which provides an offline method of counteracting the error of displacement vector by exploiting opportunistic radio encounters between many devices.

The integration of computing, storage, wireless communication, and sensing technologies in miniature packages gives rise to the Internet of Things (IoT), which is about the ability of "things" to sense and act according to the requirement of environmental conditions with Machine-to-Machine (M2M) communications. The main purpose of communications among devices is to maintain state coherency so that the users or devices can act more intelligently with the contextual information. One fundamental type of such context is the device's or its user's trajectory, namely "***locations over time***".

Many techniques have been proposed for localization, but most assume that the observers (such as cameras) or beacons (such as GPS satellites) have been deployed at known locations to provide the reference. However, it is not always possible or practical to deploy the infrastructure for complete coverage since there will always be black-out areas. On the other hand, miniature inertial sensors (such as some combinations of accelerometer, gyroscope and magnetometer) can detect relative motion by the IoT device itself. Thus, dead reckoning techniques, which roughly estimate the time-vary locations of pedestrians by the displacement of the motion detected [1, 2, 3], have been proposed for trajectory tracking using inertial sensors. Still, dead reckoning will not work if the starting location is unknown.



(a) Get the movement of target | (b) Move all particles along the path of target | (c) Some of particles are invalid regions | (d) Eliminate the invalid particles by encountered dependence

Figure 1. Working flow of ECT algorithm

The idea of M2M ECT is to share the location information among heterogeneous nodes with different sensing capabilities. For example, "Thing" A and B have inertial sensors but C has real-time clock and temperature sensor. Collaborative tracking (include localization) that is Knowing A-C and B-C distance, A and B can help C to localize. C can help A, B determine time and temperature. Fig. 1 shows the proposed algorithm based on our preliminary work which demonstrates how this algorithm utilizes the encounter event to localize itself based on particle filter. Fig 1.a list the possible location based on the movement the sensor estimated. While pair of IoT device encounter and exchange their trajectory, Fig. 1.b show the possible location set for them. Three of them are impossible location as they are out of boundary based on the floor plan we have as showed in Fig. 1.c. Therefore, we can estimate the location, where the both pair of IoT devices is.

This project is to enable localization and ultimately trajectory tracking cooperatively as nodes encounter each other. A standard feature in the popular Bluetooth Low Energy (BLE) protocol is leveraged to sense other IoT devices that are in proximity. Compared to other algorithms requiring

infrastructure, ECT provides a feasible tracking model that can be easily implemented by devices with inertial and proximity sensors only and the floor plan map data. However, as the variety of IoT devices provided, the ECT algorithm suffers from the challenge, how to scale ECT for the large number of targets by optimizing the particle filter in order to provide more accurate location estimation for devices in a power efficiency way. Considering that there are N devices located in the range which are able to exchange the movement information with each other, it roughly takes N^2 times M2M communication and every one device needs to estimate the possible location of N devices. Since the IoT devices provide limited computation ability and power budget, an optimized algorithm is required without sacrifice the accuracy of estimation and power consumption of devices.

2. Student's Involvement and Expected Outcomes

One student is required for this project. It is expected that the feasibility of developed M2M ECT algorithm for multiple devices is demonstrated through the following items:

1. The accuracy of location estimation among IoT devices (algorithm performance)
2. Responding time of the computation (algorithm complexity)
3. Power consumption of the computation (algorithm cost)

This project is conducted by using Broadcom WICED Sense Development Kit for which the following development environment and techniques may be required:

1. Android-based mobile devices
2. Broadcom WICED SDK
3. Bluetooth Low Energy (BLE) protocol

3. Student Eligibility

Student who is familiar with the following skills may be preferable.

1. Programing language: Java or C/C++
2. Embedded system development
3. Bluetooth Low Energy (BLE) protocol

4. Recommended Readings

[1] DAVIDSON, P., COLLIN, J., AND TAKALA, J. "*Application of particle filters for indoor positioning using floor plans*", In Ubiquitous Positioning Indoor Navigation and Location Based Service (UPINLBS), 2010 (Oct 2010), IEEE, IEEE, pp. 1–4.

[2] WIDYAWAN, KLEPAL, M., AND BEAUREGARD, S. "*A backtracking particle filter for fusing building plans with pdr displacement estimates*", In Positioning, Navigation and Communication, 2008. WPNC 2008. 5th Workshop on (March 2008), IEEE, IEEE, pp. 207–212.

[3] LI, F., ZHAO, C., DING, G., GONG, J., LIU, C., AND ZHAO, F. "*A reliable and accurate indoor localization method using phone inertial sensors*", In In Proceedings of the 2012 ACM Conference on Ubiquitous Computing (UbiComp '12) (2012), ACM, ACM, pp. 421–430.

[4] CONSTANDACHE, I., BAO, X., CHOUDHURY, R. R., AND AZIZYAN, M. "*Did you see bob? human localization using mobile phones.*", In In Proceedings of ACM International Conference on Mobile Computing and Networking (MobiCom '10) (2010), ACM, ACM, pp. 149–160.

[5] SYMINGTON, A., AND TRIGONI, N. "*Encounter based sensor tracking*", In In Proceedings of the thirteenth ACM international symposium on Mobile Ad Hoc Networking and Computing (MobiHoc '12) (2012), ACM, ACM, pp. 15–24.

[6] "Bluetooth Low Energy (BLE) protocol", [Online]. Available: https://developer.bluetooth.org/TechnologyOverview/Pages/BLE.aspx