GruMon: Fast and Accurate Group Monitoring for Heterogeneous Urban Spaces

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Determining the right context-specific incentive to offer to a customer, frequently requires knowledge of the group that the customer is travelling in. Unfortunately, group detection in crowded urban environments like shopping malls, is a non-trivial problem as: (1) the density ensures that at any location, a large number of people are moving together – intentionally or otherwise, (2) the location tracking systems in many indoor venues tend to be either non-existent or provide low accuracy (due to the crowd density and other reasons). The first challenge makes it difficult to build a low latency group detection system as many individuals will be co-located for elongated periods. The second challenge implies that the group detection system cannot rely entirely on the availability of accurate location data.

In this demo paper, we present *GruMon*, our system for group detection in dense indoor environments. We overcome the two key challenges by using additional data from smartphone sensors, like accelerometer, compass and barometer. *GruMon* correlates these sensor readings between individuals to determine which individuals are in the same group. On data collected from real participants from two different shopping malls, CoEX mall in Korea and Plaza Singapura in Singapore, *GruMon* is able to (a) achieve up to *97%* group detection accuracy, within 10 minutes of observing a group of individuals, even in locations with poor or even no location data. In addition, in venues where location information is available, *GruMon* (b) improves the precision of traditional trajectory tracking algorithms through the use of semantic labels by up to *22%*, and (c) improves the recall of up to *20%* groups, using inertial sensors in addition to location data information. Our main contributions are:

[a] Identify challenges of group detection: We identify that fast and accurate group detection is not a simple problem in urban spaces due to (a) unavailability of accurate location information and (b) crowd density. We empirically analyze the limitations of traditional spatio-temporal or BlueTooth proximity based approaches, in such environments.

[b] Fast and accurate group detection method: We design and implement a set of heuristics that achieve fast and accurate group detection in dense and complex urban spaces. Specifically, we devise micro-activity correlation techniques for a deployment environment lacking localization infrastructure. Also, we improve both precision and latencies of basic spatio-temporal clustering methods, using additional sensor information.

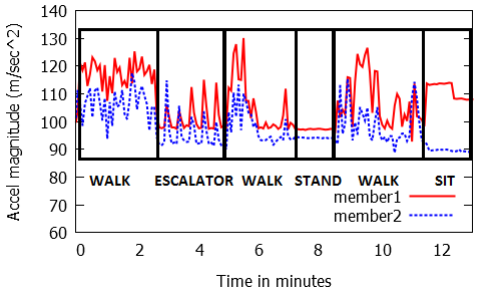

Figure 1: Motion similarity in a group

Fig. 1 shows the motion similarity of two group members as shown with accelerometer data. Likewise turn-similarity or level-change similarity, measured using compass and barometer, can be used for micro-activity correlation to detect groups. Combination of such micro-mobility features, along with traditional location features, gives better detection results.

[c] Experiments in dense indoor urban spaces: We tested our techniques at two dense indoor shopping complexes: *CoEX in Korea* and *Plaza Singapura in Singapore*, where there are 200+ stores each, and 140K and 56K visitors per day, respectively.

Venue	Accuracy	Recall	Precision
Mall1	90.07	61.16	92.15
Mall2	97.31	68.48	97.39

Table 1: Accuracy, recall, and precision

Table 1 show the accuracy, recall and precision of group detection, at 10 minutes latency, using the data collected during 258 separate shopping episodes (with 170 of them in groups) from 154 distinct individuals, at the two venues. Our demo will show the playback traces from these two venues, illustrating how micro-mobility and location features can be combined for group detection, and the associated trade-offs among accuracy, latency and power consumption for group detection. *We will need a table, a poster stand and a power supply for showing our video demo on a laptop.*