QueueVadis: Queuing Analytics using Smartphones

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Queuing is a very commonplace activity performed repeatedly by individuals daily, at places such as coffee shops, taxi stands, and movie theaters. Given the emotional aggravation and productivity loss resulting from such queuing, there is a strong interest in technologies that provide accurate, near real-time estimates of such individual and aggregated queuing behavior. Such up-to-date estimates can enable key new urban applications such as "Finding the nearby cafe with shortest waiting time" or "Giving additional coupon for long time waiting customers".

Our demo shows that it is possible to derive such estimates of queuing by leveraging on the power of automated *citizen-scale mobile sensing*. Mobile sensing-based queuing analytics is appealing as *a)* unlike infrastructural solutions such as camera-based people counting that can be deployed only at specific key locations, a mobile-based solution can provide insights on queuing behavior across a much wider range of ad-hoc spaces (at different fast food outlets in a mall's food court, at taxi or bus stands, next to street-side food vendors, or at a one-off public performance event), and *b)* equally importantly, it can perform *in-situ identification* of who is queuing, *while* the person is still queuing.

We present *QueueVadis*, a system for obtaining such individual and aggregated queuing context in public spaces using smartphone sensors, and demonstrate its ability to capture real-life queuing dynamics at *commonplace* urban locations. As its architecture is shown in Figure 1, *QueueVadis* has two novel dimensions as follows:

Detection of Real-world Queuing Activity: On the mobile phone, *QueueVadis* infers an individual's queuing activity by using an accelerometer sensor to capture a repetitive sequence of micro (or postural) activities that principally involve "stationary" for a while, interspersed with short bursts of "stepping forward". Its mobile application contains 2-tier online classifiers where the 1st layer detects Micro Activities (MAs) such as "walk", "stand" or "run" and the 2nd layer detects the queuing High-level Activity (HA) based on the MA sequence. Multiple 2nd layer classifiers execute their detection concurrently with own periodicity parameters derived from our extensive real-world queue observational studies at over 6 queue types of 39 venues.

Aggregated Analytics of Queue Properties: On the server side, *QueueVadis* applies analytics over attributes of queuing behavior from multiple people in a queue to infer its important *dynamic* properties, such as its expected wait time and service time. For total wait time estimation, we devised the *History-Driven Estimation* (**HDA**) algorithm where the server receives the estimated total wait time $T_w(i)$ from the i^{th} customer and aggregates all these reports from multiple

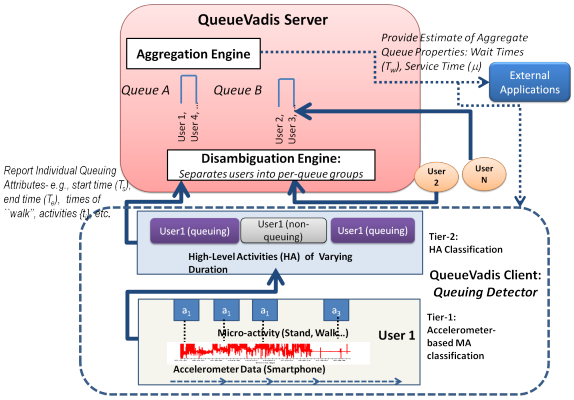

Figure 1: The *QueueVadis* Architecture (with Two-Tier Activity Classification on Client)

customers by calculating a weighted "moving average" of these $T_w(i)$ values. For service time estimation, we have investigated two different algorithms for computing the distribution of the service times of a particular queue: (1)*Departure-driven Detection* Algorithm (**DDA**) where the service times are derived only based on the end time (T_e) of each individual's queuing episode, and (2)*Activity-centric Detection* Algorithm (**ADA**) where time gaps between multiple occurrences of "step forward" during users' queue episodes will be used. Our user studies, performed by 95 cumulative total users on 15 *real-world* queues across 2 countries, show that *QueueVadis* identify *all* instances of queuing, and is able to predict service and wait times fairly accurately, with median estimation errors typically in the 10% to 20% range.

Queue Disambiguation: When multiple queues are in close proximity of one another (e.g., checkout counters at a supermarket), *QueueVadis* can detect if two customers are queuing in the same or different queues. It views their (standing, movement) sequences as two time series and measure their *cross-correlation function* to characterize the relationship.

Our demo will firstly show that the participants' queuing activities can be accurately detected by our mobile sensing system. We may need 5 participants to formulate a normal queue. Any other participant, who equips with a prepared smartphone, will join the queue sequentially. The prepared android phones will play music once the participants' queuing activity is detected. Meanwhile, we will change the queue's "moving speed" and other properties, and show that the system can still detect the queuing activities with high accuracy. Moreover, we will show the analysis and experimental results based on the data collected from the daily life queues, including the estimated queue waiting/service time and multiple-queue disambiguation. The demo uses one laptop and 5 smart phones. We will require Internet access and power points.