TPE-CMS: A Comfort Measuring System for Public Bus Service in Taipei City

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***Abstract*—We demonstrate a Comfort Measuring System (CMS) for public transportation systems in Taipei city, called TPE-CMS. TPE-CMS exploits the GPS and G-sensor of modern smart phones to measure the comfort level of vehicle rides. Then, it mashes up the sensed data with the authorized data of the public transportation system, and provides a detailed comfort statistics as a value added service. We have deployed TPE-CMS to measure the comfort levels of public bus services in Taipei city since March 2010. Based on the user-input data, we show that the system is capable of ranking the comfort levels of the bus services of different bus attributes, and monitoring the comfort levels of the public transportation system overall. In addition, the system is scalable without the cost of deploying a sensing infrastructure, and we believe that it has the potential to provide a durable and large-scale comfort measuring service for public transportation systems.**

I. Introduction

The *comfort* of rides has been identified as one of the top criteria that affect customers' satisfaction with public transportation systems [5, 6]. However, conventional comfort measuring approaches rely on either personal interviews [7] or literature surveys [4], which are generally labor-intensive and time-consuming, and are thus limited in terms of scalability and timeliness.

In this demo, we present the deployment of a Comfort Measuring System (CMS), called TPE-CMS, for measuring the comfort levels of rides on public transportation systems in Taipei city. TPE-CMS system is comprised of three parts: 1) data obtained through participatory phone sensing by volunteers who sense and score their daily transportation experiences; 2) the authorized data of public transportation systems, which provides the reliable, accurate, and detailed information about vehicles in the system; and 3) a matching algorithm that mashes up the results of (1) and (2) for further analysis and statistical purposes. Using the VProbe tool [3] and the authorized bus data provided by the Taipei e-bus system [2], we deployed the TPE-CMS system in Taipei City in March 2010. Since then, we have collected 732 trajectories from 32 volunteering participants. Based on the analysis of user-input data, we make the following observations.

1) In Taipei City's public bus system, 10% of the bus rides are considered comfortable, 15% are uncomfortable, and the rest are in between the two extremes.
2) There is no significant difference in the comfort levels of bus services provided by different bus agencies in Taipei City; and the comfort levels vary a lot among bus services operated by the same agency.
3) Public light buses are uncomfortable than low-floor and the standard (single-decker) buses.

II. The Comfort Measuring System

The Comfort Measuring System (CMS) is comprised of three components:

- *Data Collection via Participatory Sensing:*
  The CMS system exploits the capabilities of modern smart phones to sense commuters' transportation experiences in a distributed and participatory manner. CMS does not rely on any particular applications, and it supports many existing smart phone applications that provide raw sensed data about *trajectories* (i.e., the path of a moving object through space) and *vibration measures* (i.e., a sequence of 3-axis accelerations collected by the G-sensor). Using the collected data, we follow the ISO 2631 standard [9] and calculate the *comfort level* of the trajectory [1]. Note that the smaller the average comfort level, the more comfortable will be the transportation experience.
- *Authorized Data from Public Transportation Systems:*
  In TPE-CMS, we acquired the authorized data of the *Taipei e-bus system* [1]. In the *Taipei e-bus system*, each bus has an on-board unit (OBU), which transmits the bus's information (the bus identifier, GPS location, and status codes) to the network control center via the GPRS connection periodically (every 15 $\sim$ 25 seconds). In 2010, the e-bus deployment involved 4,028 buses covering 287 routes, 15 operating agencies, and nearly the entire greater Taipei area. On average, there are 3,865 trajectories and 3,235,460 data points each day.
- *Data Mashup and Statistics:*
  We calculate the Euclidian distance between the user-input trajectory and the contemporaneous e-bus trajectories, and consider trajectory contributor is on the bus that has the minimum Euclidian distance to the trajectory. Based on the results, the CMS system mashes up the comfort measurement of the user-input trajectory with

This research was supported in part by the National Science Council of Taiwan under Grants: NSC 97-2628-E-001-007-MY3 and NSC 99-2219-E-001-001.

[1]Note that the CMS system can be applied in any city anywhere, as long as there are people willing to contribute sensing data and the authorized data of the city's public transportation system is available.

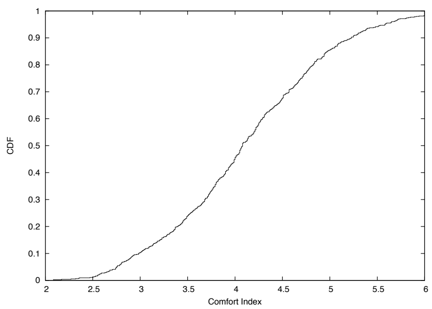

Fig. 1. The CDF distribution of the comfort index among the collected trajectories

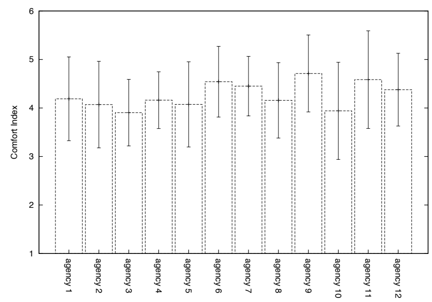

Fig. 2. The mean comfort index (± one standard deviation) with different bus agencies

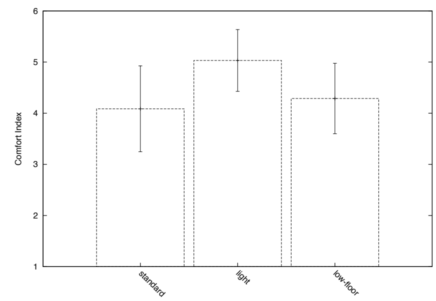

Fig. 3. The mean comfort index (± one standard deviation) with different bus types

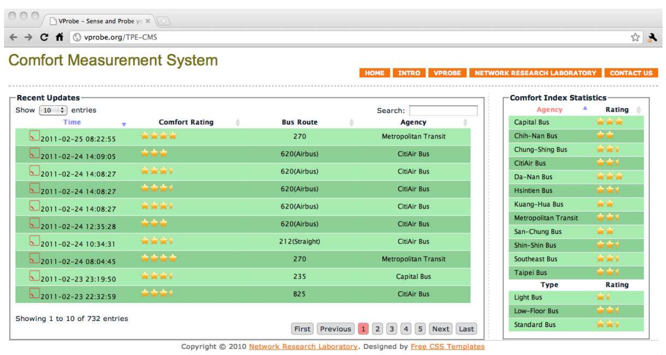

Fig. 4. The snapshot of the TPE-CMS system (http://VProbe.org/TPE-CMS/)

the matched bus in the authorized data and manipulates the statistics accordingly.

III. Preliminary Results

We deployed the CMS system in Taipei City in March 2010. Figure 4 shows a snapshot of the deployed system, i.e., TPE-CMS. Since then, we have collected 732 trajectories from 32 distinct volunteers. The trajectories covers three bus types (i.e., low-floor buses, light buses, and standard single-decker buses), 380 distinct buses, 128 routes, and 12 operating agencies.

From the results shown in Figure 1, we observe that, among the collected trajectories, 10% of them were below 3.0 (which is considered comfortable), 15% of them were above 5.0 (which is considered uncomfortable), and the rest were in between the two extremes [9]. Moreover, the results in Figure 2 show that the trajectories of bus agency 9 are relatively more uncomfortable than those of the other agencies, while the trajectories of bus agencies 3 and 10 are more comfortable.

The results in Figure 3 also show that the trips on light buses are more uncomfortable than those on low-floor buses and standard buses. The reason is that the light buses serve the areas where the routes are usually winding and the roads may not be in good condition. Moreover, we observe that the trajectories of low-floor buses and standard buses have similar comfort index values, which is counterintuitive to recent reports [8]. This is because the low-floor buses serve urban areas; thus, it is inevitable that they will stop more frequently to allow passengers to board/disembark. Consequently, there are no significant differences in the comfort indexes of the trajectories of low-floor and standard buses.

IV. Conclusion

We have presented TPE-CMS, the deployment of a Comfort Measuring System (CMS) for public transportation systems in Taipei city. Using real data collected from TPE-CMS, we show that only 15% of bus rides in Taipei are considered uncomfortable, and there are no significant differences between different bus agencies. We also find that the comfort level varies a lot among the bus services provided by the same agency, and smaller buses are the least comfortable vehicles. Work on analyzing other factors that affect comfort levels is ongoing (e.g., road conditions, drivers' behavior, and traffic congestion). We wish to report the results in the near future.

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