Wi-Crowd: Sensing and Visualizing Crowd on Campus using Wi-Fi Access Point Data

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Abstract
This paper presents *Wi-Crowd*, a system for visualizing the crowd level based on Wi-Fi usage data on campus by presenting it on an interactive 3D graphics, including map rotation, zoom-in/out, and display selections. The system uses animation to display the dynamism of crowd on campus based on the internet usage behavior in different buildings and time periods. The sensed crowd level is comparable to the student registration information. This developed system can be used to sense the crowd level and can be beneficial to future studies in campus behavior or even city-level behavior, and management of internet usage and crowd on campus such as scheduling optimization, campus traffic management and planning.

Author Keywords
Crowd sensing; visualization tool; Wi-Fi access point data; smart campus

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous;

Introduction

Today, people generally use devices that can connect to Wi-Fi for internet access, such as smartphones, laptops, tablets, and so on. Wi-Fi access points have thereby become increasingly deployed e.g., Wi-Fi access point service in the airports, campus, shopping malls, and other major institutes. On campus, Wi-Fi access point service has to be managed sufficiently for student usage. Typically, the campus IT department keeps logs of Wi-Fi access point usage for all buildings on campus. The logs data contains the information on time, date, access point location, and amount of connections. This work utilizes the available Wi-Fi access point data on our campus at Chiang Mai University, Thailand to sense the crowd level. We developed a prototype called *Wi-Crowd* that allows the user to observe and analyze the crow level on campus across space and time, based on Wi-Fi access point usage information.

Related Work

Wi-Fi data has been used to study different aspects of human behaviors. For example, Kergaard and Nurmi [1] discussed existing work in using Wi-Fi data for sensing social phenomena i.e., detecting physical proximity. Zeng et al. [2] tracked and analyzed shopper's behavior in retail stores such as standing near the entrance to review a promotion and walking quickly to the intended items, using Wi-Fi signal data. Rotiman et al. [3] described a crowd sensing system and the challenges in deploying the system in the smart cities domain. The harnessed multisource data is used to provide useful information for the officials. They presented a preliminary results on public safety. Rage et al. [4] presented a cloud-based emulation platform for carrying performance evaluation of crowd-sensing applications, focusing on addressing the challenges in predicting the performance of large-scale crowd-sensing applications in the pre-deployment phase. Calabrese et al. [5] used Wi-Fi access point data to analyze its correlation to the activity level across the campus. Our work differs from other existing work where we used Wi-Fi data to estimate the crowd level that is displayed graphically in an interactive visualization tool, which also allows the user to export data as a file for further analysis.

Sensing the Crowd

Our idea is to use Wi-Fi access point data to infer the crowd level. To ensure that the Wi-Fi usage data can reasonably present the amount of crowd, we compare it against the student registration records, which indicate the number of students registered for every class and the class room locations. Since the lectures only take place during the day but the Wi-Fi usage continues across 24 hours, so we only compare the number of Wi-Fi users during the time periods that there are registration records. Figure 1 shows the comparison result, which is highly correlated with the coefficient determination $r^2 = 0.8013$ for the fitted linear equation, $y=1.7227x + 20.829$, where x is the number of Wi-Fi users and y is the number of registrations at that particular time period. So, we use this obtained equation for the conversion from the number of Wi-Fi users to the crowd level at the location of that particular Wi-Fi access point. Each building has several Wi-Fi access points. The total crowd level for each building is then summed up accordingly.

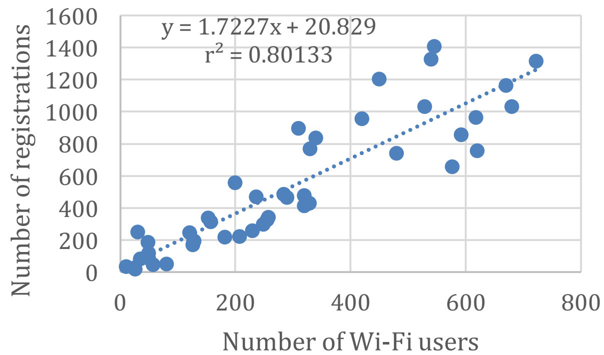


Figure 1: Correlation between the number of Wi-Fi access point users and the number of the class registration of each building at the same period.

Visualizing the Crowd

Wi-Crowd estimates the crowd level based on the obtained linear equation (Fig. 1) and displays the dynamics of crowd level through an interactive animation, which includes a 3D campus map filled with buildings each with changing color tone (ranging from green to red colors) reflecting the crowd level. Red color represents the highest level of crowd while green color indicates the lowest. The crowd level is visualized per five minutes. In addition to the 3D map, a running clock and date, day selection, top buildings per hour chart, a list of top five buildings for each hour, and crowd level graph are also displayed in the graphics. Wi-Crowd is developed as a desktop application built with the Processing Development Environment (PDE)[1].

[1] https://processing.org

Data sources

The system uses the Wi-Fi usage data on the main campus of Chiang Mai University. The data of Wi-Fi access point usage has been collected and stored in an RRD (Round-Robin Database tool)-extension file that contains date, time, and the number of internet usage connections information. The Wi-Fi data was provided to us by the University ITS Department. We considered one week of data for our system prototype. For visualization, we needed to build a 3D model of the campus buildings. We used the information about the building locations and physical appearance that was provided to us by the University Estate Department. With this information, we built our own 3D campus map using PDE.

Data pre-processing

We first filtered the data both the RRD file and the registration records to be in the period of seven days (1-9 September 2016) for our system prototype. Then, we grouped the data per building. Each building has several Wi-Fi access points, so based on the Wi-Fi access point locations given in the RRD file, we group all 1,837 Wi-Fi accession points to 22 buildings. After that, we divided the Wi-Fi usage data of each building into a five-minute interval, then converted it into the estimated crowd level using the equation in Fig. 1. Finally, the data was put into an CSV (Comma-separated values) file format for the PDE to use as an input for visualization. The pre-processing process is shown in Fig. 2.

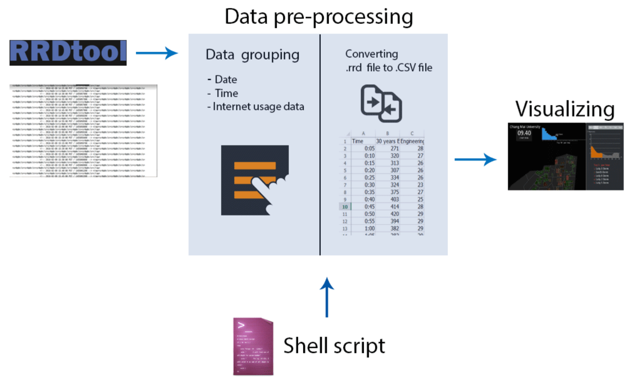


Figure 2: Data pre-processing process overview

Interactive Features

Wi-Crowd provides an interactive graphics that can respond to the user, which allows the user to choose and adjust what to view. The system has two main parts: an 3D building map, and a 2D information panel that includes useful numerical information, such as time and some basic statistical graphs.

Figure 3 shows a snapshot of the main display of the *Wi-Crowd* application that consists of eight main components as following:

1. Day of the Week: The user can choose to observe the crowd level of one of the seven days of the week to be visualized by clicking on a desired day. The visualization will start from the midnight (0:00AM).
2. Top Buildings of Each Hour: It displays a bar chart of the crowd level of the top (most crowded) building in each of the 24 hours.
3. Time: It shows a running time, so that the user can relate the visualization to a respective time.
4. 3D Map: It displays a map with 3D buildings. The map can be rotated. The user can control the camera view with the keyboard over 360 degrees. The crowd level is represented with a color ranging from green (low) to red (high) color tones.
5. Crow Level: A bar chart shows the level of crowdedness of the entire campus over the course of 24 hours. The level changes according to the time.
6. Top Five Buildings of each Hour: It shows a list of top five most crowded buildings of each hour. The list is updated as time progresses.
7. Photo: The user can click on the photo icon in the bottom right corner of the application to take a snapshot of the Wi-Crowd instance. A snapshot photo (in JPEG format) will then be saved in the user specified folder.
8. Export: The system allows the user to export the data in as an CSV file by clicking on the export icon next to the Photo icon.

Figure 3: Main display of *Wi-Crowd*

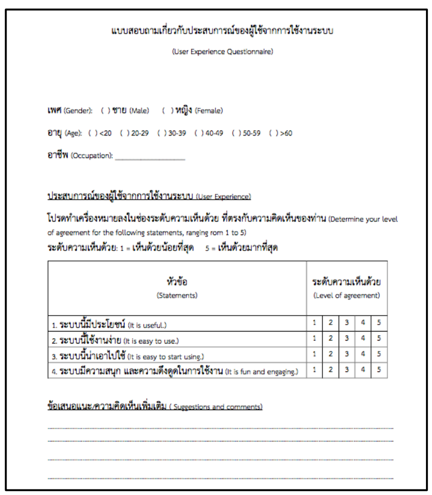
Demo

For the demonstration purposes, a video clip showing how the *Wi-Crowd* works is available at: https://youtu.be/WLuksuIWpyA.

User Experience Study

To put the *Wi-Crowd* into the test by the real users, we conducted a user experience study. Each user was asked to use *Wi-Crowd* and then asked to answer a questionnaire (shown in Fig. 4). The survey questionnaire was designed base the Theory of Four Elements of User Experience [6], which askes to the user to rate their agreement with four different statements concerning the user experience with the system that include:

1. It is useful.
2. It is easy to use.
3. It is easy to start using.
4. It is fun and engaging.



แบบสอบถามเกี่ยวกับประสบการณ์ของผู้ใช้จากการใช้งานระบบ

(User Experience Questionnaire)

เพศ (Gender): ( ) ชาย (Male) ( ) หญิง (Female)

อายุ (Age): ( ) <20 ( ) 20-29 ( ) 30-39 ( ) 40-49 ( ) 50-59 ( ) >60

อาชีพ (Occupation): ____________

ประสบการณ์ของผู้ใช้จากการใช้งานระบบ (User Experience)

โปรดทำเครื่องหมายลงในช่องระดับความเห็นด้วย ที่ตรงกับความคิดเห็นของท่าน (Determine your level of agreement for the following statements, ranging rom 1 to 5)

ระดับความเห็นด้วย: 1 = เห็นด้วยน้อยที่สุด 5 = เห็นด้วยมากที่สุด

หัวข้อ (Statements)	ระดับความเห็นด้วย (Level of agreement)				
1. ระบบนี้มีประโยชน์ (It is useful.)	1	2	3	4	5
2. ระบบนี้ใช้งานง่าย (It is easy to use.)	1	2	3	4	5
3. ระบบนี้น่าเอาไปใช้ (It is easy to start using.)	1	2	3	4	5
4. ระบบมีความสนุก และความดึงดูดในการใช้งาน (It is fun and engaging.)	1	2	3	4	5

ข้อเสนอแนะ/ความคิดเห็นเพิ่มเติม (Suggestions and comments)

Figure 4: Survey questionnaire

There are 50 participants in total that include 32 males and 18 females. Each participant was asked to give a rating of agreement level to the four statement where the rating score is a 5-likert scale where 1 means the lowest level of agreement and 5 means the highest level of agreement.

Overall, the average rating scores for the system being useful is 4.3, being easy to use is 4.6, being easy to start using is 4.2, and being fun and engaging is 4.1, as shown in Fig. 5. This result suggests that the users highly perceive that our system is easy to use, but not so fun and engaging. Our future development should consider adding or adjusting features that can improve more in this fun-and-engaging aspect of the system. Potential additional feature could be an analysis tool that allows the user to analyze the crowd level more in-depth, for example, faculty-level analysis or zonal analysis. A simulation could also improve in this aspect and be useful for simulating different scenarios by passing in some dependent parameters, which could also be used for optimization, management, and planning of crown level and flow on campus.

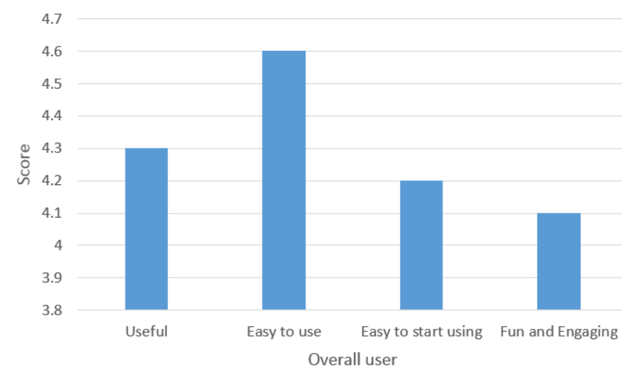


Figure 5: Overall result of the user experience study

By grouping the users by gender, the result (in Fig. 6) shows that, average male users rated the fun-and-engaging aspect the highest (4.10) and the easy-to-start-using aspect the lowest (3.75). However, the male rating scores are quite similar across the four aspects of the system. Female users, on the other hand, rated higher than male users for all aspects except for the easy-to-use aspect (3.5). The system was highest rated for being useful followed by easy-to-start-using, but rated the lowest for easy-to-use by the female users. The result suggests that the female users find it more difficult to use *Wi-Crowd* application but more appreciate other aspects of the system.

It can be interpreted that *Wi-Crowd* is more attractive to female users. One of comments from a female user is "*I really like this system. I think that the 3D model very useful*".

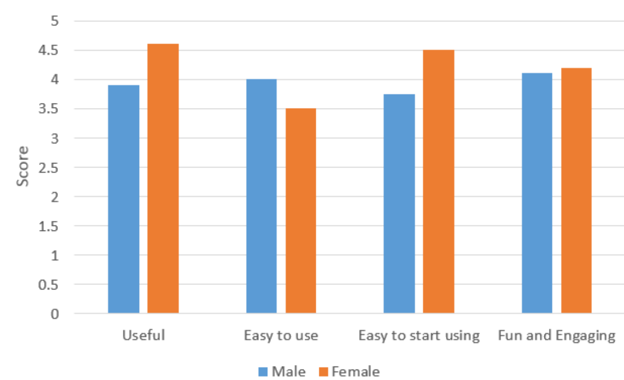


Figure 6: Result of the user experience study when grouped by gender

We further grouped the users by age range: less than 20 years old, 20-29 years old, 30-39 years old, 40-49 years old, 50-59 years old, and more than 60 years old. The result is shown in Fig. 7. The aspect of the system being useful was rated highest by the 50-59 age group (4.5), and rated lowest by the 40-49 age group (2.0). The aspect of being easy to use was rated roughly equally (slightly more than 4.0) by age groups except for 30-39 and >60 age groups. The aspect of being easy to start using, which refer to the adaptation of the system was rated highest by the 30-39 age group (4.5), and rated lowest by >60 age group (3.5). The aspect of being fun and engaging was rated highest by the 40-49 age group (5.0), and rated lowest by the >60 age group (3.7).

The age groups of <20 and 20-29 have rated all aspects approximately equally high (near 4.0). For the 30-39 age group, the easy-to-start-using aspect was rate the highest while easy-to-use aspect was rated lowest. One of the comments from the participants in this age group appreciates the system's usefulness, i.e., "*I think that it can be developed using verity sources of data and it's really useful for study of crowd on campus*". For the 40-49 age group, the fun-and-engaging was rated the highest, and being useful was rated the lowest. One of the comments is "*The 3D model makes it look interesting. I like the fact that the user can change and control camera view for seeing different angles of campus and that makes data visualization very exciting*". For the 50-59 age group, the highest average score was for the usefulness of the system while other aspects are rated generally equal at a relative high level (above 4.0). From the conversation with them, they think that the system can be useful for analyzing the crowd for solutions in traffic management on campus, or energy usage in buildings. Lastly, for the >60 age group, they found that the system is useful as seen in their average rating scores. One of participants commented that "*This system can present many patterns of data and I'm interested in crowd sensing visualization and I've never seen the use of Wi-Fi access point data for sensing a crowd before. Very interesting project*".

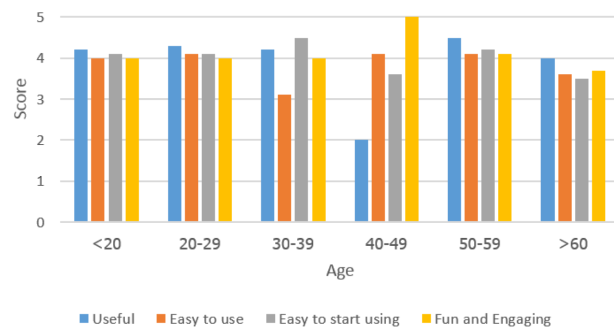


Figure 7: Result of the user experience study when grouped by age

All numerical average rating scores for the four statements concerning the aspects of the user experience is listed in Table 1.

	Male	Female	Age (<20)	Age (20-29)	Age (30-39)	Age (40-49)	Age (50-59)	Age (>60)	Overall
Useful	3.9	4.6	4.2	4.3	4.2	2	4.5	4	4.3
Easy to use	4	3.5	4	4.1	3.1	4.1	4.1	3.6	4.6
Easy to start using	3.75	4.5	4.1	4.1	4.5	3.6	4.2	3.5	4.2
Fun and engaging	4.1	4.2	4	4	4	5	4.1	3.7	4.1

Table 1: Average rating scores of the user experience study.

Conclusion

Here we present our developed tool for sensing the crowd level on campus using Wi-Fi access point data, called *Wi-Crowd*. To demonstrate our idea, we used one week of Wi-Fi access point data for our prototype. *Wi-Crowd* estimates the crowd level based on a conversion equation derived from the correlation analysis of the Wi-Fi usage data and the University registration records information. The crowd level is visualized on a map with 3D models of buildings on campus, along with useful interactive features such as view control and day selection. The visualization also includes a list and graphs of the most crowded buildings. Moreover, the system allows the user to take a snapshot of the visualization as well as export the crowd data as a CSV file for further analysis. The tool can be useful for analysis and planning of crowd level on campus as well as traffic management and academic scheduling.

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