SmileCityReport: Emotion-aware Participatory Sensing for Smart Cities with Double-sided Photo Shooting

Wataru Sasaki
Keio University
wataru@ht.sfc.keio.oac.jp

Yusaku Eigen
Keio University
eigen@ht.sfc.keio.ac.jp

Arturo Medela
TST Sistemas
amedela@tst-sistemas.es

Antonis Litke
National Technical University of Athens
litke@mail.ntua.gr

Vanessa Clemente Núñez
Worldline
vanessa.clementenunez@worldline.com

Tadashi Okoshi
Keio University
slash@ht.sfc.keio.ac.jp

Jin Nakazawa
Keio University
jin@ht.sfc.keio.ac.jp

***Abstract*—Collection of information of the events taking place in local neighborhoods along with the emotional statuses of the people involved can enable us to realize an "affective smart city map", with which, for example, the local authority can review the measures adopted for the local areas and whether their these measure have actually contributed to the quality of life (QoL) and well-being of the people. To realize such an information system having easy-deployability, real-time and secure protection of user's sensitive data, we propose SmileCityReport, a smartphone app-based participatory sensing that can easily capture both the city events and the reporter's emotion-related status based on a novel technique that uses two cameras simultaneously. For our evaluation, we evaluated 15 users over one week and confirmed that the proposed methodology contributes to more activity and (estimated) more positive emotional status of the users, and also that the emotion-related facial expression values constitute valuable data that can be publicly shared.**

***Index Terms*—smart city, participatory sensing, emotional data, facial expression, smile**

I. Introduction

The world population is increasing with the expansion of cities worldwide. More than 65% of the world population is expected to be living in cities by 2050 [1]. This has resulted in an increasing amount of physical and cyberinfrastructure, and therefore, obtaining various types of information of the cities in a timely and coarse-grained manner is becoming inevitable for better management of the cities. In addition to the objective observation of the various phenomena in the city (e.g., the water level in a river), people's subjective information (e.g., emotional data against such phenomena) is also needed to better understand people (including citizens and visitors)'s satisfaction and their long-term well-being in the city.

There are two important requirements for the collection of such data namely, (1) timely collection of data in a way that a considerable amount of people (including residents and temporary visitors) can easily deploy and participate to report both types of information, and (2) appropriate protection of private data including various types of data on the emotional statuses of people. To this end, in this study, we design and implement **SmileCityReport**, a novel smartphone app-based system that can easily capture city events using the camera and estimate the user's emotional status from the photographer's facial expression. As shown in Figure 1, its distinctive feature is the use of two cameras in a smartphone simultaneously and the capturing of two images of a city event and the user's face in a single shot.

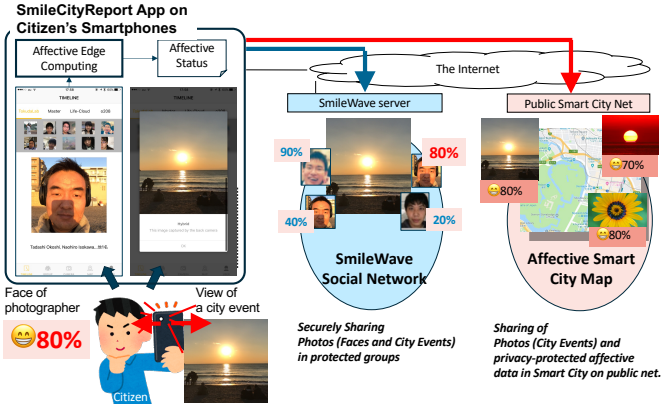


Fig. 1. Concept of Affective Smart City Map

In this paper, we demonstrate our prototype design and implementation of SmileCityReport along with our first user study results with 15 participants conducted over seven days to reveal: (1) the usability and emotional influence of SmileCityReport, (2) the effect of double-sided photo shooting and smile-based reaction feature for user activity, and (3) the users' sense of resistance against sharing different part/degree of privacy information to the public network.

II. Background: Affective Smart City

This section provides an overview of the proposed "affective smart city map." When we say "information on the city", it includes not only the current water level of the river or the current traffic condition but also additional **emotional**

information regarding people's satisfaction and their long-term well-being [2]. Therefore, this information needs to be collected in an integrated manner to realize a better QoL (for both citizens and visitors) in a smart city. Examples of such data are the photo data of beautiful cherry blossoms along with the emotion data of people nearby and the data of heavy traffic congestion along with the feelings of the people (both car drivers and residents) toward it. We herein refer to such a pair of information as "emotion-aware city-data" and the smart city where such data are massively and regularly collected as the"Affective Smart City".

For example, when we plot such a large amount of data on the map (Figure 1, we can create an "affective smart city map" [3] which the local authority can review (and revise) to revise their administrative measures for the local area and verify if the measures adopted are really contributing the well-being of the people.

III. Requirements for Systems

To enable the people to easily report emotion-aware city-data, we have the following requirements.

- R1: **Collect data in a way such that several people can easily deploy the system and participate.** Thus, special devices that cause additional burden to the participating users, such as EEG sensors, are not preferable. Furthermore, temporary visitors (such as tourists) should also be able to easily use the system.
- R2: **Real-time collection.** Data on the city event and corresponding emotional status of people should be collected in real-time, and not in a post-hoc manner.
- R3: **Appropriate protection of people's private data.** According to the proposed concept, various types of emotional statuses of the people will be detected and shared to the network. Therefore, such data have to be carefully handled to protect users' privacy and security.
- R4: **Frameworks of engagement for the continuous involvement of the participants.** As a participatory sensing system, the proposed solution needs to have an appropriate framework to continuously create user's engagement to the system. Examples of the specific framework and technique are (1) "social network" structure where users can recognize and react to posts by other users, and/or (2) a series of "gamification" techniques.

IV. Related Work

For recognizing a user's emotional status using smartphones, various studies have been conducted owing to the rapid growth of smartphones. Most studies have constructed a classification model that estimates emotions from context data obtained from the user's daily smartphone usage and self-reporting data. MoodScope [4] investigated how the user's context affects the user's mood and emotion by collecting sensor data from smartphones. Not only the emotion and mood but also various types of other internal statuses of the users, such as "interruptibility" [5], [6], have been recognized and estimated from the smartphone data. Analysis of emotions from the facial expressions of the image data has been widely conducted [7], mainly using Facial Action Coding System [8] and was also recently performed on smartphones [9] platform. This study proposes a system that goes beyond this and is complementary to the existing systems. Our proposed system can import such various smartphone sensing technique to have better emotion estimation quality.

People's emotions are known to be contagious as they are often caught by mimicking other people's facial expressions [10]. To confirm the occurrence of an emotional contagion on an online network, we previously implemented a selfie-based social network service "SmileWave" [11], wherein a user can share selfie photos and also view the selfie others' posted photos. We found a relationship between the posted photo's smile degree and changes in the viewer's smile degree. However, the system proposed in the present study is different from SmileWave in that in the present study, we try to ensure secure data sharing needs in the context of smart cities.

V. SmileCityReport

Given the requirements mentioned above, this section overviews the SmileCityReport, a smartphone application-based system for easily capturing city events using a camera and estimating the user's emotional status from the photographer's facial expressions.

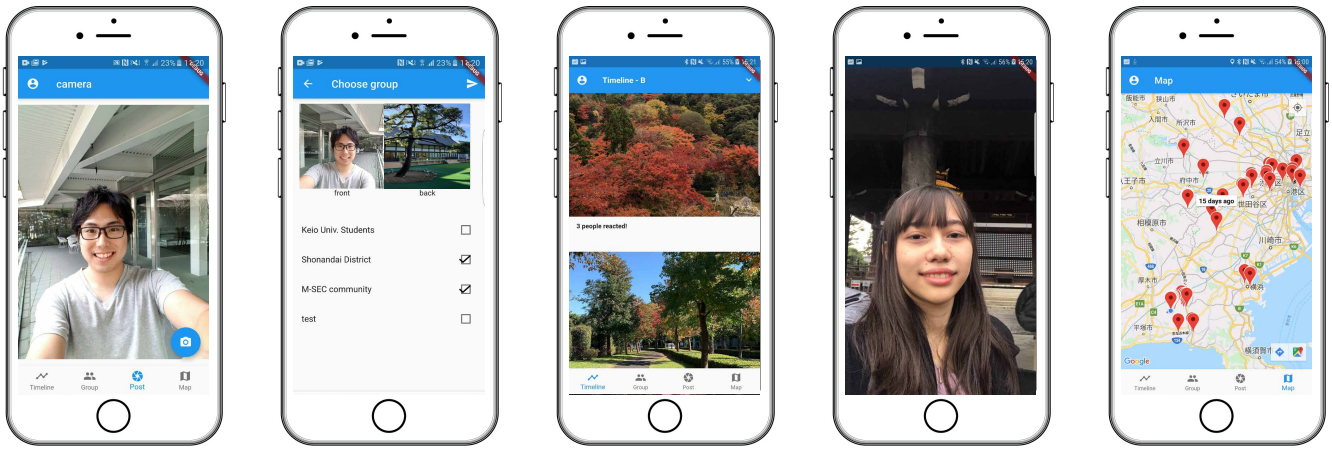
A. Our Approach

Our approach for meeting the aforementioned requirements can be stated as follows.

1. Use of smartphones: For R1 and R2, we utilize people's smartphones. We envision that even when using external, dedicated physiological sensors including EEG [12], ECG [13] or GSR [14] sensors, various other types of sensors inside recent smartphones can be used for collecting data of city events and people's emotional statuses. Furthermore, owing to the online application store, smartphone applications can be easily delivered to the users' devices. This convenience therefore meets our need of incorporating temporary visitors as users of the system.

2. Use of smile (and other facial expressions): We capture the photographer's facial expression, including the smile, and estimate his/her emotional status. As presented in related literature, various types of emotional states can be estimated from the still and moving images of a user's face. Additionally, we aim to ensure user privacy by **sending out only the estimated emotional-related status values** (e.g., smile degree) to a wide area network.

3. Use of social network structure SmileCityReport adopts a framework of a social networking service with appropriate data protection within each "user group". The users can browse and react to other users' posts **by making smiley faces**. However, the data are only accessible within each group in order to ensure privacy.



(1) (2) (3) (4) (5)

Fig. 2. Screenshots of SmileCityReport

B. System Design

Figure 1 depicts the SmileCityReport, our original social networking service that shares the photos of the city (captured by the back camera) and the selfie photos of the user (captured by the front camera). The users can post photos of the city and selfie photos as well as view those posted by other users.

Double-sided photo shooting is the most distinctive feature of SmileCityReport in which the user can take two photos simultaneously on the photo-taking screen shown in Figure 2 (1) and (2). (Notably, owing to the limitation of the smartphone OS APIs, only the selfie image (captured by the front camera) is displayed. It is not possible to show the live images from both the cameras simultaneously.) When the user presses the shooting button, the system takes both (1) the selfie photo using the front camera and (2) the photo of the city using the back camera, within a minimum amount of delay (i.e., 0.3-0.5 seconds, in our implementation). After reviewing the captured photos and selecting the groups for sharing the photos (Figure 2 (2), the photos are posted to the server.

Social networking on SmileCityReports starts from "Timeline Screen" (Figure 2 (3)) where photos of the city (e.g., a beautiful art monument) posted by others are displayed in the timeline, which the user can browse. When the user taps a photo, the photographer's selfie photo (Figure 2 (4)) pops up (right side) such that the user can view the photographer's facial expression. Note that the current design of SmileCityReport does not have a "global" (or "public") timeline. Instead, it comprises multiple protected groups where users can join and share the photos (including the user's selfie) safely among the group members. Additionally, in such protected groups, the users can access a shared view of the photo maps that contain the location of each photo, as shown in Figure 2 (5).

"Smile"-based reaction on social network enabled by continuous analysis of reactive facial expression is another key feature in the SmileCityReport that enables us to achieve continuous engagement. In the timeline of each group, the SmileCityReport displays others' photos of the city one by one and detects the viewer's (other users who are watching the photo in their timelines) facial expression continuously with the smartphone's front camera. When a viewer smiles, the reaction data will be associated with the original photo that was viewed. From the perspective of the photographer, she/he can know who in the group smiled at her/his photos.

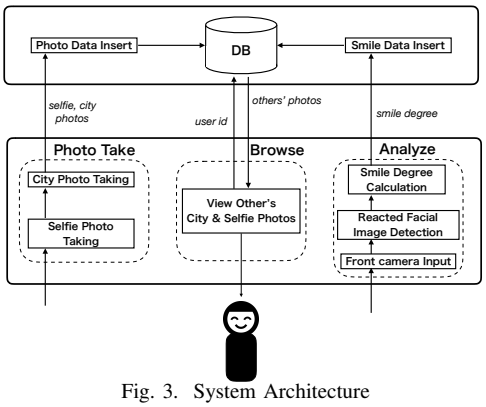


Fig. 3. System Architecture

Edge-side emotional information processing is implemented in our system to protect the private data. In particular, our strategy is to let the edge-side (smartphones) analyze the users' facial expressions (both that of photo-takers and viewers) and minimize the network transmission of such sensitive data (probably to the server-side). It also allows the system to minimize the delay time taken during image analysis. In the current prototype, we analyze the value of the **smile degree** (a numerical value from 0 to 1) in each facial expression. As a considerable amount of research already shows that a smile is closely related to a user's emotional state, we focus on the smile degree in this study.

Only privacy-protected data to be sent to the public smart city network. As described in Section 2, to achieve the "Affective Smart City Map", the collected data have to be sent to the public smart city sensor network after appropriate privacy protection processing acceptable by the users. Our current design enables the sending of only (1) the city event photos, and (2) estimated emotional-related status values (e.g., smile degree). In the subsequent sections, among our evaluation criteria, we investigate the users' sense of resistance in sharing different types of emotion-related data to the public.

TABLE I
GROUPS AND CONFIGURATIONS

Group name	Number of users	SmileX features	UI modification	Instruction to take photo
Control	5	Disabled	✓ ("smiled"→"reacted)	To take at least 5 photos (per day) about any random happenings in surrounding community.
Free	5	Enabled	✓ ("smiled"→"reacted)	
Smile	5		(none)	To take at least 5 photos (per day) about any random happenings in surrounding community, **with explicit smiley face**

VI. CROSS-PLATFORM IMPLEMENTATION

Figure 3 shows the prototype implementation of SmileCityReport. The SmileCityReport client is an iPhone and Android cross-platform application that uses the Google Flutter framework [15]. The facial expression analysis is currently performed with the Firebase MLKit API [16] that continuously calculates the smile degree in the taken selfie photos and the images containing the facial reactions.

VII. EVALUATION

Using this prototype implementation, we conducted a user study with 15 participants for seven days to better understand the way in which the SmileCityReport can be used. In particular, we wanted to investigate (1) the usability and emotional influence of the SmileCityReport, (2) the effect of a double-sided photo shooting and the smile-based reaction feature for the user activity, and (3) the users' sense of privacy protection and invasion in case of sharing different parts/the degree of private information to the public network.

A. Participants and Groups

We recruited 15 (8 male and 7 female) participants for our study, including university students, staff members, faculty members, and research engineers, aged between 18 and 22 (average=20.3, stdev.=1.5). All of the participants use either iPhone or Android smartphones in their daily lives. The subjects were not paid for their participation and were not informed of the specific objectives of the present study.

As presented in Table I, all the participants were split into three different user groups of 5 users each, namely, (a) control group (**"Control"** in short), (b) an experimental group with freedom in user's facial expression in taking photos (**"Free"** in short), and (c) another experimental group with forced smiley facial expression in taking photos (**"Smile"** in short). Additionally, the users were split into two groups (experimental and control) to investigate how enforcing the users to make smiley facial expression when taking photos make a difference, we divided into three groups. Note that the participants were not informed about their division into different groups and therefore, they were not aware of the differences between the groups or which group she/he belonged to.

B. Experimental Setup

First, we configured the SmileCityReport application to avoid biases in our experiment and to compare the effectiveness of our proposed methodology. We removed the name "SmileCityReport" from the application such that the users, especially those in Control and Free groups, did not have a bias to make a smile facial expression.

Next, we prepared three different application binary packages (APK files) for each of the three groups mentioned above.

- For **Control** group users, all the distinctive features of SmileCityReport was disabled. Our two-sided photo shooting feature was **disabled**. Moreover, a UI explaining reaction to a photo from other users was modified to "XX users reacted" (instead of "smiled") to prevent the bias. Thus, the given application was quite similar to the conventional photo-taking social networking application.
- For **Free** group users, the two-sided photo shooting feature was enabled. However, the UI explaining reaction to a photo from other users was modified to "XX users reacted" (instead of "smiled") to prevent the bias.
- For **Smile** group users, the two-sided photo shooting feature was enabled and the original UI was used, i.e. it was not modified.

C. Experiment Procedure

Our experimental procedure comprises the following steps:

1) At the beginning of the user study, each participant had a meeting with a researcher. The participant received general information and instructions for the user study via a pre-recorded video. He signed a consent form to participate in the study. The researcher installed one of the three application binaries to the participant's smartphone, according to the pre-allocated group of the participant. Each participant was asked to take at least five pictures every day, about any random happenings in his/her surrounding community. Additionally, **only Smile group users were explicitly requested to make smiling facial expression** when they take photos using the given application.
2) After the meeting, each participant were asked to use the application for seven days.
3) After this, the participants were asked to fill out the post-experiment survey, uninstalled the application, and finished the study participation.

D. Measurement

Both the selfie photos and photos of the city were uploaded to the server along with the smile degrees, location and timestamp information. The values of the smile degree of the facial reaction images (captured while the user is browsing the posted photos from others), were also uploaded to the server. Additionally, various user manipulation logs in the application,

TABLE II
DATA COLLECTED FROM THE USER STUDY

Group name	Number of posts	Number of reaction	Ave. (reactive smile for each post)	Reactive smile degree (1st frame)	Reactive smile degree (maximum of 15 frames)
Control	82	137	2.21	0.078	0.140
Free	161	332	2.78	0.090	0.174
Smile	74	161	2.68	0.089	0.157

including timestamps of when the user opened the application, and when the user transitioned the screen, were collected.

E. Collected Data

Throughout our experiment, the system collected 317 selfie photos and 235 photos from the participants. The system also captured 630 reactive facial data on the client-side. (They were not uploaded to the server, and only the smile degree values were uploaded.)

F. Result (1): Posts and Smiles

Table II presents the data and statistics obtained from the user study. **Free** group had the highest number of posts (161 photos), followed by **Control** group (82 photos) and **Smile** group (74 photos). Analyzing the usage log, **Free** group used and viewed the highest number of applications. The average number of reaction data (a set of 15 frames reactive facial data) per post was highest in **Free** group (2.78), followed by **Smile** group (2.68) and **Control** group (2.21). This result indicates that the **Free** group was the group with the most active usage and activity.

Interestingly, although the number of photos shared in the **Smile** group was less than in the **Control** group, the average number of reaction data per post in **Smile** group outnumbered that in **Control** group. Based on aforementioned numbers, we concluded that the **Smile** group users found it difficult to share photos with (forced) smiling expressions; however, it was found that they smiled when browsing other users' posts.

Table II also details the values of the smile degree in the reaction expressions, in particular, the values of the first frame and the maximum in the 15 frames. Both the values were highest in the **Free** group users, who had the freedom to use any facial expression when taking the photos. The value 0.157 in **Smile** group was better than **Control** group, but worse than that of the **Control** group.

From the data on the number of posts, reactions, and their facial expressions, we can conclude that (1) double-sided photo shooting feature of the SmileCityReport contributes to more user activity (the number of posts and reactive smiles) and higher reaction smile degrees, which in turn reflects more positive emotional states of the users. Furthermore, we confirmed that (2) forcing the user to smile (the strategy we adopted in **Smile** group) was not effective as a criterion.

G. Result (2): Usability and Influence

In the post-experiment questionnaire, a 5-level Likert scale question was asked concerning the difficulty of double-sided photo-shooting (1-Very easy, 2-Easy, 3-Neutral, 4-Difficult, and 5-Very difficult). Most participants felt that it was a simple operation (Avg: 2.2). One participant answered *"It was my first time to take a double-sided photo. Only the front camera image was shown on the application screen when shooting, however, the image captured by the back camera was enough to imagine. So I did not feel embarrassed about the double-sided shooting."*

For the question of whether the emotional state changed owing to the selfie photos being continuously taken, a subject in the **Smile** group answered, *"It was a fun time to use the application by shooting with a smile."* Furthermore, one subject in **Free** group said, *"Shooting itself did not change the emotional state, but looking at other users' selfie photos and photos of the city made me feel that our friendship had been deepened"*.

Additionally, in response to the question of how the participant felt by looking at other people's posts, a subject in the **Free** group *"Since there are both users' selfie and landscape photos on the timeline, unlike other social network services, it was interesting to browse it"*. Furthermore, a subject in the **Free** group replied, *"I was interested to know what scenes other people were seeing with such facial expressions"*.

H. Result (3): Sense of Resistance for Data Sharing

1) **Sharing Data inside Groups***:* First, all the 15 subjects were asked on whether they were fine with or reluctant to sharing the photos of the city in their groups. Fourteen participants (93%) responded that they were not reluctant. However, four out of 14 (29%) responded that they had taken all photos outdoors in this experience because they were reluctant to uploading the photos in their houses.

Next, we asked 10 subjects (in Free and Smile groups) to share their selfie photos within the group. Four of them (40%) reported resistance and one female subject answered *"I do not want to share without makeup"*. Additionally, in case of two of the four subjects who reported resistance (20%), their feelings of resistance gradually faded as they viewed and browsed the photos posted by other users.

We asked the aforementioned four subjects, who reported that they hesitated to share their selfie photos, if they felt the same when sharing the data on "facial expression" (such as the value of the smile degree or types of facial expressions in FACS [8]). All the four subjects answered that they were fine with sharing such the data.

Finally, regarding the resistance to sharing the location information of the phone within the group, 12 subjects (80%) answered that they were not hesitant, whereas three (20%) reported they were hesitant. However, eight out of 12 (53%) participants reported that it is better to avoid sharing their home location information.

2) **Sharing Data Publicly***:* All the questions so far were focused on sharing information within a group. However, in

the case of the "Affective Smart City" network, our aim was to upload data to the network, which is publicly accessible, with some amount of privacy protection. The subjects' consents to share various data to the public network was needed for the purpose of investigation.

First, we asked the participants if they would be hesitant when sharing (1) photos of the city, (2) selfie photos, (3) their location information and (4) emotion-related facial expressions (e.g., smile degree) to the public network.

For (1), three out of 15 (20%) subjects were reluctant to sharing photos in the city with the public. One of them answered *"It is acceptable if photos in the city are shared after a certain time instead of real-time sharing"*.

For (2), seven out of 10 (70%) subjects were hesitant when sharing their selfie photos publicly. One of them answered *"Sharing a group photo may be fine, but sharing my alone selfie cannot be accepted."* A subject who felt no resistance answered *"I am a YouTuber, so I am totally fine with sharing."* From the aforementioned results, it was therefore found that sharing selfies publicly was rarely acceptable, and differences in personalities of the subjects greatly impacted their decisions of sharing their photos.

Third, for (3), 12 out of 15 (80%) subjects were reluctant to publicly sharing the information on the shooting location. However, an interesting comment was reported, *"In this experiment, various things were shared within the group. However, by continuing this, it may become accustomed to sharing to the public location information even though I think this is a privacy-sensitive data."*

Finally, no (0%) participants were reluctant when sharing in the case of (4). Therefore, we can conclude that emotion-related facial expression values can be considered to be valuable for sharing emotion-related data of people whose photos can be shared in the public network.

VIII. Future Work

As a future work, we plan to estimate the emotional state from the selfie photos and share it on the "affective smart city" map without violating the privacy of the users. The contribution is a system design/implementation of the SmileCityReport along with preliminary evaluation, especially, on the usability of the aforementioned system. In this study, we focused on the value of the smile degree, which is closely correlated to the emotional state estimated from the selfie photos. Therefore, estimation of the emotional state directly from the selfie photos is one of our future research focuses.

In this paper, we recruited 15 participants for three different groups for the preliminary evaluation. A further study with a greater number of users will be our future work that is expected to reveal the effectiveness more precisely.

IX. Conclusion

This paper proposed SmileCityReport, a smartphone application-based participatory sensing that can easily capture city events using a camera and estimate the user's emotional status based on the photographer's facial expression. From our initial user study, we confirmed that the double-sided photo shooting feature contributes to more activity and (estimated) more positive emotional status. We also found that emotion-related facial expression values constitute valuable data to be shared with the public. Our future work includes improving our design and implementation and evaluating it at scale.

X. Acknowledgement

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