MeetDurian: Can Location-Based Games be Used to Improve COVID-19 Hygiene Habits?

Dongliang Chen¹,*  , Antonio Bucchiarone²,*  , and Zhihan Lv³

Abstract
The COVID-19 problem has not gone away with the passing of the seasons. Although most countries have achieved remarkable results in fighting against epidemic diseases and controlling viruses, the general public is still far from understanding the new crown virus and lack imagination on its transmission law. Location-based games (LBGs) have been challenged during the on-going pandemic. No research has shown that LBGs can be used to help prevent COVID-19 infection. Therefore, we designed the game MeetDurian, which integrates entertainment, sports, and education. For investigating factors influencing intention to play the MeetDurian, we proposed some comparative evaluation. Data were gathered from participants who participated in capturing virtual durians and completed questionnaires about immersion into the game, workload assessment, user’s emotions, learning outcomes, and personal hygiene. These results proved the acceptability and usability of the mobile game-based MeetDurian for preventing the infection and severity of the COVID-19 pandemic.

Keywords
COVID-19, mobile game-based MeetDurian, exergaming, education, questionnaires

¹College of Computer Science and Technology, Qingdao University, Qingdao, China
²Motivational Digital Systems (MoDiS) Research Unit, Fondazione Bruno Kessler (FBK), Trento, Italy
³Faculty of Arts, Uppsala University, Uppsala, Sweden

*D. C. and A. B. contributed equally to this work.

Corresponding Author:
Antonio Bucchiarone, Fondazione Bruno Kessler, Via Sommarive 18, Trento 38100, Italy.
Email: bucchiarone@fbk.eu
Introduction

COVID-19, a new type of coronavirus, made 2020 an extraordinary year. The number of incubation days also varies with the host’s age or the surrounding environment to survive in the host; a credible and conservative number of days of this period are about 14 days (Lauer et al., 2020). China was the first to announce the discovery of the new coronavirus, and China has achieved obvious results in fighting the epidemic, and its prevention and control. However, the current global epidemic situation has not subsided. Therefore, we plan to develop a novel and serious game to improve people’s hygiene habits and reduce the risk of infection. We inadvertently noticed the location-based game (LBG). LBG refers to mobile application games that are generally installed on a mobile phone or tablet that can be conveniently carried by the user and encourage users to move around frequently (Zhang et al., 2019). Sociality is also a positive experience of LBGs, which allows strangers to be interested in the game to meet in the real world (Paavilainen et al., 2017). Although these are undoubtedly positive things under normal circumstances, to slow down the virus’s spread, people were advised and even forced to do the exact opposite such as staying at home and avoiding social contact during the COVID-19 pandemic (Laato, Islam, & Laine, 2020).

The currently most popular LBGs (Laato, Laine, & Islam, 2020) are Pokémon GO(PG)1; Orna: The GPS RPG (Orna)2; Ingress Prime (IP)3; The Walking Dead: Our World (TWDOW)4; Minecraft Earth (ME)5; Harry Potter: Wizards Unite (HPWU)6; and Jurassic World Alive (JWA)7. Unfortunately, these games’ main aim is to motivate people to go out, explore, and meet other people. Admittedly, these related games made some rule changes during the COVID-19 pandemic. For example, social games like TWDOW and JWA discouraged face-to-face meetings and provided project time for online social collaboration, and so on. PG’s actions to combat COVID-19 include canceling the Social Community Day event of Lugia Raid Week and Raid Hour, announcing that they want their players to keep their distance while playing. Similarly, IP canceled some social events. Orna, to protect players from going out and contracting COVID-19, recommended that players play at home without having to move around.

The LBGs mentioned above almost always advised players not to go out but did not completely change the game rules by using some popular means to entice players to play at home. However, it is inevitable for players to buy some necessities for life, such as face masks and effective tools to protect themselves against the disease. From the perspective of prevention and control efforts and basic cases, many countries and regions in the world can effectively control this epidemic. For example, in Italy, the method of change from the lockdown to more relaxed situations had been adopted. However, it is essential for citizens to develop good health habits in the long-term.

The issue of our research was launched against the background of the above pandemic. The main goal is to develop a serious mobile application game designed to improve users’ hygiene habits: MeetDurian.8 In simple terms, players need to enable the geolocation service and use their accounts to log in. Before starting each game, players are forced to wear face masks. After entering that game, some durians appear
randomly to nearby players. Players can capture the durian by reaching a virtual durian location and next, capture it through a question-and-answer (Q&A) session. After successful capture of the virtual durian, the player can get 1 game point (wrong answer = player’s HP $-0.5$). The game point is used to rank players, purchase items, and redeem ‘Hero Title’ in the app. Since our research needs to be flexibly adjusted according to some changes during the pandemic, we chose the extended design scientific process model (DSPM) (Lv, Esteve, Chirivella, & Gagliardo, 2015), following the scientific design perspective commonly used in software engineering (Venable, 2006). Figure 1 illustrates the entire development cycle.

To sum up, the main contributions are as follows:

1. We have built a new mobile application MeetDurian for Android and iOS operating systems which incentivize people to use games to improve their hygiene habits of COVID-19 subtly.
2. We propose the DurianToRoads algorithm, which can intelligently transfer the durian from abnormal locations to the nearest road to improve players’ game experience.
3. We have done technical evaluation tests. Test 1 showed that virtual durians can appear evenly scattered around the players within a particular zone. In test 2, face mask recognition can adapt to complex shooting environments, including changes in photos that are too bright or too dark due to various strong light, low light, and reflections at different times throughout the day.
4. We conducted a series of evaluation experiments, mainly involving five kinds of questionnaires. The learning outcome questionnaire showed that MeetDurian
could improve players’ hygiene habits while allowing players to pay more attention to the latest epidemic situation.

Organization: The remainder of this article is organized as follows. We formally define the MeetDurian, including the game inspiration, background, system flow, features, rules, and cooperation in the MeetDurian section. The main technologies of MeetDurian are presented in the Main Technology section. We give the statistical analysis, and we evaluate the MeetDurian through extensive questionnaire experiments in the Pilot Study section. After that, we conclude this article.

MeetDurian

MeetDurian is a location-based game, built to encourage citizens to learn about more aspects of COVID-19. Now, we describe the game inspiration, background, system flow, features, rules, and introduce the cooperation in MeetDurian.

Game inspiration

The original design inspiration of “MeetDurian” came from this passage: “We can design a Grab Durian game. Because of the smell and appearance of durian, players need to wear a mask and keep their distance. Durians are produced anywhere in the area. The more players grab the durian, the more points they earn. If players’ distance is too close, both players will lose points, so players should keep their distance. And only if the mask is detected on the player’s face can the player start to grab durian. Try to make as many durians as possible can encourage players to move and help players exercise and stay healthy.” The reason we consider durian as the theme is because it is a delicious but malodorous fruit from Southeast Asia used in strong competitions for different groups of people (Gale & Lazarus, 2020). Some people like durian, so we borrowed its image; on the contrary, some people are extremely disgusted with it because of the powerful and disgusting smell and stay away from it, so we consider ‘face mask’ as the partition tool. Well, under the premise of wearing a face mask, everyone can catch durians with personal feeling of like or dislike, respectively.

With this goal in mind, MeetDurian conducts research and development. It is worth noting that the COVID-19 situation can change at any time, we have adopted the business continuity plan (Epstein & Khan, 2014) to adjust the game according to the actual situation.

Background

Marchi (2012) studied teenagers’ behaviors and attitudes, especially those of people under 30 who do not subscribe to newspapers but learn about current affairs from social networking sites. From the beginning of 2020 to 2021, the number of confirmed cases of the new crown pneumonia worldwide has increased. Unfortunately, misinformation about COVID-19 has gone viral, which comes from many sources. Pennycook,
McPhetres, Zhang, Lu, and Rand (2020) believe that citizens who rely on social media for information about the coronavirus are more likely to rely on misinformed symptom theories and go outside to breach lockdown rules, as many citizens think that the new crown pneumonia is far less terrible than the news reports. Some of them refuse to wear masks to fight off the disease. Part of the reason is that citizens fail to think adequately about whether or not the content is accurate when deciding what content to share or because the social media environment focuses on factors other than accuracy. Therefore, it is necessary to find other ways to guide people to correctly re-understand the coronavirus. This research was launched based on four sub-questions (SQ).

SQ1: Re-Engaging Young People in Education: Can Serious Games be Used for Learning?. Game-based learning and gamification positively impacted students’ academic performance and interest in learning (So & Seo, 2018). Recently, in-game education, Huizenga, Admiraal, Dam, and Voogt (2019) conducted an interesting evaluation experiment: the authors studied learning based on mobile collaborative games in 181 middle school students in an urban environment. These students participated in the “no credit, GameOver” team game activity. The game provides an interactive learning context about debt, requiring two or three students to use a tablet and reduce debt. The results demonstrated that the students showed more subject knowledge after playing the game than before and were more interested in the topic.

SQ2: Re-Engaging Young People in Games: Can Location-Based Games Work?. While the study around diversity in providing science-based information on preventing COVID-19 or personal care games developed well during the pandemic (Gaspar et al., 2020), this is not the case with location-based games. A literature search did not yield established work on serious location-based games to solve the above problem during the pandemic. Serious location-based games mainly face an unavoidable challenge: maintaining a safe social distance (at least 1.5 m) during the COVID-19 pandemic. As a positive measure, players who live within a high-risk area are not recommended to participate in the game. Players who are eligible to participate must wear face masks for the duration of the game; otherwise, they are banned from playing by the game developer.

SQ3. What Does a Gamer Look Like?. MeetDurian is improving and innovating based on the LBG, so the target audience is similar to that of the LBG, with a movement focus. Players expect many people between the ages of 8 and 40 who want to strengthen their knowledge of preventing COVID-19 and personal care. Students are the target audience for this serious game; however, children and adults with mobile phones can also play.

SQ4. Why Should Citizens Download and Use it?. Due to the pandemic, citizens’ hiking activities have decreased sharply, but it is only a temporary phenomenon. MeetDurian adopts interesting Q&A and incentive strategies to fully mobilize people’s enthusiasm for wear face masks when they go out and consider the normalization of the pandemic in the future.
System Flow

MeetDurian has a complete front-end and back-end to increase the software’s feasibility and corresponding user privacy policy protection and other related instructions. The project does not use sensitive user data, even if the game involves user registration, and uses email registration instead of the phone number. Player registration information only needs a nickname (a unique identifier used to display global rankings) without involving personal details such as real name, gender, age, etc. The system automatically generates the rest of the data used (such as player scores and player blood volume). The project clarified the indirect use of non-sensitive data to users in an objective, clear, and timely manner. As of December 2020, the system flow of MeetDurian is shown in Figure 2.

Features and Rules

In this section, we discuss the basic features and the rules of MeetDurian. The detailed information on how to implement the features is provided in Table 1. Table 2 explains where and why these rules are defined in the overall application architecture.

Figure 2. The system flow of MeetDurian. Proceed from left to right and from right to left until the game interface is entered through face mask detection. This app is a simple and easy-to-operate location-based game, which mainly contains 16 interfaces. In fact, either success or failure in capturing a durian will count as one part of a game, with a fixed number of six durians appearing in a game, which means there will be six parts.
Features

F1: Language selection. The multi-language version includes Italian, English, and Chinese. All questions, tips, graphics, and the privacy policy will be translated while players are changing the game’s language in the initial interface and the game lobby.

F2: Auto login. Automatically jump according to the registered email address and password when players have registered an account or logged into the game.

F3: Introduction. A novice tutorial helps players better integrate into the game. Four short films include the background, features, rules, and precautions.

F4: COVID-19 dashboard. A dashboard of the COVID-19 data is in motion to track the outbreak as it unfolds and is updated every day (Moroney).

F5: Face mask recognition. Before entering the game, the mobile phone’s front camera takes pictures to detect the face mask of players. The result:

1. No face detected = Failed
2. Face is detected, but no mask is worn = Failed

Table 1. The proposed MeetDurian application feature realization.

| Feature | Realization |
|---------|-------------|
| F1      | MeetDurian implements multi-language switching based on ngx-translate. Using getBrowserLang to obtain the device browser language so the software can set the default language for the user’s first installation |
| F2      | The local storage resource was employed to save data in users’ mobile phones locally |
| F3      | Getting video URLs which are in mp4 format from Firebase Storage (Moroney, 2017) and using HTML5 video tag to play the automatic video. Use the Toast method to guide players |
| F4      | Using <iframe> tag to embed HTML into a web-based interactive dashboard that can track COVID-19 in real-time |
| F5      | To meet the requirements of mobile phones with different configurations to quickly identify face masks, a cloud server is used to synchronously transmit photos for analysis and processing |
| F6      | Successively geolocation.getCurrentPosition method, equation (1) method |
| F7      | Intelligently adjust virtual durians at abnormal locations to the nearest road, based on algorithm 1 |
| F8      | Keeping track of the whereabouts of the player, who has entered the game, by using the method watchPosition of HTML5 geolocation |
| F9      | Each time players enter the leaderboard interface, the information is retrieved from the database in real-time, which uses a bubble to sort the players’ scores in descending order of score |
| F10     | After answering a question, there are two methods for synchronously updating gamer information: HTML5 local storage and Firebase Realtime Database |
| F11     | Players can purchase virtual merchandise through the obtained game scores, and the information update is the same as F10 |
Table 2. The proposed rules causes and corresponding position.

| Rule | Flow                          | Reason                                                                 |
|------|-------------------------------|------------------------------------------------------------------------|
| R1   | Registration                  | Initial information to fair competition                               |
| R2   | Game lobby                    | The first part of the game is aimed at the user to quickly understand the features and rules |
| R3   | Attention                     | Protect game players from diseases and cultivate the habit of wearing face masks when going out |
| R4   | Game                          | Effectively improve the game players’ outdoor exercise time, conducive to physical and mental health |
| R5   | Game                          | Questions to enable game players to master more comprehensive knowledge of COVID-19 and improve their ability to prevent new coronavirus pneumonia |
| R6   | Game                          | Maintain a safe distance to protect gamers and others to the utmost |
| R7   | Game                          | Just as life is given but once                                      |
| R8   | Game                          | Motivate players with intrinsic rewards                               |

(3) Face detection is detected, wearing mask = Success

F6: Location management for durians. When the player enters the map (based on Google Maps), six virtual durians will appear randomly according to their location. It is worth noting that the location of virtual durians meets the following conditions:

(1) Durians need to appear quickly when the player enters the map.
(2) Durians cannot appear in places that players cannot reach.
(3) The durians’ location should not be too close to the player and vice versa.
(4) The location of durians should be randomly and evenly distributed around the player.

F7: DurianToRoads. Players can re-randomize the abnormal durians in unreachable areas to the nearest road nearby.

F8: Monitoring players. A toast message appears on the screen, and the green label indicates the player has moved near the durians. In contrast, the red label warns the player about the abnormal speed.

F9: Real-time Leaderboard. Players can compare their points with other players in the global ranking interface, which shows the nickname, and points, and relevant title.

F10: Multiple-choice Question. The capture of the durian needs to be judged based on the player’s answer. Moreover, we implemented an algorithm so that when users answer questions, only questions they have not answered or for which they gave wrong answers are randomly displayed.

F11: Shopping.

(1) Virtual merchandise, such as a tool that can increase the effectiveness of the capture distance, means players will find it easier to capture durians.
(2) Game Easter egg. Players who are qualified can receive the ‘HERO TITLE’ in the shop. When N players get the ‘HERO TITLE’, the game egg will be unlocked. Getting the ‘HERO TITLE’ means that the player has captured a considerable number of durians.

**Game Rules**

The game rules are proposed based on the background and the game objective, and can play a role in restraining and adjusting the behavior of players playing this game, which can improve the players’ hygiene habits very well.

Rule 1: The initial health point (HP) of each player is 3, and the initial game point is 0. Each time after entering the game, the total number of durians is 6.
Rule 2: After registering, the new users will be guided to watch the novice tutorial.
Rule 3: Players need to wear face masks to enter the game. They are not allowed to remove the mask during the game.
Rule 4: Players need to walk or run to reach the place where the durian appears. It is forbidden to take the car, subway, and other tools. MeetDurian can continuously monitor the moving speed of the player (e.g., if player’s average speed is greater than 7m, it can be determined that the player uses travel tools)
Rule 5: When a player approaches a durian, the player will catch the durian by answering the question. If the answer is correct, the durian will be captured successfully, and then their point will be increased by 1; if the answer is wrong, their HP will be deducted by 0.5. After the above two actions are executed, the related durian will disappear from the map.
Rule 6: Players need to keep a safe distance from pedestrians. If the distance between the two parties is less than a certain value, the blood volume will be deducted by 1.
Rule 7: If a player’s HP is 0, the player will be forced to quit the game; the points will no longer change, and the account cannot restart the game.
Rule 8: After successfully capturing all durians on the map, there will be bonus points.

**Cooperation**

The COVID-19 pandemic is the most serious global public health emergency for all countries across the globe. In line with the research of this literature (Benvenisti, 2020; Brown & Susskind, 2020; Kokudo & Sugiyama, 2020; Luengo-Oroz et al., 2020), cooperation has become a keyword to overcome global challenges. Inspired by the above, MeetDurian also emphasized the spirit of cooperation in the game, although players were forbidden to meet each other due to the rules. In this game world, the honor gained by an individual is just a name displayed on the leaderboard; the safe city cannot be unlocked by personal power alone. MeetDurian requires players to work together, and each player is the protagonist in the game. Only when each player
captures a certain number of durians will the final session of the game be triggered: a safe city will appear, which means Course Clear.

**Main Technology**

This section introduces the three core technical solutions implemented in MeetDurian, including the (1) Durians’ location, (2) Face Mask Recognition, and (3) DurianToRoads.

**Durians’ Location**

Many location-based game developers publish fixed mission locations via servers for members to get to know each other in person, such as geocaching, each treasure is hidden and by another player, and some of them like to share their GPS location to inviting different players to come for adventure. Unlike most GPS games, MeetDurian tries to keep players from meeting to the greatest extent by randomizing quest points. When the player enters the map, durians appear immediately (i.e., average time < 241 milliseconds). The system obtains the latitude and longitude of the player’s positioning and the random number principle and related conditions. The durians are dispersed as evenly as possible around the player, and the distance is acceptable. We use the following formula to control the location of durians

\[
D(x, y) = \begin{cases} 
\text{Longitude} + \frac{(\text{Math.random}(x) - 0.5) \times 2}{n}, & 0 < n \leq 1000 \\
\text{latitude} + \frac{(\text{Math.random}(x) - 0.5) \times 2}{n}, & 0 < n \leq 1000 
\end{cases}
\]

(1)

Where Longitude and Latitude are, respectively, the longitude and latitude measured after the player enters the game. `Math.random()` is to make the system randomly select a pseudo-random double value greater than or equal to .0 and less than 1.0. `(Math.random() - .5) \times 2` is used to realize that durians appear around the player with equal probability; \( n \) is a variable used to control the distance between the durian and the player.

To better evaluate this function, we conducted several simulation experiments, using the latitude and longitude of the four corners of the Qingdao University area as the scope and the latitude and longitude of the university library as the experimental object, as shown in Figure 3.

Some experimental evaluations of the durians’ distribution are shown in Figure 4. The number of durians increases from left to right. The Golden inverted triangle is the randomly generated location of the virtual durians, and the red dot is the latitude and longitude of the university library.
Figure 3. Evaluate the selection of the target range for the trial.

Figure 4. The location distribution of durians (gold) relative to a target point (red). Although there are some durians outside the target range, the results show that our approach performs much better as the number of durians increases, which demonstrates that the function could better evenly distribute the durians within a specific area while providing a better gaming experience to the gamers. In addition, different tests may correspond to different results. All latitude and longitude data are displayed through a GitHub repository, along with relevant test code.
Face Mask Recognition

In the early days of the COVID-19 pandemic (February 2020), a risk-based approach was generally adopted in China, and there were recommendations for using face masks among health-care workers and the general public (Feng et al., 2020). Eikenberry et al. (2020) used some mathematical models (i.e., a multi-group Kermack–McKendrick-type compartmental mathematical model) to show the general public using face masks has a potentially high value in curtailing community transmission and the burden of the pandemic, even if they used self-made masks with poor effects. Therefore, masked face recognition has become one of the current research hotspots (Ding, Peng, Huang, Geng, & Tian, 2020).

We exploited the face detection method in Google Cloud Vision to perform masked face recognition for this task. In the case of good picture quality, face detection can detect multiple faces in the picture and has high robustness. The main purpose of adopting this method is to detect the main facial features and obtain about 27 relevant confidence points for the eyes, nose, mouth, cheeks, etc. in total. We perform data processing and analysis on these large numbers of confidence points to recognize the masks’ task. The example results in Figure 5 illustrate the concept and draw a box around each face with corresponding data. If the player covers the three important parts of the nose, mouth, and cheeks simultaneously, the system may determine that the player is wearing a mask. Wearing a KN95 mask may increase the pass rate. Also, to quickly respond to the player’s request for facial mask recognition, after taking a photo, the system automatically compresses the image’s resolution to be uploaded to 300*400.

Players cannot avoid overexposure or too low brightness and unclear images with noise when taking selfies with their mobile phones. Therefore, we modify our test images by attacking them with these three errors and comparing the error image with the original image’s output. The brightness of the image is increased by the non-linear superimposition of the target image by using MATLAB, given by equation (2)

\[ F(x) = P(x) + (1 - P(x)) \times P(x) \times K \]  

where \( P \) represents the pre-processed image (normalize data to 0–1 range) and \( F \) represents the processed image, including exposure and over-dark processing. Parameter \( K \) represents the control range (e.g., \( K = 1 \) performs exposure processing, and on the contrary, \( K = -I \) performs over-dark processing) and the number of iterations of the algorithm is \( I \).

Gaussian noise is a kind of random noise, and the probability density function of noise obeys Gaussian distribution. The mathematical model of Gaussian noise consists of probability density function (PDF) expressed by

\[ f(x) = \frac{1}{\sigma \sqrt{2\pi}} \exp \left( \frac{(x - \mu)^2}{\sigma^2} \right) \]
The density function $f(x)$ can be understood as probability, where $x$ represents the grey value, $\sigma$ represents the SD, and $\mu$ represents the average value. The PDF is used to specify a random variable’s probability of falling within a specific value range, rather than accepting any value.

Taking the detected face mask image samples as the condition, image 1 (Figure 5d) and image 2 (Figure 5e) have been chosen for this experiment. The aim is to inflect the images with the above three attacks, feeding them to the proposed face mask recognition API, and comparing the outputs and original images. The results are shown in Table 3. It is obvious that the correct recognition of face masks is easily affected by Gaussian noise, and the image cannot be recognized under certain circumstances. On the contrary, the application of overexposure and low brightness to the target sample images has low impact on the recognition situation. Hence, when a game player wears a face mask, keeping the phone camera stable will greatly improve the accuracy of mask detection.

The DurianToRoad Algorithm

DurianToRoad, as the name implies, is to reset the location of an abnormal durian to the road near it. Although resetting the target durian to the road is not very difficult, the distance between the reset durian and the original location is an unknown number that is difficult to guarantee. Imagine the following: “When a player reaches a certain durian location on the map, and the player finds that the durian is in the middle of the lake so that he cannot capture the durian. If the player only simply resets the target durian and may find that the durian appears on the road, but 10 kilometers away from the player, this is a very bad thing.”

This section will introduce our DurianToRoad, as shown in Figure 6, which takes location-based key attributes and the number of iterations into account. More importantly, our DurianToRoad algorithm adopted a mechanism that is like the greedy

![Figure 5. Schematic diagram of face mask detection principle in MeetDurian.](image-url)
algorithm. It can make the best choice in the current view, but this result is not necessarily the optimal global solution. The aim of adopting this mechanism is to improve the reset speed and shorten the running time. The system needs to detect a total of four routes and collect up to 100 GPS points along any route with the longitude and latitude coordinates of the abnormal durian. For faster detection, the system performs two-way detection, of which 50 points are set in the positive direction and 50 points are detected in the negative direction. Target points are a complete path, and the only need is to find a set of data locations that meet the conditions.

For two points, under the condition of equal latitude, each latitude differs by .00001°, and the distance difference is about 1 m apart. Under the condition of equal longitude, each longitude differs by .00001°, and the distance difference is about 1.1 m apart (Yu, 2014). We control the distance between the reset durian and the original durian by setting the degree range. As the number of iterations increases, the distance will become farther and farther. It is an acceptable range in general.

### Pilot Study

Participants’ opinion records are very important criteria for system evaluation and reporting assumptions. To test the potential of MeetDurian in improving players’ living habits or personal care and raising the awareness of public health and safety, we designed our questionnaires that were divided into two stages and included four aspects to obtain participants’ responses to the model: Q1, game immersion; Q2, user workload evaluation; Q3, social acceptance; Q4, learning outcomes; and Q5, personal hygiene.

We promoted this research through campus social media and campus advertising and then recruited 18 students to participate in our research. This research consists of five stages (see Table 4). Before starting this investigation, students were asked to fill out a questionnaire Q5, and they did not know MeetDurian and the research content in advance. In addition, a small set of players from the United States and Europe have submitted questionnaire reports through the game. We assume that these players participated in the survey after experiencing the game. We received 27 responses in

| Parameter Value | Type of Attack      | Image 1 | Image 2 |
|-----------------|---------------------|---------|---------|
| $K = 1, l = 1$  | Overexposure        | Success | Success |
| $K = 1, l = 3$  | Overexposure        | Success | Success |
| $K = -1, l = 1$ | Low brightness      | Success | Success |
| $K = -1, l = 3$ | Low brightness      | Success | Fail    |
| $\mu = 0, \sigma = 0.02$ | Gaussian noise | Success | Success |
| $\mu = 0, \sigma = 0.05$ | Gaussian noise | Success | Fail    |
| $\mu = 0, \sigma = 0.1$ | Gaussian noise | Fail    | Fail    |
Algorithm 1 DurianToRoad Algorithm

Input: $i$, $X_{mod}$, $Y_{mod}$, where $X_{mod}$ and $Y_{mod}$ are both online variables, which change according to the change of $i$
Input: $D_x$ and $D_y$, where $D_x$ and $D_y$ are the longitude and latitude of the target durian
Output: LocalPosition $(D_x, D_y)$

1: $i \leftarrow 0$
2: while $(i \leq 3)$ do
3: if $i = 0$ then
4: $X_{mod} \leftarrow degree \in [0.000002, 0.000004], Y_{mod} \leftarrow 0$
5: else if $i = 1$ then
6: $X_{mod} \leftarrow degree \in [0.000001, 0.000002], Y_{mod} \leftarrow (0 - X_{mod})$
7: else if $i = 2$ then
8: $Y_{mod} \leftarrow degree \in [0.000002, 0.000004], X_{mod} \leftarrow 0$
9: else if $i = 3$ then
10: $Y_{mod} \leftarrow degree \in [0.000001, 0.000002], X_{mod} \leftarrow (0 - Y_{mod})$
11: end if
12: for all $j \in [1, \ldots, 50]$ do
13: $Forward_{Dx} \leftarrow D_x + X_{mod}, Forward_{Dy} \leftarrow D_y + X_{y}$
14: if Position $(Forward_{Dx}, Forward_{Dy})$ FindRoad then
15: Update LocalPosition $(D_x, D_y) \leftarrow Position (Forward_{Dx}, Forward_{Dy})$
16: end while
17: end if
18: $Backward_{Dx} \leftarrow D_x + X_{mod}, Backward_{Dy} \leftarrow D_y + X_{y}$
19: if Position $(Backward_{Dx}, Backward_{Dy})$ FindRoad then
20: Update LocalPosition $(D_x, D_y) \leftarrow Position (Backward_{Dx}, Backward_{Dy})$
21: end while
22: end if
23: end for
24: $i \leftarrow i + 1$
25: end while
26: if $i > 3$ then
27: Update LocalPosition $(D_x, D_y)$ base on Equation 1
28: end if
29: return LocalPosition $(D_x, D_y)$

Figure 6. The DurianToRoad algorithm.

Table 4. The five stages of the game MeetDurian.

| Stage | Duration | Description |
|-------|----------|-------------|
| 1) Questionnaire | 10 minutes | Fill out questionnaire Q5 |
| 2) Video | 30 minutes | The moderator introduces the gameplay and rules of MeetDurian via demonstration |
| 3) Game | A week | A week-long competition on the campus, there will be material rewards for reaching the top three |
| 4) Questionnaire | 30 minutes | Fill out 5 questionnaires |
| 5) Interview | 30 minutes | Randomly select a few students, explore students’ experiences, and discuss opinions |
total. As a filter requirement, based on the participant’s answer time, if it is less than 100 seconds, they are not eligible to participate. After screening data, 21 valid questionnaires were used for data analysis (7 females included). All data were published on the online visualization screen.

In addition, in order to fit the findings and analysis into the allocated five questionnaires, the weighted response was designed to analyze the individual questions. In this way, all answers can be measured by the same positive or negative response. Any reading above 50% is closer to the positive and anything less than 50% is closer to the negative answer. Unfortunately, the report size does not allow for an expanded analysis of responses to each question due to size constraints. A more detailed breakdown of the results and analysis can be found on the expanded worksheet.

**Participants’ Immersion in the Game.**

After a week of gameplay, we invited students to measure their immersion in the game through 10 items in the questionnaire after the game. These questions were answered on a five-point Likert scale with 1 = completely disagree and 5 = completely agree. For Q1 (Cronbach’s α = .78), the result suggests a high internal consistency among the Q1 (Toda et al., 2019). As a sampling, we chose the player’s willingness to capture virtual durians, the degree of forgetting their daily worries, and memorable game as dependent variables for analysis of variance (ANOVA) to analyze the factors in which participants are immersed in this game. We performed 30 repeated-measures ANOVA and determined the significant main effect between the respective sub-question in Q1. Table 5 shows the statistical results. Winning the first place is the motivation for the player to work hard to capture the virtual durian. In addition, the game environment has a very important impact on the player’s sense of immersion, allowing players to temporarily forget their daily worries, and the game experience directly affects the player’s impression of the game.

| Measure                  | Factors              | F    | p      |
|--------------------------|----------------------|------|--------|
| Capture virtual durian   | Attention            | 2.450| .099   |
|                          | Effort               | 2.872| .067   |
|                          | Get first place      | 3.697| .032   |
| Forget daily worries     | Attention            | 3.814| .029   |
|                          | Game environment     | 2.473| .097   |
| Memorable game           | Challenging          | 3.410| .042   |
|                          | Game experience      | 7.939| .002   |

Table Note. Only $p \leq .10$ are shown.
For weighted response (Kølbæk, Jefsen, Speed, & Østergaard, 2021), in the test for the Q1, the game scored consistently high with all of the immersion questions and maintained a positive response rate above 73% on all questions. This translates into the lowest reading of 73.33% on Q1.2 and Q1.3 and the highest of 84.76% on Q1.6 (e.g., Q1.2 and Q1.3 represent the 2nd and 3rd questions of questionnaire 1, and so on and so forth).

Workload Assessment and Satisfaction.

NASA-TLX, a multi-dimensional survey based on workload measurement to determine the prevalence of a particular workload score (Grier, 2015). The NASA-TLX workload assessment project determined mental demand ($m = 10.57$ and $SD = 18.66$), physical demand ($m = 12$ and $SD = 20.95$), temporal demand ($m = 13.90$ and $SD = 18.59$), effort ($m = 12.76$ and $SD = 15.39$), and frustration level ($m = 9.67$ and $SD = 16.53$); for weighted response, the workload perception is verified depending on the questions. The users did not find the game too mentally demanding with a value of 50.34%. Only 57.37% felt physically tired. On average, users spent 11 minutes 43 seconds on the game and felt the achievement was 66.21% satisfying. Users felt that they used only 60.77% of their potential effort and felt only 46.03% frustration.

Participants’ satisfaction with the game is measured by the five items in the subjective questionnaire after the game. For this questionnaire (Q3, $m = 21.14$, and $SD = 2.96$), the Likert-style five-point rating system is used, from 1 to 5. Users were very satisfied with the game and consistently gave it an above 80% positive response. The game scored 82.86% for graphics, 83.81% for comfort, 87.26% for app acceptance, and 80.95% in terms of interest. In this game, user satisfaction seems to be affected by the degree of challenge the user faces, often related to workload assessment (Q2, $m = 70.38$, and $SD = 14.24$). For example, in projects with the NASA-TLX workload of fewer than 70 points, 60% of participants were not satisfied with MeetDurian. Participants with relatively high workload evaluation scores, from 78 to 98, were generally satisfied with this application.

Improve Results

Participants’ learning outcomes are measured through nine sub-questions. All items were answered on a five-point Likert scale, where 0 = completely disagree and 5 =

Table 6. Analysis of correlation in Q4.

| Project | M   | SD  | Gender | Q4.2 | Q4.3 | Q4.5 | Q4.7 |
|---------|-----|-----|--------|------|------|------|------|
| Gender  | 1.33| .48 | 1      | Null | Null | Null | Null |
| Q4.2    | 1.05| .22 | .32    | 1    | Null | Null | Null |
| Q4.3    | 1.05| .22 | .32    | 1.00**| 1    | Null | Null |
| Q4.5    | 1.57| .51 | 0      | -.26 | -.26 | 1    | Null |
| Q4.7    | 3.38| .92 | .37    | .15  | .15  | .47* | 1    |
completely agree. Each item in this questionnaire (Q4) was selected for analysis of correlation (Rao & Sachs, 1999). Table 6 shows the statistical results for this model (only the associated items are shown). When participants understand the positive effects of wearing a mask (Q4.2), it will promote the behavior of wearing a mask outside (Q4.3). Interestingly, participants who questioned the questions in MeetDurian (Q4.5) generally had a high degree of the correct understanding of COVID-19, indicating that they were willing to spend time learning relevant knowledge. This also opens up new ideas for this game. In the future, we may add a part in MeetDurian that is used to correct wrong knowledge and perception of COVID-19.

To further investigate the factors that affect player learning outcomes, we performed regression analysis using the learning time they spent as the dependent variable (Castronova & Falk, 2009; De Schutter, 2011). The application acceptability (regression coefficient = .49, t = 2.82, F = 7.962, p = .011) means that the acceptance of the application by the player will have a significant impact on the player’s willingness to spend time learning about COVID-19. The immersion for catch durians that players are eager to capture virtual durians (regression coefficient = .29, t = 1.67, and p = .112), the causal relationship is not significant. Possibly because there were few times of answering questions in MeetDurian, which only appeared after meeting the conditions of capturing a durian. In the future, during the player’s walk to the mission location, random questions may appear on the phone screen.

**Will the Game Change Personal Hygiene?** Participants’ hygiene is measured through nine sub-questions in Q5, which include the part of the pre-game and post-match. The line graphs of the changes in hygiene habits of the participants before and after the game are stored on the online visualization screen. It is obvious that the results are positive; for example, the percentage increases in the number of players’ bathing and bedroom cleaning are particularly significant, increasing by 52.35% and 42.82%, respectively. Some participants indicated they had become accustomed to wearing face masks, so the change in wearing a mask when going out was not evaluated in this study. However, this study focused on players’ cleaning and disinfection of their belongings, including mobile phones and keys. After the game, 57.14% of players are willing to use alcohol to keep their personal belongings clean. Regarding the way of handwashing, even before the game, participants generally thought they needed to wash their hands more often, and of course, after the game, more participants increased their use of hand sanitizers. All the users expressed that they exhibit behavioral changes after the game on each of the questions, and all the categories saw a major improvement of around 20% on average.

**Interview**

At the end of this evaluation, we selected three students (the first place, median, and last place based on the score ranking) to participate in a 30-minute interview, designed to explore their experience with and opinion of MeetDurian.
SQ5: Is it difficult to finish a whole game?. Participants felt that a complete game was difficult to achieve. However, when walking has a specific goal, it becomes a fun way to explore the outdoors. “When I entered the game, I found that there were only 6 durians around. I thought it was easy to complete, but then I found that it was not easy. I spent an afternoon capturing these 6 durians. Their positions look close to me, but I walked 15 kilometers in total and ranked first in the number of steps on WeChat. It is a very proud thing.” Moderate participation in the competition will motivate students to keep exercising, which may become peer pressure (Kandel & Lazear, 1992).

SQ6: Did MeetDurian motivate students to self-learning during COVID-19?. One participant said: “Sometimes, the competition is fierce, and I have to put down my work to compete with them. I also encourage my partners to work hard to earn points. We compared our scores with each other during the break.” Two participants thought that MeetDurian was very helpful to improve their hygiene habits, especially helping them learn a lot about COVID-19, but one participant did not think so: “The school attaches great importance to students’ knowledge about COVID-19. I can easily notice that there are publicity banners posted on the campus for epidemic prevention and control. However, this game often reminds me to wear a mask. A very common phenomenon is the students. Masks are rarely worn on campus. One of the reasons may be that the school is relatively safe, but in fact, there is a big safety hazard.”

Overall, students were enthusiastic about MeetDurian’s potential, especially in preventing COVID-19 and personal care. Participants showed enthusiasm for Meet-Durian’s gameplay, execution, and goals.

Discussion

From the respondent findings, we can see that the respondents found the game very immersive. They found that it required a satisfactory level of workload, and it is interesting and engaging, and that it did not require too much time or make them frustrated. The user satisfaction was consistently high with all the application’s aspects. The users had a pretty good understanding of the pandemic, and generally followed the rules and regulations, and wanted to learn more through a range of different methods. When comparing user behavior before and after the game, all saw a major increase in their pandemic safety measures awareness and implementation.

Conclusion and future directions

This article introduces a serious location-based game that helps users improve hygiene habits and understand the prevention and control of COVID-19. What is more, good hygiene habits will accompany and benefit entire lives of people. Some diseases, such as flu and tuberculosis, affect people annually, and good hygiene habits could be useful. Although the COVID-19 pandemic challenges mobile positioning-based games, we improved the game’s functions and rules, and enabled MeetDurian to respond to this
challenge, and by randomly generation durian method, let the player mobile capture, capture through epidemic related problems, meet the purpose of the game setting, in the continuous development of the epidemic, the game well fits the actual needs, so that people in the body, better understanding of the epidemic and infectious diseases.

In the future, COVID-19 will pass from pandemic to prosaic. Therefore, without changing the existing game rules, future iterations of this game will explore more complex game mechanisms to adapt to the new reality; “team roles” could be implemented. At the same time, as different things motivate different people, personalizing the incentives and rewards can be highly beneficial (Vassileva, 2012). Therefore, tailoring at the level of social influence strategies may positively contribute to the effects of persuasive technologies (Kaptein, Ruyter, Markopoulos, & Aarts, 2012). When individuals’ preferences are neglected, in static gamification, researchers observed inconclusive or even negative results (Aldenaini, Alqahtani, Orji, & Sampalli, 2020; Hamari, Koivisto, & Sarsa, 2014; Seaborn & Fels, 2015). Thus, how to adapt and personalize gamified applications became an essential research challenge to consider in the future development of MeetDurian.

**Declaration of Conflicting Interests**

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

**Funding**

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported in part by the National Natural Science Foundation of China (No. 61902203).

**ORCID iDs**

Dongliang Chen https://orcid.org/0000-0001-7700-4729
Antonio Bucchiarone https://orcid.org/0000-0003-1154-1382

**Notes**

1. https://www.pokemongo.com
2. https://orna.guide
3. https://www.ingress.com
4. https://www.thewalkingdeadourworld.com
5. https://www.minecraft.net
6. https://www.harrypotterwizardsunite.com
7. https://www.jurassicworldalive.com
8. https://play.google.com/store/apps/details?id=io.game2.meetdurian
References

Aldenaini, N., Alqahtani, F., Orji, R., & Sampalli, S. (2020). Trends in persuasive technologies for physical activity and sedentary behavior: A systematic review. *Frontiers in Artificial Intelligence, 3*(7).

Benvenisti, E. (2020). The WHO—Destined to fail?: Political cooperation and the COVID-19 pandemic. *American Journal of International Law, 114*(4), 588–597.

Brown, G., & Susskind, D. (2020). International cooperation during the COVID-19 pandemic. *Oxford Review of Economic Policy, 36*(Suppl_1), S64–S76.

Castronova, E., & Falk, M. (2009). Virtual worlds. *Games and Culture, 4*(4), 396–407.

De Schutter, B. (2011). Never too old to play: The appeal of digital games to an older audience. *Games and Culture, 6*(2), 155–170.

Ding, F., Peng, P., Huang, Y., Geng, M., & Tian, Y. (2020). Masked face recognition with latent part detection. In D. Feifei, P. Pelxi, H. Yangru, G. Mengyue, & T. Yonghong (Eds.), Proceedings of the 28th ACM international Conference on multimedia (pp. 2281–2289). Seattle, WA, USA: Association for Computing Machinery.

Eikenberry, S. E., Mancuso, M., Iboi, E., Phan, T., Eikenberry, K., Kuang, Y., Kostelich, E., & Gumel, A. B. (2020). To mask or not to mask: Modeling the potential for face mask use by the general public to curtail the COVID-19 pandemic. *Infectious Disease Modelling, 5*, 293–308.

Epstein, B., & Khan, D. C. (2014). Application impact analysis: A risk-based approach to business continuity and disaster recovery. *Journal of business continuity & emergency planning, 7*(3), 230–237.

Feng, S., Shen, C., Xia, N., Song, W., Fan, M., & Cowling, B. J. (2020). Rational use of face masks in the COVID-19 pandemic. *The Lancet. Respiratory Medicine, 8*(5), 434–436.

Gale, R. P., & Lazarus, H. M. (2020). Does a durian smell like a rose? The dangers of jargon. *Bone Marrow Transplantation, 55*(2), 280–282.

Gaspar, J. D. S., Lage, E. M., Silva, F. J. D., Mineiro, É., Oliveira, I. J. R. D., Oliveira, I., Souza, R. G. D., Gusmão, J. R. O., De Souza, C. F. D., & Reis, Z. S. N. (2020). A mobile serious game about the pandemic (COVID-19 - did you know?): Design and evaluation study. *JMIR Serious Games, 8*(4), e25226.

Grier, R. A. (2015). How high is high? A meta-analysis of NASA-TLX global workload scores. *Paper presented at the Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 59*(1), 5.

Hamari, J., Koivisto, J., & Sarsa, H. (2014, 6–9 January). *Does Gamification Work? – A Literature Review of Empirical Studies on Gamification*. Paper presented at the 2014 47th Hawaii International Conference on System Sciences.

Huizenga, J., Admiraal, W., Dam, G. t., & Voogt, J. (2019). Mobile game-based learning in secondary education: Students’ immersion, game activities, team performance and learning outcomes. *Computers in Human Behavior, 99*, 137–143.

Kandel, E., & Lazear, E. P. (1992). Peer Pressure and Partnerships. *Journal of Political Economy, 100*(4), 801–817.
Kaptein, M., Ruyter, B. D., Markopoulos, P., & Aarts, E. (2012). Adaptive Persuasive Systems: A Study of Tailored Persuasive Text Messages to Reduce Snacking. ACM Transactions on Interactive Intelligent Systems, 2(2), Article 10.

Kokudo, N., & Sugiyama, H. (2020). Call for international cooperation and collaboration to effectively tackle the COVID-19 pandemic. Global Health & Medicine, 2(2), 60–62.

Kolbæk, P., Jøfsen, O. H., Speed, M., & Østergaard, S. D. (2021). Mental health of patients with mental illness during the COVID-19 pandemic lockdown: A questionnaire-based survey weighted for attrition. Nordic Journal of Psychiatry.

Laato, S., Islam, A. K. M. N., & Laine, T. H. (2020). Did location-based games motivate players to socialize during COVID-19?. Telematics and Informatics, 54, 101458.

Laato, S., Laine, T. H., & Islam, A. K. M. N. (2020). Location-based games and the COVID-19 pandemic: An analysis of responses from game developers and players. Multimodal Technologies and Interaction, 4(2), 29.

Lauer, S. A., Grantz, K. H., Bi, Q., Jones, F. K., Zheng, Q., Meredith, ... Lessler, J. (2020). The incubation period of coronavirus disease 2019 (COVID-19) from publicly reported confirmed cases: Estimation and application. Annals of internal medicine, 172(9), 577–582.

Luengo-Oroz, M., Hoffmann Pham, K., Bullock, J., Kirkpatrick, R., Luccioni, A., Rubel, S., ... Mariano, B. (2020). Artificial intelligence cooperation to support the global response to COVID-19. Nature Machine Intelligence, 2(6), 295–297.

Lv, Z., Esteve, C., Chirivella, J., & Gagliardo, P. (2015). A game based assistive tool for rehabilitation of dysphonic patients. Paper presented at the 2015 3rd IEEE VR International Workshop on Virtual and Augmented Assistive Technology (VAAT), Arles, France, 23 March 2015.

Marchi, R. (2012). With Facebook, blogs, and fake news, teens reject journalistic “objectivity”. Journal of communication inquiry 36(3), 246–262.

Moroney, L. (2017). Cloud storage for firebase. In L. Moroney (Ed.), The definitive guide to firebase: build android apps on google's mobile platform (pp. 73–92). Berkeley, CA: Apress.

Paavilainen, J., Korhonen, H., Ala, K., Stenros, J., Koskinen, E., & Mayra, F. (2017). The Pokémon GO experience: A location-based augmented reality mobile game goes mainstream. Proceedings of the 2017 CHI Conference on human factors in computing systems (pp. 2493–2498). Denver, Colorado, USA: Association for Computing Machinery.

Pennycuick, G., McPhetres, J., Zhang, Y., Lu, J. G., & Rand, D. G. (2020). Fighting COVID-19 misinformation on social media: Experimental evidence for a scalable accuracy-nudge intervention. Psychological science, 31(7), 770–780.

Rao, N., & Sachs, J. (1999). Confirmatory factor analysis of the Chinese version of the motivated strategies for learning questionnaire. Educational and Psychological Measurement, 59(6), 1016–1029.

Seaborn, K. & Fels, D. I. (2015). Gamification in theory and action: A survey. International Journal of Human-Computer Studies, 74, 14–31.

So, H.-J., & Seo, M. (2018). A systematic literature review of game-based learning and gamification research in Asia: The synthesized findings and research gap. In J. Kerry,
Kennedy, & L. John Chi-Kin (Eds.), Routledge international handbook of schools and schooling in Asia (1st ed., Vol. 37, pp. 23). England, UK: Routledge.

toda, A. M., Oliveira, W., Klock, A. C., Palomino, P. T., Pimenta, M., Gasparini, I., et al. (2019). A taxonomy of game elements for gamification in educational contexts: Proposal and Evaluation. Paper Presented at the 2019 IEEE 19th International Conference on Advanced Learning Technologies (ICALT). Maceió, Brazil, July 15–18, 2019.

Vassileva, J. (2012). Motivating participation in social computing applications: A user modeling perspective. User Modeling and User-Adapted Interaction, 22(1), 177–201.

Venable, J (2006). The role of theory and theorising in design science research. Paper presented at the Proceedings of the 1st International Conference on Design Science in Information Systems and Technology. DESRIST 2006, Las Vegas, NV, May 14–15, 2012.

Yu, Y. H. (2014). Study on intelligent augmented reality tourist guide application based on android smart phone. Applied Mechanics and Materials, 668-669, 1399–1402.

Zhang, X., Wang, J., Li, Y., Jantti, R., Pan, M., & Han, Z. (2019). Catching all pokémon: Virtual reward optimization with tensor voting based trajectory privacy. IEEE Transactions on Vehicular Technology, 68(1), 883–892.

Author Biographies

Dongliang Chen is currently pursuing the M.S degree with the School of Data Science and Software Engineering, Qingdao University, China. Dongliang Chen’s research direction include Deep Learning, Computer Vision, Serious Game, Cyber Security, Reinforcement Learning, Game Analysis. He has published 8 papers in IOTJ, FGCS, TOIT, SCS, IMAVIS journals.

Antonio Bucchiarone is currently a Senior Researcher at the Motivational Digital Systems (MoDiS) research unit of the Bruno Kessler Foundation (FBK) in Trento, Italy. His research activity is focused principally on many aspects of the Software Engineering for Adaptive Socio-Technical Systems. In the last 12 years, he has investigated advanced methodologies and techniques supporting the definition, development, and management of distributed systems that operate in dynamic environments, where being adaptable is a key intrinsic characteristic. In 2018, he started a new research topic in his research group on Gamified Software Modeling with the objective to define methods, theories, and tools to bound gameful mechanisms to existing software applications and create gamified scenarios in Software Engineering. He has been actively involved in various European research projects in the field of Self-Adaptive Systems, Smart Mobility and Constructions and Service-Oriented Computing. He was the General Chair of the 12th IEEE International Conference on Self-Adaptive and Self Organizing Systems (SASO 2018) and he is an Associate Editor of the IEEE Transactions on Intelligent Transportation Systems (T-ITS) Journal, the IEEE Software Journal and the IEEE Technology and Society Magazine.

Zhihan Lv (SM’19) has contributed 300 papers including more than 50 papers on IEEE/ACM Transactions. He is Editor-in-Chief of Internet of Things and Cyber-
Physical Systems (KeAi), an Associate Editor of 18 journals including IEEE Transactions on Intelligent Transportation System, IEEE Transactions on Network and Service Management, IEEE Technology Policy and Ethics Newsletter, and Leading Guest Editors for 40 special issues including 9 IEEE. He is Co-Chair or TPC of 50 conferences including ACM MM 2021, ACM IUI 2015-2022. He has reviewed 400 papers. He has received more than 20 awards from China, Europe, IEEE. He has received 1.5 million US dollars funding as PI. He has been involved in many European and Chinese projects supported with funding of 25 million US dollars. He has given more than 80 invited talks for universities and companies in Europe and China. He has given 15 keynote speech for International conferences.