Application Framework for On-Site Quality and Safety Inspection based on WeChat

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Abstract:

Nowadays, almost everyone has a smart mobile phone or tablet, which brings a new paradigm for on-site inspection. Generally, standalone Apps or websites were utilized for inspection data collection. However, too much effort in App development/maintenance and obstacles to guarantee opening rate have a significant impact on their application. To address these problems, a new framework for on-site inspection based on the widely used mobile App WeChat was established. In the proposed framework, built-in support like quick response code scanning, photo taking and communication in WeChat was fully utilized to reduce the efforts for application development. Meanwhile, the whole process of inspection was also considered in the framework, that is to say, it is possible to track the recording, forwarding, and resolving process of an inspection issue. Based on the proposed framework, a prototype micro-App was developed and tested in a real project. Validation results illustrate that standardize interfaces and modules from WeChat can reduce the time for mobile app development and deployment, therefore improving the work efficiency. Furthermore, such an application makes it possible to track, discuss and resolve safety or quality issues with high efficiency and flexibility. Finally, it is concluded that the proposed application framework for inspection is feasible and useful for safety and quality management during construction.

Keywords: On-site inspection, mobile App, safety, quality, WeChat.

1. INTRODUCTION

The construction project is quite complex due to its dependence on multiple stakeholders involved at various levels through the lifecycle of the project (Arora & Ogra, 2012). Generally, successful implementation of the project is influenced by factors including cost, quality, safety, productivity as well as human behaviors, which, if not properly managed, usually lead to delays, loss of revenue or out of budget (Assaf & Al-Hejji, 2006). Among all these factors, safety and quality are gaining more and more attention. Management of construction projects necessitates not only controlling their time and cost but also the safety and quality to meet the planned targets. These need timely data the reflect the status of the project to take corrective actions, if needed (El-Omari & Moselhi, 2011). Which means, it is important to monitor, audit and report the construction phases periodically so that constructed project meets all the contract requirements at any of the construction stages (Arora & Ogra, 2012). However, traditional ways for safety and quality inspection are still paper-based files like drawing, data collection forms, which is not efficient for information exchange and communication, usually leading to overlooking of important issues and deferred on-site decisions (Garcia et al., 2014).

With over 5 billion cellphones in a world of 7 billion inhabitants, inevitably, mobile phones are the most quickly adopted consumer technology in the history of the world. As the availability of commercial mobile and wearable computers increases, inspection data can be collected and retrieved on site using a variety of sensor systems, data management tools, and information systems (Horak et al., 2014). By integrating automated data acquisition technologies, with the scheduling system, relational database, and AutoCAD, El-Omari and Moselhi (2011)proposed a method for construction progress reporting and decision making. Furthermore, CAD drawings could also be improved through building information modeling (BIM) technologies to achieve effective and efficient inspection of construction (Tsai et al., 2014). As for quality inspection, mobile GIS was also adopted for information collecting and sharing to enhance the reduction of construction delays by quality compliance and efficient coordination at various stages (Arora & Ogra, 2012). It is reported that mobile technologies can reduce the amount of time typically needed for the document research task and transfer the time onto the general inspection task, like observing ongoing construction activities (Asbahan & DiGirolamo, 2012). Further benefits including reduced interruptions to operations, increased safety, enhanced thoroughness, more rapid determination of results, and more accurate recording of activities are also observed (HorakDeLand & Blair, 2014). Yamaura and Muench (2016) also concluded that project inspectors using mobile technology experienced productivity gains on the order of 25%, collected and shared 2.0 times as many observations, and improved the timeliness of daily reports and overall data availability. Application of mobile devices for the safety inspection and management (Li, 2015; Zhang et al., 2016), as well as supply chain management (Shi et al., 2016) are investigated. Inevitable, there is a trend to adopt various mobile technologies (Omar & Nehdi, 2016) to enable complete and consistent data, improved data accessibility and work efficiency.

Though recent advances in mobile computing capabilities, including networking, global positioning systems (GPS), audio-video recording, and augmented reality (AR) features represent chances to provide both inspected state parties and inspection team members with convenient access to efficient data recording and collaboration, they also bring variety in hardware, software as well as difficulties in corresponding application developing technologies. First, the developer needs to handle various hardware types including camera, accelerator as well as GPS sensors, and also different software architectures like Android, iOS. That's why technologies like cross-platform development are introduced develop an App works both on Android and iOS, even on other systems. Therefore, the developer doesn't need to learn different technologies, and code base can be shared. However, this also means you can't use the official libraries of different companies directly and potential issues like inconsistencies in the behavior of platform specific code (Cruxlab, 2017) fewer choices of software development libraries are introduced. Performance of the developed App may be also a problem when utilizing cross-platform technologies back-ended by HTML5. Except for issues in App development, another problem is that quite a bunch of Apps are installed on the user's mobile, it is for the users to learn different Apps and keep using them.

Nowadays, giant Apps like WeChat, AliPay become more and more popular in China, they provide various application programming interfaces (APIs) as well as in-App micro-App development abilities to establish a large-scale ecosystem. With quite a large amount of users, support for various devices, sensors, and system platforms as well as development tools are built-in features of this kind of Apps with detailed documents and examples. Meanwhile, it is also easier to access user information, spread your micro-App among different users and keep a better open rate.

Hence, this research proposed an application framework based on WeChat for on-site quality and safety inspection. With the proposed framework, features of WeChat including quick response (QR) code scanning, photographing, speech to text conversion as well as audio and video recording are utilized to create an easy and flexible micro-App. Meanwhile, inspection and issue resolving workflow are also incorporated into social communication ability of WeChat, so that users can comment on inspection records and forward them to others for issue resolving. Then, based on the framework, a micro-App is developed following the inspection workflow and tested in different projects. Results show that proposed framework and prototype micro-App is feasible and flexible for quality and safety inspection, corresponding data including text notes, images, audios, etc., are collected and shared among different users, therefore improving the efficiency for on-site inspection and issue resolving.

2. METHOD AND FRAMEWORK

2.1 In-App Micro-App development of WeChat

With more than 700 million monthly active users and 10 million organizations using their official accounts to spread ideas, news and services, WeChat provide a new open capacity called micro-App or instant-App at the beginning of 2017 (WeChat, 2017). Developers can rapidly develop a micro-App which can be shared and acquired easily within WeChat, with excellent user experiences (Jiang, 2017).

To control extra effort for learning new technologies, WeChat defined an App development stack similar to HTML5. As shown in Figure 1, user interaction (UI) interfaces or views are defined by WeXin (pinyin of WeChat) markup language (WXML) for UI structures and WeiXin style sheets (WXSS) for UI styles. App services for UI behavior and third-party API control are based on javascript. The interaction between views and App services as well as invocation of built-in APIs are implemented by JSBridge. That is to say, events generated from user input are sent to built-in APIs and App services through JSBridge, while both App services and built-in APIs can feedback data to views through JSBridge. In this manner, WeChat exposes various APIs to access cameras, GPS sensors, audios, local storage, network, and so on. Moreover, platform differences among Android, iOS, and even Windows are hidden by WeChat, so the developer doesn't need to deal with it.

Since WXML and WXSS are quite similar to hypertext markup language (HTML) and cascading style sheets (CSS) of HTML5, and both WeChat and HTML5 utilize javascript for app services, it is very easy for web developers to create micro-Apps. However, UI elements and their styles in micro-App have less flexibility than in HTML5, utilization of javascript libraries should also follow some rules when developing micro-Apps. Therefore, WeChat can ensure the performance of micro-Apps.

Within this framework from WeChat, various features like GPS sensing, audio and video recording, QR code scanning and unified APIs for developers are provided, therefore reducing the efforts needed for development. Since all UI elements and their styles are embedded in WeChat, who has done a lot work to optimize the performance, the performance of micro-Apps is approximately the same as native Apps and better than HTML5-based web applications in most of the scenarios. Meanwhile, UI interfaces and styles similar to WeChat are adopted, it is easier for the users to learn and use. Furthermore, this also means that micro-Apps will get a high open rate because the users usually open WeChat quite a lot of times per day.

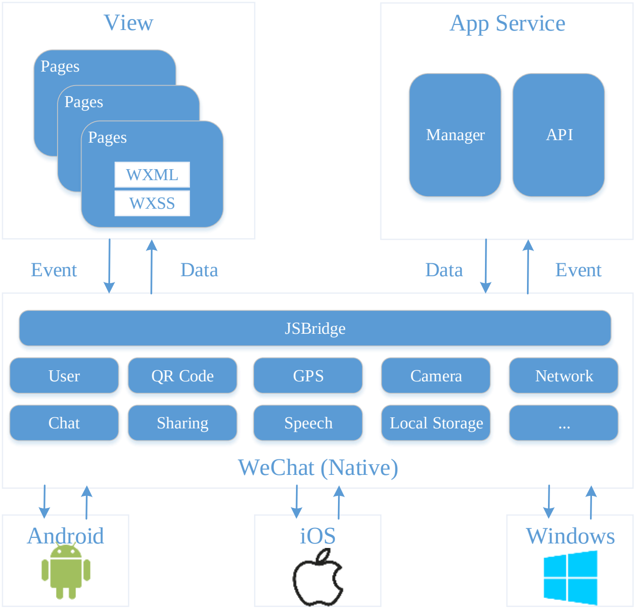


Figure 1. The in-App micro-App framework of WeChat

2.2 Application Framework for On-Site Inspection

Based on the micro-App framework of WeChat, this research established an application framework for the on-site inspection (Figure 2). The framework is mainly composed of two parts: the micro-App in WeChat as client-side (left part of Figure 2), and the server side (right part of Figure 2) for data storage and service.

As shown in Figure 2, the server side the proposed framework is based on AliCloud, a cloud platform from Alibaba, and is consist of four components: Alibaba object storage service (AliOSS), a relational database called PostgreSQL, content delivery network (CDN), and API service. The first three components are provided by AliCloud and developers can utilize them for unstructured data storage, structured data storage, high availability of data respectively. The final component is the API service for data accessing and processing at the server side, for example, querying data based specific requirements in PostgreSQL database and sending it to the client side. Therefore, other clients like desktop applications can also be integrated into the large system through the internet. While the bottom part of the client side on the mobile is native WeChat application that encapsulates network accessing, various sensor abilities for GPS and cameras, as well as user authentication and other features. All the features are exposed to micro-Apps through JSBridge as mentioned before.

Finally, the proposed micro-App for on-site inspection has 9 abilities: except setting function for user permission control and server configuration, the other 8 functions are inspection recording, searching, tracking, comment, forwarding, resolving, as well as notification and reports of inspection records. Each function is described as follows:

1) Recording: records location, description, type, level of importance, the requirement for rectification, and related attachments and images;

2) Tracking: tracks the status of recorded issues or problems, like who is in charge of the issue, any new comments and images;

3) Forwarding: forwards existing records to different users, for example, the manager may forward an issue record to the engineer who can resolve it, and once the engineer resolves the issue, he and forward it back to the manager;

4) Resolving: when resolving the recorded issues, the users can add comments, images and update the status of record;

5)Search: supports the user searching inspection records by different parameters including time, corresponding users, type, level of importance, etc.

6)Reports: statistics and reports generation with tables and charts, providing a summary and overview of quality and safety issues;

7) Comments and 8) notification: these are common features that utilized by the above-mentioned functions. The users can create notes on inspection records to express his or her comments and opinion so that different users can communicate with each other. And once the inspection record is changed or forwarded, the corresponding user will get informed.

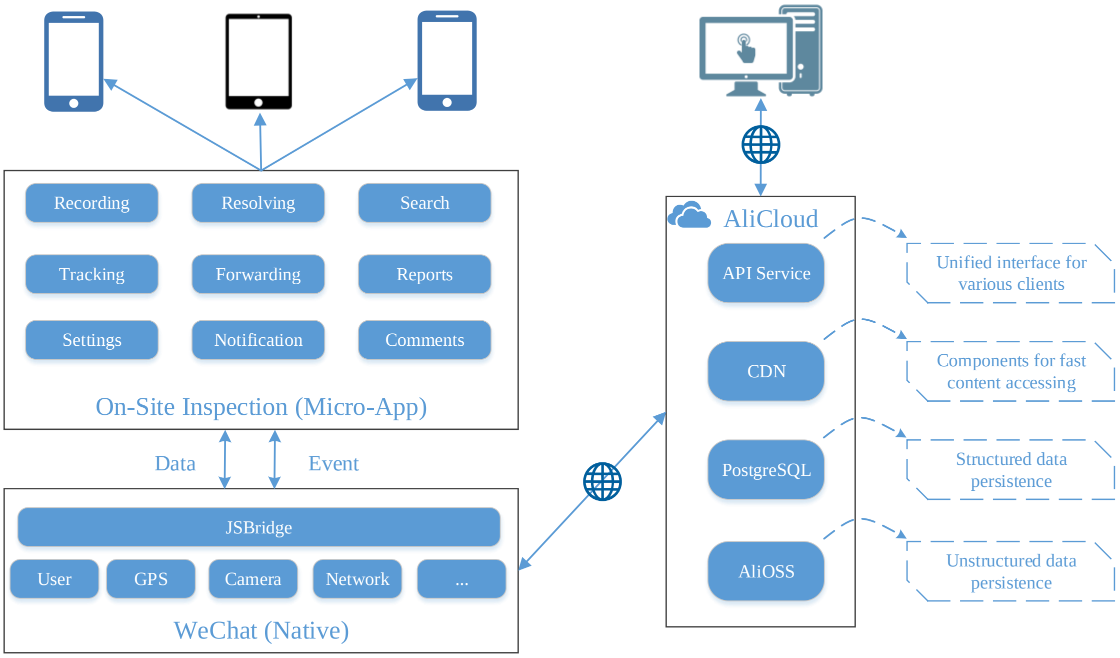


Figure 2. Application framework for on-site inspection

2.3 Database Design for On-Site Inspection

To capture inspection records and corresponding comments and attachments, database schema based on PostgreSQL database is also designed. Generally, the schema can be taken as two parts: the bottom part for definition of users and their corresponding roles, while the top part for definition of inspection records, related comments, and the forwarding process.

As the definition of users and related roles is quite common in database schema design, here we just show the basic elements of each table. Since we try to persist data of different projects in the same database, so we add *ProjectID* as a column of each row. Table of the users has four basic columns, except *ProjectID*, they are *ID*, *Mobile*, and *Status* of the user. Note that we just utilization the authentication interface provided by WeChat, so there is no need to save the password for the user. Similarly, table of roles should define *ID*, *Name* and maybe other properties of the role, and we can assign *Permission* to each role. Finally, the relation between users and their corresponding roles are stored in the table *role_rel_user*, each row of the table is filled with the *ID* of the user and the *ID* of the role in column *UserID* and *RoleID* respectively.

The other part comes to the main tables for recording inspection data. Firstly, all tables have a column called *ProjectID* to support multiple projects as mentioned before, and an *ID* column for identification of each data record. Core table of this part is *issue_record*, which is used to capture on-site inspection data for safety and quality. In this table, *Description* and *Rectification* are designed for possible notes about the issues and the way to resolve the problem, while *Location*, *PicUrls*, and *Attachments* are used to track the location where the issue is and related images or documents. Then, *TypeID* is a flag used to distinguish records for quality inspection and safety inspection. Meanwhile, importance level like common, most important and status like pending, resolved are kept in column *LevelID* and *StatusID* respectively. Creators, possible users responsible for the issue, and users that should pay attention to the issue are stored in column *CreatedBy*, *OperatorIDs*, and *CC* too. Creation time and the deadline for issue resolving are important for the tracking of the inspection issues, are persisted in column *CreateAt*, and *Deadline*. The other two tables are *issue_comment* and *issue_forward*. The former one is used for the storage of possible comments from the users, which will keep content, images, creator, creation time and the related issue of each comment in *Content*, *PicUrls*, *CreateBy*, *CreatedAt*, *IssueID* respectively. The latter one is used to describe how an issue is transferred to different users. Related data kept in this table is the source user, the target users, forwarding time, status, and the identifier of related issue, which are persisted in column *FromUserID*, *ToUserIDs*, *CreatedAt*, *StatusID*, and *IssueID*. In addition, whether the issue is resolved and approved by the manager as well as possible action taken to resolve the issue can also be stored in column *ApproveStatus* and *IssueAction*.

With these tables, information for on-site quality and safety inspection and corresponding users can be properly collected and kept. Further analysis of the data and generation of issue reports are also possible and will benefit the process for decision making during construction management.

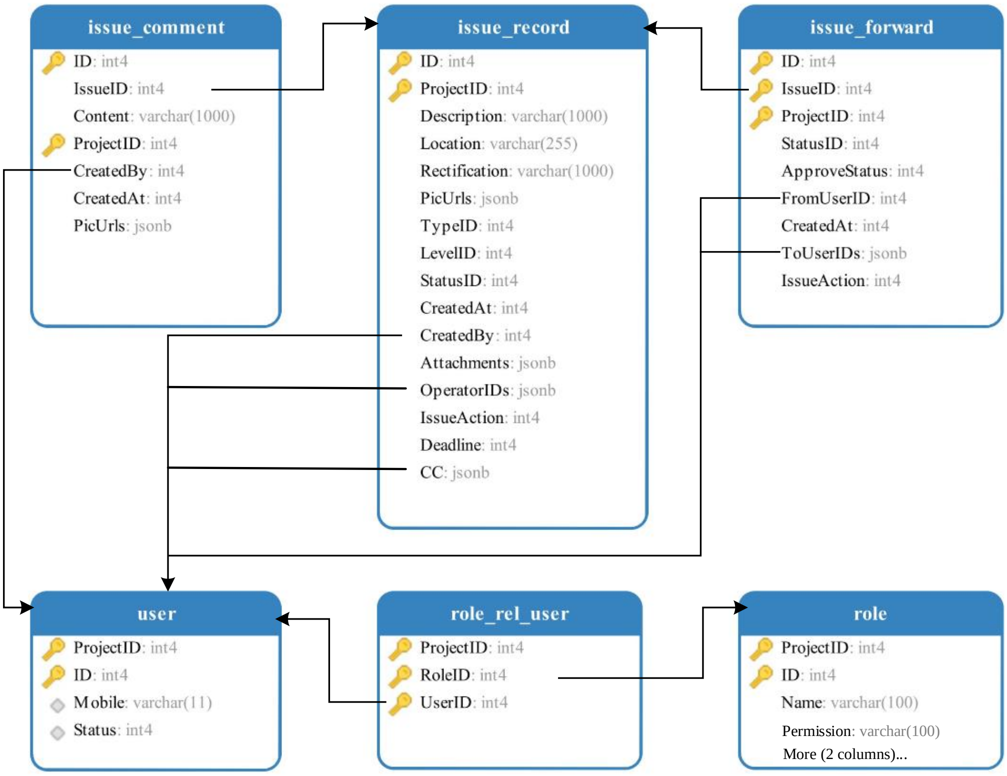


Figure 3. The database schema for on-site inspection

2.4 Inspection and Issue Resolving Workflow

With the above-proposed framework, a general workflow basic on everyone on-site inspection process is summarized (Figure 4). The inspectors or other users responsible for on-site safety and quality inspection first record issues found in their daily inspection. Description, location and related images of the issue can be recorded. And this information can be transferred to the manager or related engineers directly. Once the manager receives the information, he or she can further add requirements and possible guidance on issue resolving before forwarding the record to the engineers and corresponding contractors if necessary. Then, the engineer responsible for the issue will check and try to resolve each of the pending issues. During the resolution of issues, the engineer can continuously add notes, and images to share the progress of issue resolving. Once the inspection is resolved, it will be submitted to the manager, who will confirm whether the problem is resolved or not. At any step or status of the issue, users always can make comments on the record, so that they can immediately share thoughts and concerns on the issue. Moreover, issues can also be transferred to another engineer if one encounters problems when dealing with it.

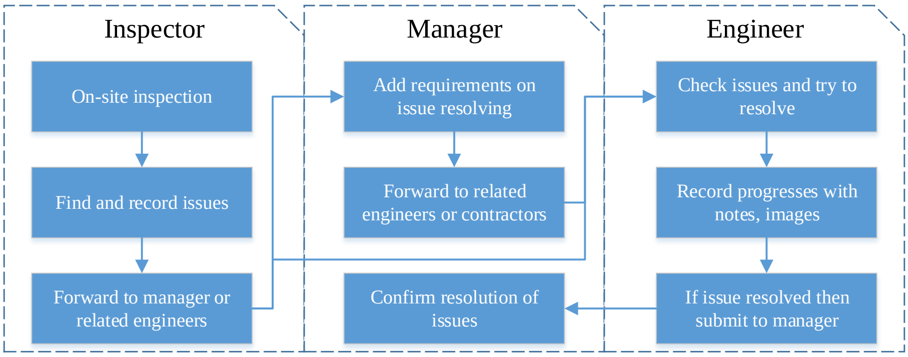

Inspector
On-site inspection
Find and record issues
Forward to manager or related engineers
Manager
Add requirements on issue resolving
Forward to related engineers or contractors
Confirm resolution of issues
Engineer
Check issues and try to resolve
Record progresses with notes, images
If issue resolved then submit to manager

Figure 4. Issue recording and resolving workflow

3. DEMONSTRATION AND DISCUSSION

With proposed framework based on WeChat, a micro-App for on-site safety and quality inspection was developed. Then developed prototype application and above-mentioned workflow are demonstrated in the construction of WuFengShan bridge over the Yangtze River, which is located in Zhenjiang, Jiangsu. As shown in Figure 5, the total length of the bridge is about 1416m, and it is a large scale project that should pay much attention to its quality and safety.

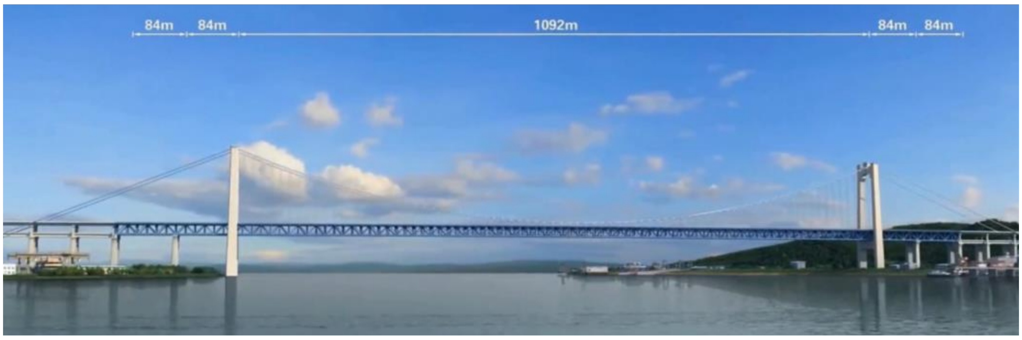
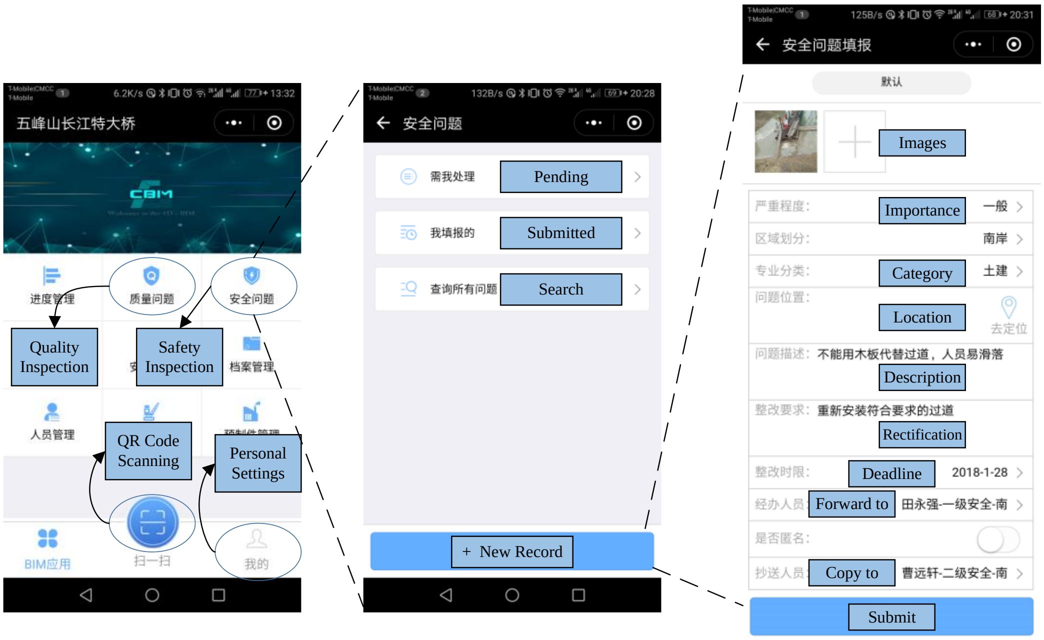


Figure 5. The virtual model of WuFengShan bridge over the Yangtze River

To facilitate construction management of the project, not only the functions for on-site inspection but also the functions for progress tracking, document management, labor management, etc., are developed and adopted for daily management. This research will focus on the part related on-site safety and quality inspection.

In the main interface of developed micro-App, various functions are listed (left part of Figure 6). Users can switch between different projects through personal settings and can touch one of the listed functions to enter its detailed page. If there are QR codes attached to devices, elements, or components in the construction site, it is also possible to scan the QR code, then go directly to related pages. Taking safety inspection as an example, the detailed page has four main menu items (middle part of Figure 6). The above three ones are used to search and track issue records, users can view pending records, or all records he/she submitted, and search all records based on different parameters. The final menu item is for the creation of new inspection records. Once a new safety issue is found during the on-site inspection, the user or inspector can take photos of the issue, and specify importance, location, category, description of the issue, then add users that this issue should be forwarded or copied to in the page for inspection recording(right part of Figure 6). For example, one issue may be submitted to the safety manager and related engineers of other sub-contractors, to remind them to pay more attention to the issue or similar problems. Meanwhile, the manager or the inspector can also add possible requirements and guidance for issue resolving on this page.

Every time the inspection is submitted or updated, corresponding users will receive a message in WeChat notifying them the change of data (left top of Figure 7). Then the user can tap on the message to view the changed record directly or check the statistics of all the data. Basically, the micro-App will create a chart to summarize the status of the inspection records, thus the users can get an overview of the project’s performance (left of Figure 7). When tracking the status of the inspection record, the user can view basic information and related comments and images of the issue. Creation of new comments is also supported when tracking issues. Once the problem is resolved, the engineer who is responsible for this issue can add new photos to reflect the resolved status of the issue, and all the users including the manager can get an intuitive view of what have done to resolve the issue.



严重程度： 一般

区域划分： 南岸

专业分类： 土建

问题位置：

问题描述： 不能用木板代替过道，人员易滑落

整改要求： 重新安装符合要求的过道

整改时限： 2018-1-28

经办人员： 田永强-一级安全-南

是否匿名：

抄送人员： 曹远轩-二级安全-南

Figure 6. Screenshots of safety inspection recording

With more than 6 months' adoption of the proposed framework and developed micro-App, the authors collected quite a few feedbacks based on interviews, and iteratively improve the framework and the micro-App. Except for the above-mentioned benefits of mobile Apps, one advantage of the micro-App is that the users can be promptly notified and start the micro-App more quickly. This is because WeChat is used widely and frequently (Zhang et al., 2017), and always running in the background with good optimization for performance and communication, therefore bringing a good user experience for developed micro-App. Observation of typical scenarios shows that micro-App can provide a similar performance as native Apps. Another benefit is that the users, especially the manager can get an overview of all the reported issues and track the progress of any issue at any time. That is to say, he or she doesn't need to worry about that the issue is left there without any further action or missed. And if possible problem encountered when dealing with the issue, it can also be revealed in time. With abilities for comments and issue forwarding, the users can share their thoughts, ideas, and concerns about the issue, and transfer the issue to proper engineers to resolve it more quickly. Thus, the users can communicate and collaborate with each other in a flexible way. Furthermore, all the inspection data is kept in a database of AliCloud with various APIs exposed, it is easy to incorporate this work with other applications like building information modeling software, GIS tools, and so on.

4. CONCLUSION

Considering complex developing environment and difficulties in attracting and cultivating users, this research introduces a new application framework based on a widely used App – WeChat – to facilitate on-site quality and safety inspection. In accordance with the proposed framework, a relational database schema is designed and general workflow for on-site inspection is summarized, which will benefit other on-site inspection research in the future. By demonstrating the proposed method and developed micro-App in a large scale project, results illustrate various benefits including flexibility in communication and collaboration, work efficiency improvement, easy to learn, and feasible to integrate with other applications, which shows great potential in on-site inspection and construction management.

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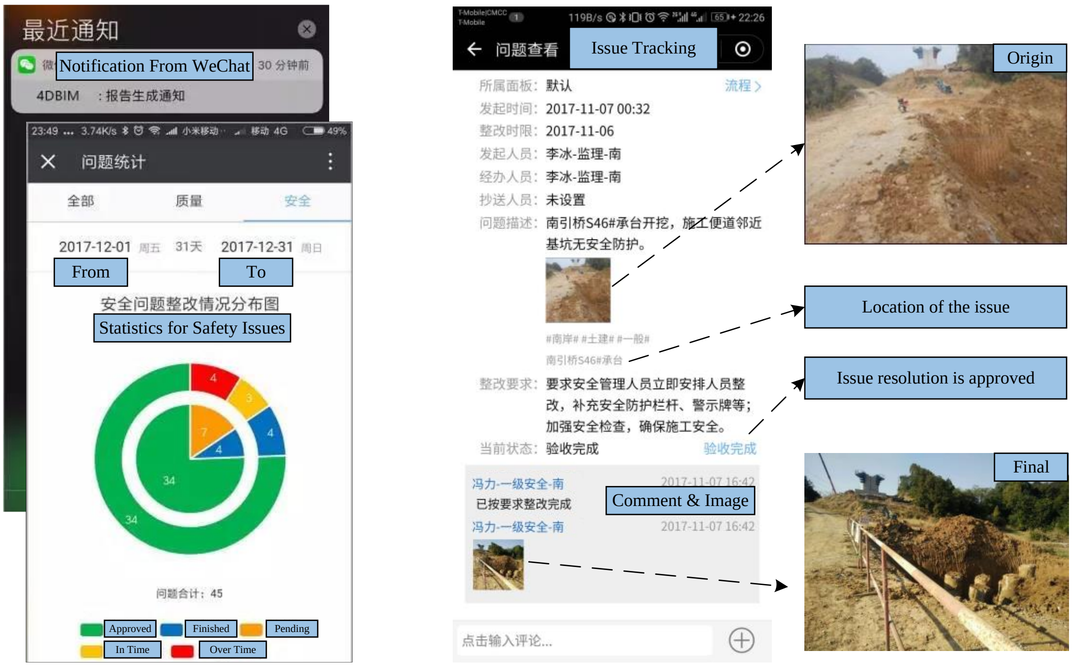

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南引桥S46#承台
整改要求：要求安全管理人员立即安排人员整改，补充安全防护栏杆、警示牌等；加强安全检查，确保施工安全。
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Figure 7. Statistics and tracking of issues

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