Using Web Technologies and Secure Methodologies to Equip Digital Societies with Infrastructure Planning of Smart City Neighborhoods

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Abstract

The purpose of this research is to develop an easy to access online information base of neighborhoods of a particular region, or community in Pakistan which will enable the residents, authorities, and visitors to view deep information about their surroundings. The research for this paper was conducted in two phases, the first being the proper mapping of waterlines, gas connections, pathways, and plot allocation and the second being the development of an online interface to provide as easy access to the information database. This facilitates the locals and the authorities such as water boards, electricity companies and natural gas providers to view this information and communicate at the same frequency with a centralized reference. With further data collection, we aim to incorporate more information so that people become more aware of their surroundings and start to take ownership of their neighborhoods and help with data analytics.

1. Introduction

In today's world, the competency and effectiveness of a developed state is judged by the kind of infrastructure the state holds. Proper plot cutting, organized water, gas and sewage lines contribute to a stable infrastructure of a state or a country. Karachi, the largest city in Pakistan, has grown rapidly over the years. This rapid expansion demands more resources and better infrastructural planning to accommodate the fast population growth. Due to some unfortunate circumstances and lack of planning, the city has experienced a wide range of unregulated infrastructural construction mainly because there was no central state information system to keep track of these changes and handle the demands of mass accommodation. This led to occupation of railway lines by land grabbers, clogging of the drainage systems, deforestation and even shutting down of whole nurseries in favor of creating more accommodation.

Our work handles such state infrastructural kiosks by providing a centralized and automated system powered by latest web technologies which store information about a neighborhood right from the start. [5] discusses a similar kind of approach in the context of smart cities, urban regeneration, and sustainability by integrating Information and Communication Technology (ICT) and the data available of neighborhoods and communities. Every change in the neighborhood is tracked through surveys and the metadata of existing infrastructures is effectively managed inside the system. This system enables the local residents to view their neighborhood's information and helps them with the planning and development of future endeavors in accordance with the existing infrastructure. The centralized system also lets electricity, water, sewage, and gas authorities to easily view the whole neighborhood information and helps in allocating their resources efficiently.

2. Materials and Methods

The approach taken for this research is inspired from [2] where the basis for a software platform was set up to support communities with their data management by extracting structure, exploiting the extracted structure, and maintaining the extracted structures. In Pakistan, the metadata of state infrastructure is isolated to government or private authorities of respective infrastructural entities. There is no cross communication between these authorities which results in an information blackout among them. The planning done by one authority is opaque to the other, which results in high chances of misbalancing the infrastructural design. At the same time, the local residents are also unaware of these plans and are directly affected by the changes made by these authorities without them knowing the consequences. This gap in information availability leads to disturbing the state's infrastructural design which in turn leads to further mismanagement. Furthermore, this mega-city lacks a detailed database about hospitals, clinics, pharmacies, retail shops, schools, etc. The need for a centralized database system is vital so that residents and visitors can search them in accordance with their need.

2.1. Methodology

The first task for our project was to breakdown the

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state-level problem into smaller research problems. For this purpose, the scope was shifted from state-level to community level. The research had two main practical phases. In the initial phase, the sole task was to gather the metadata of the subject community, Gari Khata. Gari Khata is a small area in Saddar Town of Karachi, Pakistan. This was done with the help of local communal authorities in surveying their surroundings. In the second phase, the focus was to practically shape the prototype of solution using web technologies.

2.1.1. Technologies used: Mongo DB was used for storing plot drawings, water lines, gas lines and sewage flow. For server communication, we used Node.js. Ionic 3 was used to develop a data collecting mobile application which the residents and local community managers utilized to easily feed information about their neighborhood. All these technologies were synchronized using the concept of RESTful APIs which was responsible for reflecting all the changes to the metadata database in real-time.

2.1.2 Information gathering: Upon considering a comprehensive guide towards the better form of neighborhood governance and as described by [8], rather than addressing this as a state or government level problem, we started off by visiting the subject community, Gari Khata where a team consisting of around 20 delegates met the community managers of that area. The community managers had manually written down information which included the plot size, plot name and had information about the water, gas, and sewage lines. By communicating with the managers, we took the manual blue prints of the area and generated Scalable Vector Graphics (SVG) files. Our next job was to think of a way these SVG files can be used to have a display on the web portal. For this purpose, we developed an SVG parser in Python which identified the shapes and their coordinates inside the SVG files.

After getting meaningful data from the parser and inspiring by the concept of making use of unstructured data to formulate a structured data as detailed by [3], we developed a JavaScript generating engine in Python which took the data from the parser and automatically generated JavaScript code that could reproduce the visual data using p5.js or Processing thus producing a map that can be displayed on a web portal. Along with Processing, jQuery and Bootstrap were also used for tweaking the shapes. Each shape on the portal represented an infrastructural entity in the real neighborhood. Each shape, when generated, was assigned an auto-generated unique ID to distinguish between the buildings and plots and ensure redundant information is not fed into the system.

Once the development part was done, we pushed our system in the actual environment to test and analyze the system for glitches and real-time changes. For this purpose, we visited the subject community again and asked the residents and community managers to use our data collecting mobile application (see Figure 1) to feed sample data about the community's buildings and plots. The information collection process was a closed process and it was based on certain parameters. In the initial stages of our research, the parameters used for information collection were namely Plot ID, Plot Use, Front Width, Building Name, Official Plot Number, Year of Built, Number of Floors and Each Floor Usage. Based on the above-mentioned parameters, the residents and community managers easily fed the information into the system.

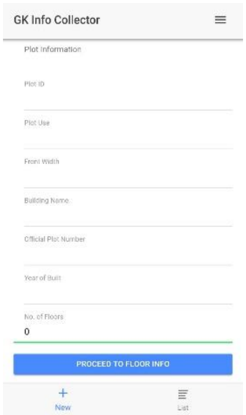

Figure 1. Mobile application for subject community, Gari Khata

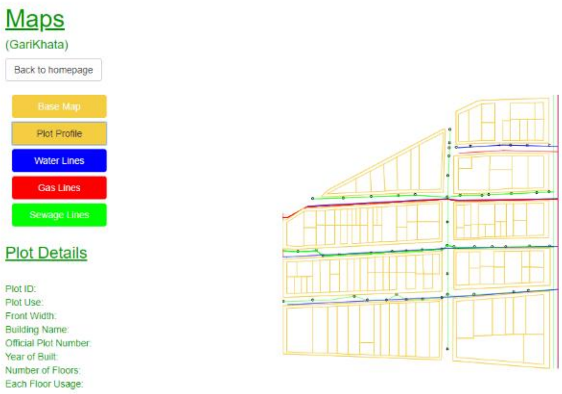

Figure 2. Web portal for subject community, Gari Khata

The next phase was to test the web portal (see Figure 2). The best way to test the portal was to deploy the system in the subject community. After the successful deployment, residents used our mobile application to feed the primary information about the community. Every new entry in the system was being reflected at the main application portal at runtime to entertain better accessibility and facilitation. It was found that the system was showing the information fed by residents and managers on the portal without any redundancy and information wastage.

2.1.3 Further enhancements: After the successful development, testing and deployment of a prototype for the subject community, our next step was to expand our system to other communities. As a result, a thoughtful approach to upgrade the system for generic purposes was observed. During the process, we were able to upgrade our SVG parser and JavaScript generating engine and now the parser can parse the SVG files for community maps and generates a meaningful data which is further used by the efficient JavaScript generating engine to automatically produce JavaScript files for any community, area, or city (see Figure 3).

Figure 3. Layered base map information

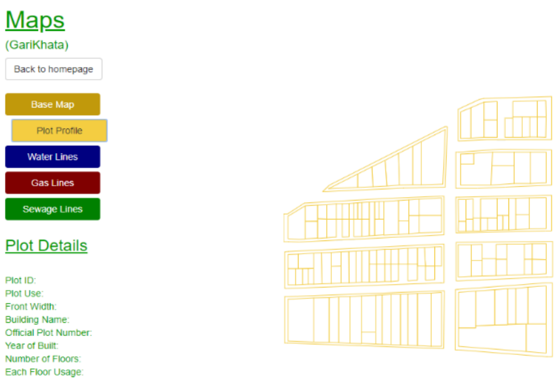

Figure 4. Layered plot profile information

Furthermore, in the case of individual community maps, the JavaScript generating engine automatically detects the area of map and adjusts the scaling factor accordingly along with storing it in the JavaScript files. This is done to maintain a common viewport for each community or locality's maps. Since it comprises of base map, plot profile, water lines, gas lines and sewage lines, the system has been built in layers, i.e., each entity is a separate layer. By turning the various UI buttons on or off on the web interface, the user can view respective layers according to the need as shown in Figure 2.

The information shown on the web portal is in accordance with the data collection done by the local community. The information flow can be accessed by clicking on the plot (see Figure 4) and the portal shows the detailed information about the selected plot. The information viewable on the portal includes the purpose/usage of that plot; for instance, if a plot is commercially used or it is a residential plot, the front width of the plot, the name of the plot, etc. For example, if it is a commercial shop then the name of that shop must be registered on the portal, the official plot number of the selected plot, the information about allotment of that plot; i.e., the year when the selected plot was allotted/built and the number of floors in that plot. Furthermore, the portal also displays the detailed usage of each floor on a particular plot; for instance, if a plot contains three floors (ground plus two) then the user/resident must be able to access the information that what type of work/procedure is followed on each floor (especially in case of commercial plots), whether there is a shop on ground floor, followed by if there is a clinic on first floor, and so on. Our system gives rights to local residents and government authorities to view every information about their locality in a precise and straightforward way.

Our research is a step towards smart city management. As we proceed in our research, we tend to seek the goal of converting the manual metadata maintaining techniques with automated and organized data management system whose primary aim is to allow the community managers and residents to have a detailed view of their locality. The next task which is at the top-most priority, is to track the history of localities right from the beginning. This will help researchers a great deal in understanding the society's growth or decline flow and predict the nature of its development for the future. Our research also opens ways for predictive analyses based on statistical learning from the historic data of a certain locality. We aim to expand this research up to a city or even a country level.

3. Data Security and Access Management

If we look at the system and setup discussed so far, the functionality and flow are well aligned. However, we have not really taken the security and privacy aspects into account yet. In this section, we will see how our system integrates these essential elements to ensure data security, privacy, and protection.

3.1. Importance of data privacy

According to the recent Forbes study, the amount of data produced every day online is in the range of quintillion bytes. We are living in an era where data has become a liability. The more data you have, the more responsibilities you are required to fulfill. The data regulations placed all over the world bound corporates as well as emerging players to comply with certain standards and justify it. The data protection laws, especially GDPR, have placed strict guidelines and procedures to respect the privacy of individuals as well as groups. Those who fail to abide by such regulations are penalized for non-compliance, which may lead to strict legal actions [9].

In our system, even though we have an example and community from Pakistan, which does not have any strict data privacy regulations, but we did not want to limit the general outreach of this research just because of this. The long-term goal is to enable the neighborhoods across the world to deploy a secure and compliant infrastructure planning solution for their locality.

3.2. Integrating privacy measures in data collection and portal access for neighborhoods

The first agenda that we decided in incorporating privacy measures was not to store any PII (Personal Identifiable Information) in our system – apart from the regular in-app credentials (as those are inevitable). This was not just a random decision, in fact, after studying the entire system and foreseeing its prospective usages, we came up to a conclusion that our system does not require those. Apart from role-based access control, none of our system components require any sort of confidential PII. This decision eventually saved us from hoping onto the liability of dealing with potential Data Subject Rights (DSR) requests [13]. Another major advantage that we got for not storing PII was that it saved us from any potential data breach penalization and obligations.

We plan to make our system more compliant with maximum privacy regulations across the world. In the near future, we are headed to creating and maintaining a full-fledged privacy policy for our system that gives a detailed insight to end consumers of how the system deals with data privacy and security.

3.3. Access management

Since the system is divided into two key components, the management of access had to be dealt separately for both of them.

3.3.1. Managing access for data collecting mobile application. As mentioned previously, the scope of current data collecting mobile application is limited to community managers only. The experiential design (not the UI) of the application (see Figure 1) is also developed to cater to that specific user segment only. Hence, it is necessary to place proper access controls so that no person other than the community managers or maintainers can access this application. To ensure first level of access control, we have purposely kept this stage manual in MVP version. We have not made this app publicly available on OS stores; it is only available on request. We manually verified the community maintainers' identities and then installed the application on their devices.

In parallel to this manual step, we created accounts for them in our system with role named CPMMUNITY_MANAGER. This is a key step to allow them the app access. Once the account is created, they can log in to the app, the backend system verifies their access identity based on the role, and allows access to the app. This role-based access ensures that no person other than the community manager can access the data collection app. In future, when we add support of automatic information validation, we can grant role-based and selected access to local residents as well as visitors.

3.3.2. Managing access for portal and maps: Just like we managed the access for data collecting mobile application, we had to ensure a similar sort of behavior on the web portal side as well. The difference here is that no one is restricted to access the portal entirely. Based on the kind of role a person has, certain functionalities within the portal are restricted. If you see Figure 2, it has a full-blown information access including base map, plot profiles, water lines, sewage lines, and gas lines. This is the kind of view that we do not want everyone to access. For instance, the information about water, gas, and sewage lines is completely relevant for community managers and other government authorities, but this information is of no use to local residents or visitors – neither it is recommended to expose this level of granular information to visitors. Hence, the people who have the role of either COMMUNITY_MANAGER or AUTHORITY_PERSONNEL can only access the view in Figure 2.

On the other hand, if someone with the role of RESIDENT or GUEST access the web portal, they will be restricted to access information about water, gas, or sewage lines, but they can still access the base map and plot profiles for navigation and general information outlook (see Figure 3 and Figure 4).

4. Results and Discussion

After the testing and deployment phase, the residents and community managers of Gari Khata started using our product for their community. The users found it appealing to use a web-based community management system rather than maintaining and tracking the Microsoft Excel sheets manually which were being used for quite some time before the introduction of our system. The community showed interest in the future directions of our project and gave us more ideas to incorporate such as census of community which we will add in our next development iteration. When the prototype was deployed on the subject community, the community managers put forth one important aspect which was missing in our system. In our system, the various infrastructure pipelines were just one-time creation of shapes and lacked any further analysis and use-cases. The research provides the most current data but does not provide any information about how any future development might impact the current system or what can be done to further enhance or optimize the current system. Requests like these have started to produce the usage of our system now that the community members have clear information about their surroundings.

This research opens the avenue towards developing solutions for various state/community level problems. Instead of relying on physical copies of metadata, the information can be secured as soft copies over the web which has been a highly effective way to access information as found out by our various surveys.

4.1. Future Milestones

Along with working on the census generating feature, we are also currently working on incorporating those aspects of a locality's surroundings which are often ignored or neglected. One such neglected entity comes in the form of flora and fauna. Currently, there is no existing record base where the information about trees, plants, animals, and insects is stored which is extremely important when it comes to invasive species which can be harmful to the local fauna and flora. In the next phase of our research, we plan to incorporate these environmental aspects by providing a centralized web interface where the information about natural resources in a certain locality is freely available.

Our system is currently quite open and we want to build a methodology that verifies that the submitted information is valid. This is a challenge as the data is gathered by the community and we need to have some measure of trust when acquiring information, but we also need to check the validity of the submitted data.
In the later phases of our research, we aim to modify and upgrade the SVG parser and JavaScript generating engine to display the maps of localities with less hassle of manually generating SVG files using the blueprint snapshots of the locality. This type of smart city management can help in designing new infrastructure in regard to the existing entities with least amount of effort. One of the main and important deliverables of this research come from [6] where they significantly explore the relationship between analysis of existing community data and the plans for new and continuously growing infrastructures. [7] discusses the importance and relevance of development management and development control to organize and entertain the new and demanding infrastructural requirements.

Furthermore, at some point, we want to expand the realm and explore how we can integrate a Blockchain-based solution for better reliability and consistency of data available on the platform. Blockchain and Web3 solutions are gaining a huge tech traction, particularly in the space of smart cities. Based on the confidence that we gained during initial literature review, we are certain that there is a lot of room for improvement and innovation, especially in infrastructural planning for neighborhoods. The current literature talks about developing secure Blockchain based applications [11] for smart cities, exploring the possibilities of opportunities and challenges in incorporating Blockchain technology for smart cities [12]. Our future work will target opportunities and gaps in developing secure Web3 applications for smart neighborhood planning by maintaining a distributed ledger that keeps track of historical data as well.

Apart from that, after this MVP, we want to migrate to cloud infrastructure so that instead of reinventing the wheel for multiple technological solutions, we just focus on the actual problem solving and contribute to the digital society in a better and effective way.

As part of future aspirations, we also want to extend this MVP to a full-blown product for managing smart city neighborhoods. We wish to integrate multiple neighborhoods at a time and figure out efficient communication mechanisms among neighborhoods as well as authorities – and of course, preserving the tourism and visitor aspect at the core.

5. Conclusion

Infrastructural management and planning are primary issues in Pakistan. The global non-serious attitude towards neighborhood and community planning, as discussed by Keating, W.D. and [4], has influenced the infrastructural growth in a serious alarming manner. Due to lack of planning and management, there is no record of legitimate infrastructure entities that the people and the authorities can easily access. This research can help in solving various infrastructure management problems by providing an easy-to-use online web interface. Our research aims to develop an online experience maintained by the people for the people. The information is not limited to specific individuals or authorities but is open to all so that the best decisions can be made with the most critical information at the fingertips.

6. Acknowledgement

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