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Monitoring and Management System Enabling Quasi-Real-Time Information Inquiry of Battery EV Charging Stations in Korea

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ABSTRACT

Due to changes in the automobile market and technology, Korea in the 2020s has entered the era of electric vehicles. However, due to the lack of supply of charging stations for electric vehicles, there is not enough supply of car chargers to the public. In this situation, if electric vehicle drivers are notified of the charging station status information accurately, they can efficiently share and use insufficient numbers of car chargers. The existing electric vehicle charging station information inquiry applications have the disadvantage of limited range and accuracy of information provided to users, such as failing to provide sufficient detailed statistics on chargers owned by each charging station. In this paper, we developed a system that collects the usage status of charging stations in semi-real time and allows users to determine when to charge themselves. Data were collected for several weeks to verify the effectiveness of this system, and an experiment was conducted, and it was verified that it is possible to check the charging station usage status in real time and provide on-time help on selecting one of the most appropriate charging stations based on needs of their users.

Keywords - **Distributed System, Data Management, Inquiry, Open API, Data Collection & Filtering.**

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I. INTRODUCTION

Currently, electric cars are the most popular sort of cars among consumers in the automobile market[1]-[4]. As a result, applications[5]-[8] that can check the status of electric vehicle charging stations have also begun to be released, but most of them can only check simple information such as charging station locations and charger terminals. Among them, there is an application[6] that analyzes the congestion time of each charging station, but there is a problem that it does not sufficiently consider the different types of charger terminals that exist at each charging station and fails to provide accurate statistics enough.

In many cases, different automobile manufacturers may have different charging terminals and charging methods. For this reason, there occurs a problem that not all charging stations can accept charging terminals and methods for all battery-operated electric vehicles. For example, plug-in hybrid electric vehicles cannot be charged at high speed and can only be charged at slow charging stations. In addition, it is difficult to solve this incompatibility with charging adapters because different manufacturers use different terminals and charging methods between battery-operated electric vehicles.

In order to address these important issues, in this paper, we develop a novel monitoring and management system to collect and store electric vehicle charging station and charger information in Korea through the open API provided by KEPCO[9] and, implement a mobile app that maximizes user convenience and quasi-real-time accuracy by offering a variety of useful features such as charging station information inquiry and search using data analyzed for each charger in the system[10].

II. RELATED WORK

2.1 Development tools

In this paper, applications, servers, and data collectors were developed using the following development tools. The first tool, React Native[11], is a framework that supports the development of native apps in cross-mobile platform environments with React[12], a web front-end JavaScript library. The framework is basically aiming for single page application(SPA) and has several features such as virtual document object model(DOM), component-oriented development method, and state management, providing high development productivity. It is designed to automatically convert a React Native code into a customized user interface according to the type of smartphone operating system. In addition, to configure basic app environments, we use Redux, a state management library, React Native Navigation, which manages routing and navigation of React apps, Native Base, a design library, and Expo, an app distribution framework.

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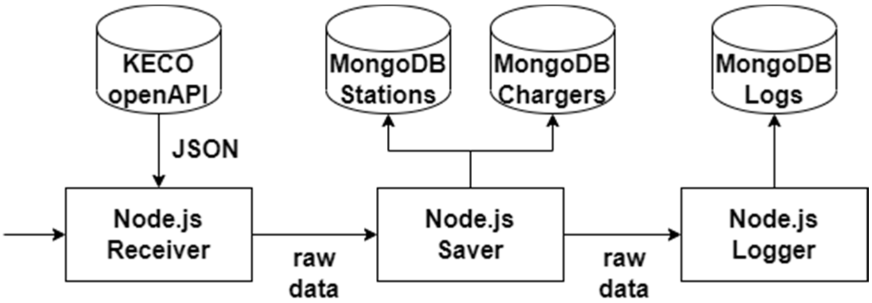

Fig. 1: Data Management System

For rapid development, we use the react-native-maps library[13] developed by Airbnb that facilitates the connection of Google Maps APIs in React Native environments. The library enables most operations related to the map, such as touch feedback, manipulation of the map using GPS values, checking the boundary coordinates of the screen, and displaying charging station locations. We also developed servers, data collectors and fast and web applications with RESTful APIs using Node.js and Express.js[14].

Since the system developed in this paper must be implemented as a quasi-real-time service, frequent large-scale data update and inquiry operations must be performed. To meet this purpose, MongoDB[15] that easily provides the bulk transmission function, and Mongoose.js[16], a library connecting Node.js and MongoDB, are used. In particular, the developed system that shares large-scale real-time charging station data is built in the form of a cloud-based MongoDB cluster in consideration of operating environmental characteristics.

2.2 Comparison with existing applications

evmodu[5], elecvery[6], EV Infra[7], and KEPCO PLUG[8] are the representative applications that provide their own services stably among electric vehicle charging station inquiry ones released in Korea. All of these applications provide their own services based on maps and have common features such as information inquiry, filtering, search, and community functions. Given that electric vehicle drivers strongly hope to charge where they usually stay [18], providing statistical data on the use of chargers through the app will be of great help to car charging plans. However, the existing systems don't have sufficient functional capability to provide such statistical data-based quasi-real-time charger information with high accuracy.

III. THE DEVELOPED SYSTEM

3.1. The Overall System Architecture

The system consists of three subsystems: data collector, information management server, inquiry app. The data collector is a subsystem that automatically collects and filters the charging station and charger information and charger usage log data required for users from the open API provided by KEPCO, and structures them to facilitate fast inquiry. The inquiry app. is a subsystem that maximizes user friendliness so that users with their mobile devices can quickly, accurately, and intuitively obtain various charging station-related real-time information from the server.

3.2. Data Collection and Filtering

Data collection and filtering subsystem is developed with Node.js to collect information on electric vehicle charging stations distributed across the country using the open API like in Fig. 1. The open API provides 130,000 charging stations and charger information nationwide in real time. Like in Fig. 2 and 3, each information provided by the API server includes the name, ID, address, GPS location, available time, operating information and parking fees of each charging station and its charger ID, charger type, charger status, status update date and time, last charging start date, last charging end date and time, features (capacity, method, terminal, etc.), and usage restrictions. Charger usage information organized from repeated data collection and update processes is very suitable for use as statistical data and is used when implementing the function to efficiently use the charging station, one of the primary modules of the development system.

Fig. 2: Charging Station Data

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```
{
  "_id": "ME00010201",
  "chgerId": "01",
  "chgerType": "06",
  "lastTedt": "20220811111543",
  "lastTsdt": "20220811111543",
  "method": "단독",
  "nowTsdt": "",
  "output": "50",
  "stat": "9",
  "statId": "ME000102",
  "statNm": "농소2동 주민센터",
  "statUpdDt": "20220811124810"
}
```


Fig. 3: Charger Data

For this purpose, it may be developed to automatically analyze charger data and create statistical data by continuously accumulating raw data without deleting the collected information. However, with 130,000 charger data obtained per collection cycle, if this process is continuously repeated, there may occur a critical problem that a lot of data accumulated cannot be managed by the system within a short period of time. To solve this problem, this paper devises the following efficient method. In general, most electric vehicle drivers want to charge at similar places according to their regular time plan. First, if you find an electric vehicle charging station in the parking space, you want to charge your own car to prevent future charging stress even if the car battery is somewhat charged. Second, the driver hopes to charge the electric car for as long as possible once it is charged. Third, drivers hope to charge in places where they have to park their cars for a long time, such as at work, home, or commercial facilities, during their daily lives[19]. This means that drivers will only use certain charging stations. In other words, it also means that there are certain people who often use a particular set of charging stations[20]. Putting these reasons together, it is very likely that similar people will always use electric vehicle charging stations regularly at similar times. Therefore, statistics on the use of real-time usage information and congestion of charging stations and chargers by day and time can be very convenient and time-saving for users to plan for charging.

It is necessary to create statistical data on when the charging stations of interest are in use with a small capacity data storage, and since each charger may have different types, a weekly log of the charger should be collected, not based on the charging station. In the development system, a log of charging station ID, charger ID, parking, and use by day/hour of the week can be generated on a weekly basis like in Fig. 4, and data distortion due to data accumulated in the long term can be prevented by requiring only statistics for the last five weeks. If the log data for statistics are created, they will be comprehensively used in the charging station inquiry application to be described later.


```
{
  "_id": "202236ME00010201",
  "chgerId": "01",
  "logs": {
    "mon": {…},
    "tue": {…},
    "wed": {…},
    "thu": {…},
    "fri": {…},
    "sat": {…},
    "sun": {…}
  },
  "region": "울산광역시",
  "statId": "ME000102",
  "week": "202236"
}
```


Fig. 4: Charger Usage Log

3.3. Inquiry App and Information Management Server

Using the charging station and charger information collected in real-time and charger usage log data described above, an electric vehicle charging station inquiry app and an information management server are implemented. This app is developed using React Native, Redux, Native Base, and Expo, and the management server is built using Node.js, Express.js, and Mongoose. The server receives the requested data from the MongoDB cluster server described above and provides it to the app. The app has a map-based charging station inquiry function using the Google Map API, searching for requested charging station data from the server and drawing a marker on the map indicating the location of each charging station. If the data of 30,000 charging stations nationwide are displayed on the map at once, the app performance is extremely degraded due to the lack of resources of the smartphone. In addition, there is a problem that too many markers are drawn on the map, making it impossible to properly examine the map like in Fig. 5.

To solve this problem, we develop a Map Marker clustering algorithm. The Google Map API provides the GPS value of the center of the current map and also provides the delta values for each latitude and longitude. Using them, it is possible to know the GPS coordinates to the current smartphone display boundary, so only information on charging stations within the current display boundary is inquired to the server to draw markers of those charging stations. It is optimized in a way that only a small number of markers are provided by accurately requesting only the range within the screen that the user is currently viewing. However, if the user shrinks the map too much, there occur a problem that the entire country enters the display and eventually requests nationwide data. Therefore, the problem is solved by accepting requests only when the delta values of latitude and longitude are 0.13 or less.

When displayed on a map data on charging stations obtained in this way, it can be used together with data on chargers owned by each charging station to express their usage status in color based on Table 1 like Fig. 6.

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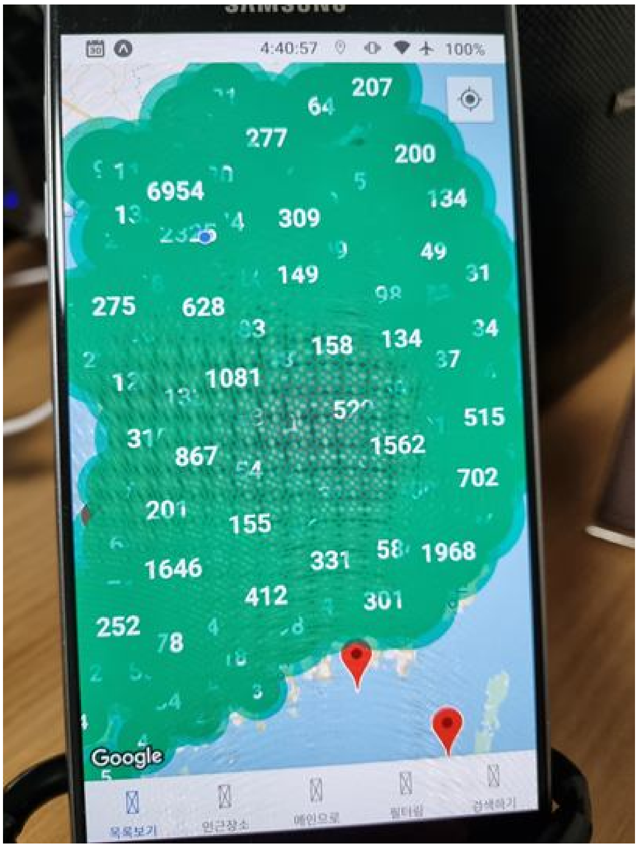

Fig. 5: Marker rendering when delta values are too large

Table 1: Marker Color Configuration Based on Utilization Rate and Availability Status

Description	Color
Error	Gray
Not Available	Red
Utilization Rate ≥ 50%	Yellow
Utilization Rate < 50%	Green

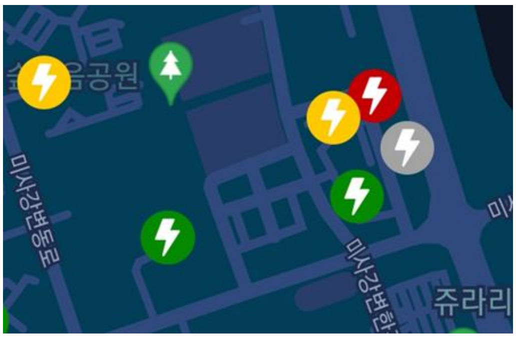

Fig. 6: Marker Color Representation based on Table 1

In addition, by providing statistics on the use of chargers for each charging station drawn on the map, users can see the degree of congestion of chargers by day and time of the week at specific charging stations like in Fig. 7. Users can quickly and conveniently set up their charging plans based on this information and reduce congestion between charging stations.

Fig. 7: Degree of Congestion Visualization

The system not only provides data on local charging stations corresponding to the screen the user is currently viewing, but also implements a dynamic search function that allows users to search for charging stations in real time on a national scale. If a user clicks on a charging station listed in the search box, it is possible to immediately move the screen to the relevant area, and whenever a character is entered in the search box, the corresponding charging station information is repeatedly searched from the server, and the result is obtained and provided as a list. However, if the user enters the text at a very high speed and the search operation requested according to the previous text input is not completed, it sends a stop signal not to execute the old operation and makes the new operation begin to be performed.

IV. IMPLEMENTATION

4.1. Data Collection and Filtering Functionality

By connecting Node.js to the open API provided by KEPCO, the collection and filtering server automatically and infinitely performs the entire process without operator intervention as shown in Fig. 8. It is implemented to store the raw data received from the API separately into charging station and charger data, and to leave the status information of the charger in use as a log.

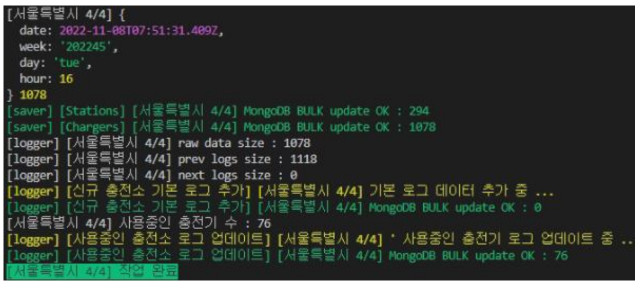
[서울특별시 4/4] {
  date: 2022-11-08T07:51:31.409Z,
  week: '202245',
  day: 'tue',
  hour: 16
} 1078
[saver] [Stations] [서울특별시 4/4] MongoDB BULK update OK : 294
[saver] [Chargers] [서울특별시 4/4] MongoDB BULK update OK : 1078
[logger] [서울특별시 4/4] raw data size : 1078
[logger] [서울특별시 4/4] prev logs size : 1118
[logger] [서울특별시 4/4] next logs size : 0
[logger] [신규 충전소 기본 로그 추가] [서울특별시 4/4] 기본 로그 데이터 추가 중 ...
[logger] [신규 충전소 기본 로그 추가] [서울특별시 4/4] MongoDB BULK update OK : 0
[서울특별시 4/4] 사용중인 충전기 수 : 76
[logger] [사용중인 충전소 로그 업데이트] [서울특별시 4/4] ' 사용중인 충전기 로그 업데이트 중 ..
[logger] [사용중인 충전소 로그 업데이트] [서울특별시 4/4] MongoDB BULK update OK : 76
[서울특별시 4/4] 작업 완료

Fig. 8: Data Management System

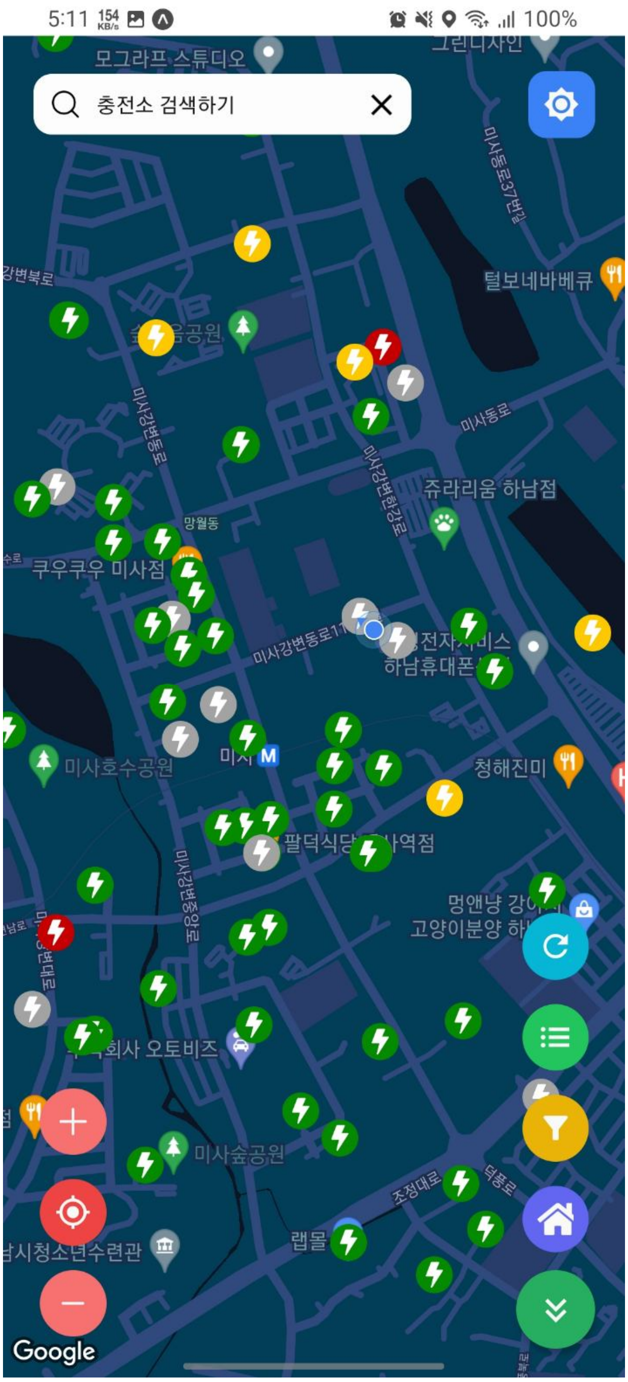

Fig. 9: Charging Station Map in App.

4.2. Inquiry Capability

Users want information about specific charging stations displayed on the map. By clicking on one of the markers of the charging stations displayed on the map like in Fig. 9, you can briefly inquire not only the name, address, operating institution, and operating time of the corresponding charging station, but also the status information of the chargers in the station. Markers basically make it possible to fast recognize congestion level by color. Also, users can view the available time, contact information of operating agencies, parking fees, user restrictions, and usage analysis data as detailed information for each charging station, and inquire about the list of chargers owned by the charging station and the status information for each charger like in Fig. 10 and 11. In particular, by referring to the analysis data on the use of charging stations, users can minimize charging time and cost by recognizing the usage patterns of the charging stations they usually visit.

Fig. 10: Charging Station Info. and Analysis Results

Especially, like in the lower part of Fig. 10, the app provides the usage statistics of a specific charging station selected, which means that the darker the color, the more frequently it was used during the corresponding time of the day. In addition, you can also look at the usage data of the charger by selecting the area to check the status of individual chargers as shown in the upper part of Fig. 11. If the searched charging station is crowded, the function is also implemented to check information on all charging stations within 300m in real time and provide it as a list like in the lower part of this figure, allowing users to choose where to go right away if charging is urgent.

When you click on the charging station map, a bar for searching for a charging station appears, and you can use it to immediately search for the desired charging station like in Fig. 12. Selecting one of the searched charging stations, you go to the inquiry screen for that charging station.

Both PHEV and BEV have limited chargers that can be used by each manufacturer. In addition, due to the charging station payment plan subscribed for each user, he or she may want to use only the charging stations that can be paid for charging with the plan. Therefore, it is not necessary to provide information on any chargers that are not related to the user's vehicle to the app user, and thus a charger filtering function as shown in Fig. 13 is implemented.

Fig. 11: Charger Usage Details & Alternative Stations

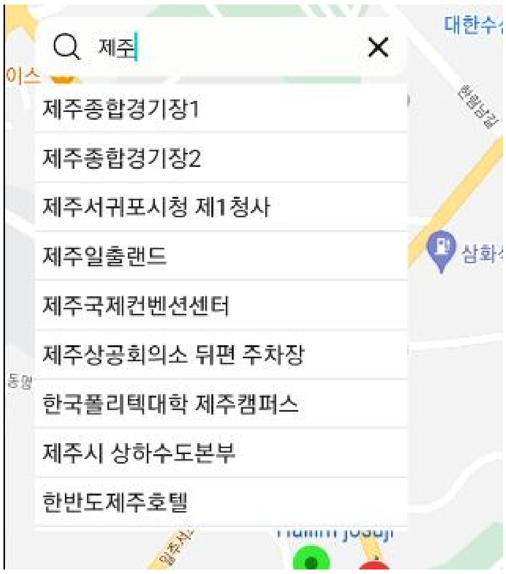

Fig. 12: Illustration of Dynamic Search

Fig. 13: Charger Filtering Options Menu

V. CONCLUSION

In this paper, an integrated system was developed to facilitate the user's convenient use of charging stations by providing detailed records of the use of electric vehicle charging stations and chargers. The various solutions developed in this paper confirmed that users can conveniently check information on electric vehicle charging stations within the desired time by enabling the latest information to be updated in a quasi-real-time manner, despite a large number of charging stations and charger data collected at once. Additionally, the filter developed to address heterogeneity of charging terminals and charging methods between automobile manufacturers

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provides a function for inquiring about electric vehicle charging stations with charging terminals suitable for the user's vehicle and preferred charging methods. Moreover, users can check additional useful information regarding whether or not to use chargers and the degree of their usage congestion by day and time zone based on the data collected by KEPCO, quickly determining the time available for charging stations.

For future work, we plan to implement a new authentication and authorization mechanism to greatly enhance security in an efficient manner[21][22] and apply it to the system developed in this paper.

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