A Real-time GIS to Improve the Survival of Sudden Cardiac Arrest Outside Hospitals

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Abstract

In this paper, we study a real time GIS system for Sudden Cardiac Arrest (SCA) rescue outside hospital. This system employs mobile devices to find the quickest available rescue for the SCA victims outside hospitals. We improve the existing system using OpenStreetMap Route Services (ORS) and propose a real time optimizing algorithm that can reduce the time to patient and bring the Automated External Defibrillators (AEDs) before EMS arrives.

Keywords: Real time GIS, Automatic Routing, and Optimization

1 Introduction

Sudden Cardiac Arrest (SCA) is a sudden loss of blood flow because of the failure of heart to effectively pump. SCA causes around 20% of all deaths in Europe. In the United States, SCA outside hospital occurs in about 13 per 10,000 people per year (326,000 cases). It is deadly within minutes if left untreated and survival rates are just 5–20% (Benjamin et al. 2018). SCA is a life-threatening condition, but it can be treated successfully with CPR, defibrillation, advanced cardiac life support, and mild therapeutic hypothermia. When bystanders intervene immediately by giving CPR and using automated external defibrillators (AEDs) before EMS arrives, survival rates increase from an average of 10% to 50%. It is critical to send the rescue with AED to the SCA patient as quick as possible.

Along with the widespread of mobile devices, it is increasingly possible to find out the closest rescuer with the nearby AED. In Sweden, an SMS Lifeguard is developed based on short messages to improve the rescue of SCA. It is a system for alerting volunteer lifeguards to a suspicious cardiac arrest. Since 2010, the system has been used for a research project in Stockholm County. The results of the research showed that when voluntary lifeguards were alerted by SMS, the proportion of cardiovascular resuscitation increased by more than 50% (LuceCaputo et al. 2017).

In 2015, a technology development was launched and the SMS Lifeguard system is now based on a mobile application downloaded to the user's mobile phone. SMS Lifeguard system now uses GPS technology to position the volunteers, making it faster and more accurate. The new technology solution also enables data from Sweden's Heartstart Register to be incorporated into the app.

Since the summer of 2015, the new app has been used in Stockholm for a continued scientific evaluation of volunteer lifeguards, in addition to performing heart lung rescue, may also be called upon to fetch cardiac arrestors. In October 2016, the project was also extended to Västra Götaland. According to the history static data of latest two years, it is indicated that the SMS Lifeguard has saved a lot of people.

In this paper, we first introduce the existing SCA rescue system in Sweden and report its spatial temporal analysis from 2015-2017. Based on the current situation, a real-time GIS system is designed to improve the volunteer selection and AED retrieve based on the Open Route Services. Finally, a dynamic interactive system is designed to correspond the real-time replies from the volunteers.

2 Methodology

Currently the existing SCA rescue system in Sweden has integrated the digital map and GPS information. However, the user selection and helper assignments are mainly based on Euclid distance that do not consider about the accessibility information such as water or high speed road segmentation. To improve the SCA rescue response time, we introduce the dynamic routing service and optimize the assignment allocation strategy.

Accurate estimating the transportation time from helpers to patient is essential to reduce the SCA rescue time. However the existing road network is complex and changing dynamically along the development of city infrastructure. Therefore, it is not accurate to calculate the distance based on static road map. Meanwhile continually updating and maintains the road network is also too costly for the SCA system. In this paper, OpenRouteService (ORS) is selected for transport time estimation. ORS is developed by University of Heidelberg GIScience (Geoinformatics) Research Group. It supplies the route services based on the Openstreetmap (OSM) which is continually updated by millions of volunteers. In ORS, five types of services are supplied directions, time-distance matrix, geocoding, location and isochrones. In this paper, we first apply the isochrones analysis to select the active helpers in a distance from the patient with certain travel time, and then the time-distance matrix between the candidate helpers to patient is requested from ORS. Besides directly find the helpers near the patient, it is also necessary to guide the helper to fetch the Automated External Defibrillator (AED) for SCA. The distance matrix from candidate helpers to nearby AEDs is also required from the ORS. Therefore, in total, one isolations and three time-distance matrix services (helper-patient, helper-AED and AED-patient) are requested for assignments optimization. According to our tests, four ORS requests can take up to half minutes (related to the selected number of helpers, AEDs), while it can save several minutes after the optimization which is essential for the success treatment of SCA.

Assignments optimization. To optimize the allocation of assignments for nearby helpers, we first select the top five helpers with minimum time to the patient. For AED fetching, the time is calculated by adding helper to AED and AED to patient. Sometimes AEDs are located inside the buildings which could not open or not accessible during certain time, e.g. off work hours, weekend or holiday. These unviable AEDs will be flitted. When a helper is on both lists (top N minimum time to patient and minimum sum time to AED-patient), the helper will be assigned to fetch AED unless he/she is the top 1 minimum time to patient, since AED can effectively increase the success of rescue.

System integration. Currently we run our framework independently from the existing system. A parallel processing is evoked when a SAC call comes in. The analysis results will be sent to the corresponding helpers to guide their rescue missions

3 Results

Currently, the existing system has running over two years. Every month, around 150 calls are received as shown in Figure 1. For each call, less than 20 registered volunteers nearby are selected to help the patient. Figure 2 indicates the joint distribution of number of assignments and acceptance to help.

Figure 1: Number of calls by month.

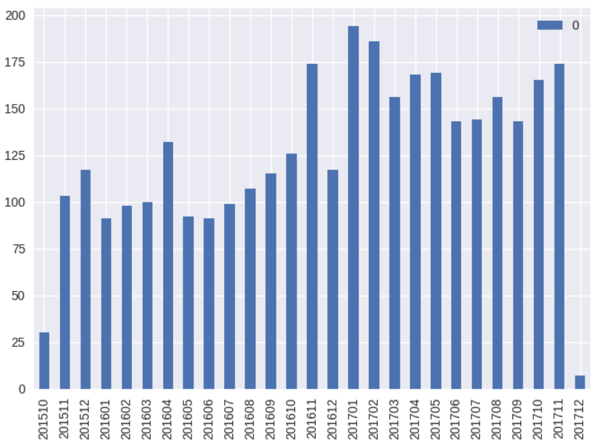
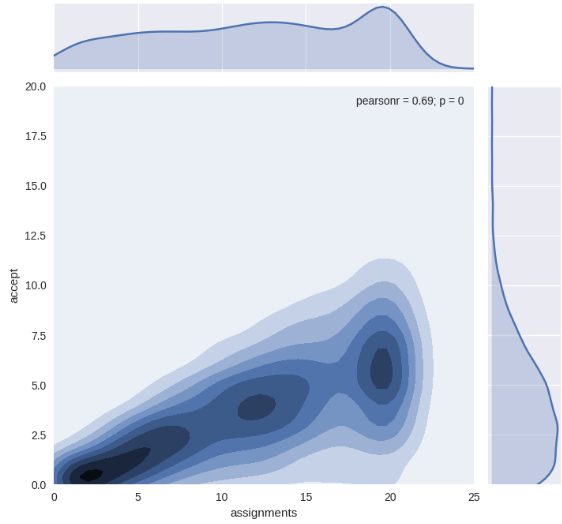
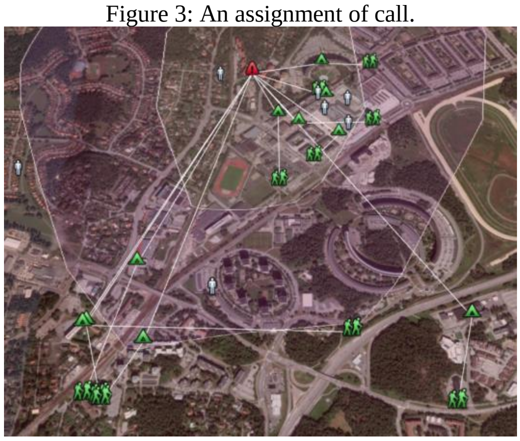


Figure 2: Distribution of assignments and accepted numbers.



In each call, the accepted volunteers are divided into two groups: rescue patient and retrieve AED as shown in Figure 3. However, currently the system is not well optimized to minimize the arriving time of AEDs. Meanwhile the availability of AEDs such as accessible time in buildings or number of floors should be taken into considerations. In this paper, the Open Router Serve is employed to improve the distance estimation and volunteers/AED selection for faster retrieving.

Figure 3: An assignment of call.



Usually, the SCA rescue is performed by multiple volunteers, it will be more efficient if real-time communications are performed among the system and volunteers. Therefore, we designed a dynamic situation evaluation and interaction system based on data mining algorithms and it can learn from the historic data and improve its efficiency iteratively.

4 Conclusions

In this paper, we will explore the ability of real-time GIS for smart city management in emergency correspondence. The simulations results indicate that the proposed framework can effective improve the existing system. After certain system adjustment, the proposed methods will be employed in the real system. Furthermore, the designed dynamic routing and decision making system can be adjusted and extended in other applications.

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