CLOUD BASED MEDICAL PATIENT TRACKING SYSTEM (MPTS) FOR MULTIPLE SIMULTANEOUS RUNNING EVENTS

Siniša Malinović[1]*,
Zora Konjović[2]

[1]RationaleTech,
Novi Sad, Serbia

[2]Singidunum University,
Belgrade, Serbia

Abstract:

Approximately two million people participate in long-distance running races in the United States annually. During marathons, the incident rate is significantly high - 1,01 per 100.000 runners experience cardiac arrest. Reports of race-related cardiac arrests have generated concern about the safety of this activity and the industry in general. The Race Associated Cardiac Arrest Event Registry (RACER) aims to address these issues. The registry collected data from the most recent decade of long-distance running races to determine the incidence, clinical profile, and cardiac arrest outcomes in these events. Ultimately, the system is supposed to provide real time medical information about runners to attending doctors in case of emergency. This paper presents a cloud-based medical patient tracking system (MTPS) to provide real-time medical information about runners to attending doctors in case of emergency.

Keywords:

Cardiac Arrest, Marathons, Patient Tracking.

INTRODUCTION

Big sports events, in general, have a problem monitoring the overall medical situation of events, either in case of emergency or in regular situations. Organizers of such events must be aware of the real time medical status (situational awareness) of all potential patients and medical infrastructure (medical tents, aid stations along the course, EMS – Emergency Medical Service vehicles or transportation to hospitals). [1]

MPTS system architecture proposed in this paper, relying upon the RACER registry [2] , extends the functionality of medical data acquisition to the real-time tracking of medical facilities and critical data on the race event day (medical bed occupancy, number of runners with medical problems and their diagnoses). The proposed MPTS solution shall provide the event organizers with the ability to:

Correspondence:
Siniša Malinović

e-mail:
sinisa@rationaletech.com

DOI: 10.15308/Sinteza-2022-256-261

1. respond to an acute medical event (notify nearest Automated Defibrillator (AED) certified medical volunteer),
2. find patients in treatment at medical facilities along the course,
3. overview of cumulative patient treatments,
4. manage medical volunteers and provide medical licenses background checks.

The original contribution of this paper is the software architecture of the MPTS system designed and optimized for multiple simultaneous running events. The software implementation based on this architecture is already used by numerous running event organizers worldwide.

The proposed architecture is designed to respond to follow major challenges:

1. Provide a comprehensive and intuitive user interface (UI) for medical volunteers without training or minimal training.
2. Support secure medical data governance and medical volunteers' licenses background checks.
3. Ability to provide accurate and real-time data regarding the medical situation at the race (Medical tracking).
4. Prevent system overloading when there are simultaneous running-races events.
5. System reliability and availability in an environment with limited network infrastructure and low bandwidth.

2. EXISTING SOLUTIONS

The patient tracking systems often play a critical role in incidents to facilitate real-time situation awareness, information management, and communication. There are various approaches to solve the above challenges.

Visibility of patient whereabouts for providers and incident commanders across the incident, and certainly the hospital staff, is non-existent after EMS triage, treatment or transportation. Long-term documentation of patient tracking is also problematic with paper-based solutions. This was caused due to EMS's inability to provide an adequate unique identifier to the patient (a barcode or triage card was not suitable). [3] The suggested solution is to utilize a patient's face as an identifying feature.

This approach was interesting but, in our solution overwhelming since runners are already equipped with a unique identifier – their race number (BIB), which is used in our solution.

Some of the information systems did not optimally support incidents. Organizers found challenges with an unidentified patient naming convention, real-time situational awareness of patient location, and documentation of assessments, orders, and procedures.

One solution was to track RFID technology for tracking runners' location and medical facilities utilization. At most events, runners have an RFID tag in their race number (BIB). The systems use RFID technology to perform various tasks: locate patients in different areas and measure patient care times and waiting times.

However, the limitation of this approach was the low quality of acquired medical data. Plane number of injured runners and their location on the course is not enough information for medical directors to make a decision. Information about diagnoses, complaints and treatments could provide more insights, better situational awareness for organizers and support a decision if an event should be cancelled, for instance.

3. SYSTEM REQUIREMENTS

The whole system must fulfil the following base requirement regarding handling runner medical records and providing critical medical information.

The system is expected to be secure in dealing with runners' personal medical information and to be compliant with the healthcare data governance guide. In order to protect injured runners' data and medical records, MPTS keeps all communication between central servers and field devices over secured connections and all data located either on servers or mobile devices at medical facilities is also encrypted. Additionally, anonymization takes place on all medical data on mobile devices, and such data is stored on secured data storage.

The system must be reliable. To address the problem of reliability, we introduced the cloud computing concept and system disconnected functionality. The system is supposed to be fully functional in disconnected mode as it is in connected mode. In case mobile tablets in the field do not have access to the event network, all collected data is stored locally in the device, and it is synchronised as soon as a network connection is established again.

The system is scalable and flexible. MPTS must be configurable and able to adapt to each event's specific requirements. Configuration parameters depend on the event size and type, as well as base system parameters (patient diagnoses, complaints, weather information, attending doctors, number of medical units).

The system is designed to be open and implement an API to provide a way to collect patient data for remote locations regardless of the existing mobile platform (tablets, smartphones, laptops). Since data is synced with the central server in real time, the system can provide info about each medical unit's work overload. Information like this helps event medical service in better medical staff management.

Thus, MPTS will become a central repository of all runners running and medical data that could be used in an emergency.

4. FUNCTIONALITY OVERVIEW

MPTS system provides a real-case solution to automate the processes of:

1. acquire runner relevant medical information before the event,
2. collecting real time runners' medical information on the event day
3. reporting, alerting and notifying about the medical situation on the event day
4. processing, analysis and archiving of those data after the event
5. assists with medical volunteer staffing

MPTS is developed to collect information about patient location, admittance and discharging information and other important medical information from each medical unit (tent, aid station, EMS…) and sync that data with a central system. On the event day, this information is collected through mobile devices.

Real-world applications which are in usage at the moment use Android tablets since their size, weight and screen resolution appears to be the best for medical staff in the field.

On the event side, MPTS provides additional modules:

1. Family Reunion module where family members will be able to get the runner's whereabouts according to the BIB# or runner description. This application could be used by Red Cross staff.
2. EMS module - for tracking EMS vehicles' current status.

Long retention of the patient in each medical unit is also reported. Depending on the time period, the system will send alerts or warnings to a predefined list of event staff.

The central system provides support for two-way communication with medical staff in medical facilities, real time reporting to the event management about all medical parameters (beds occupancy, admitted participant per hour, frequency of diagnoses and complaints,) and notifying and alerting.

Data archiving is performed after the event. The system processes, organizes and synchronizes all event medical information in a central repository. Data stored: runners medical info captured during the event, all needed medical infrastructure - physician, medical staff, medical tents.

Thus, stored data present the medical history of each event, and it could be used for better and faster event organization in the future.

All collected medical data about the runner will be kept as a runner's medical history, which will be available in further events in case of emergency only with the runners' explicit permission.

In order to provide better medical support for the event, MPTS has defined pre-event, event day and post-event procedures:

1. pre-event procedures define event setup and all needed steps to prepare the system to be fully functional on event day. Pre-event procedure implies defining medical infrastructure - medical units, staff, doctors, translators, and other medical related info. In this step event medical history could be used.
2. Event-day procedures cover exact steps for emergency situations: runners checking in, checking out, transferring and transporting.
3. Post-event procedures contain steps that lead to the closure of medical units, data processing, archiving and reporting. [3]

Using the MPTS system, race organizers can understand participants' medical conditions throughout an event based on real-time visualization. MPTS data analysis has the potential to contribute to expanding knowledge on medical care at marathons and large endurance events and to improving resource allocation until predictive models are developed and validated. [4]

The central system is implemented as a web application developed in Microsoft .Net technology with an SQL database as storage in the background.

5. MPTS CLOUD ARCHITECTURE

5.1. ARCHITECTURE OVERVIEW

Relevant medical information is data provided by runners in the pre-event period and medical information collected about the runner during previous and current events. During event registration, runners should submit their medical records and other information estimated as useful in case of an emergency. The solution should provide for a bi-directional information flow. Thus, in case of an emergency, patients' relevant medical information is available to the operating doctor in real time at the event location.

From the system's business logic point of view, medical information is tracked across two main processes. The Medical process provides key data points: patients who required hospital transport, patients in treatment at medical facilities along the course, and cumulative patient treatments. Medical Tracking is responsible for providing data on the number of current patients, the overall utilization of beds, and the total number of patients seen for each medical location.

Since the majority of events take place on weekends and there are events varying in sizes that, in addition, can take place simultaneously across wide geographic areas, the system's workload experience differs temporally (picks are expected during weekends) and raises the issue of distributed data management.

Finally, the true value of the system proves itself in the case of an emergency, which requires the system to be available at any moment of the event - so a backup system must be ready in the case of the main system failure.

Having had all this in mind, we decided to accept a cloud computing architecture for MTPS. This approach allows us to create a scalable system that can process large amounts of distributed data but also can dynamically re-allocate resources as per demand (downgrade during idle periods).

The cloud system allows traffic segmentation and, in general, the ability to distribute traffic over multiple nodes. Traffic can be segmented by location (by event), pre-assigned criteria (user ID, specific IPs,) or load balancer. Cloud architecture is good for the provision of functionality that addresses the problem of collecting real time medical information during the event from the field.

The proposed solution consists of server-side modules and a mobile application. Mobile application is used by volunteers in medical facilities for collecting injured runners' medical data. A server-side application is used for storing and analysing collected medical data, and generating reports, alerts and notifications. Figure 1 depicts the proposed system architecture.

The system design strictly obeys a single responsibility principle: each component implements one set of functionally related features with no overlapping. Such design allows system functionality to be easily spread across different nodes, locations, and networks - so each function has the best chance to survive the failure of a specific server. In case of simultaneous events and large data load, the number of all components can easily be increased, thus contributing to system scalability.

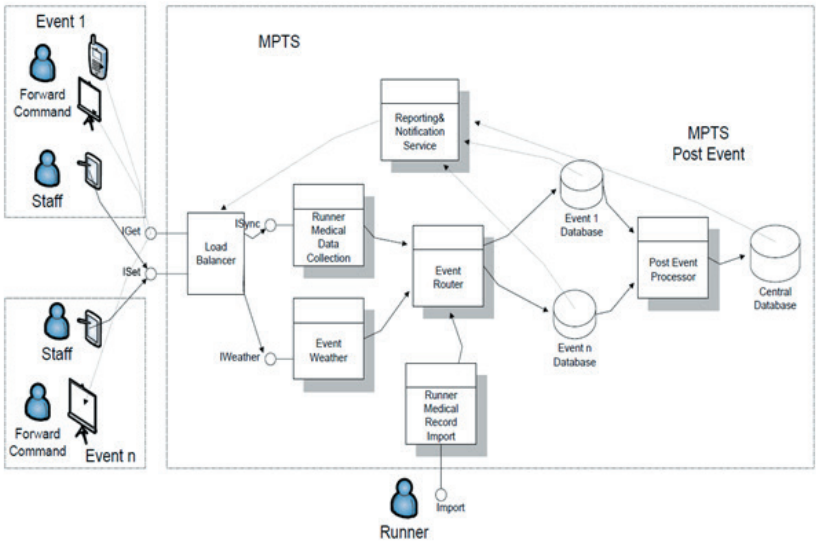

Figure 1 - MPTS Modules

5.2. MODULE'S OVERVIEW

MPTS consists of multiple modules (services) whose functionality is described below.

Runner Medical Data Collection module is designed to collect all medical information on event day. Depending on event size and system workload, the system could be configured to have multiple Data Collection components. This module communicates with mobile applications and synchronizes all the data collected in medical facilities and along the course.

For each medical treatment following data are gathered: runner details, exact time of check-in, complaints and final diagnoses. All details of medical treatment and further transportation are also kept. Figure 2 shows the MTPS medical questionnaire UI.

Event Weather module tracks exact weather conditions on event day. The medical situation at the event is dependent on weather conditions at the course. MPTS is also collecting parameters from third party services which provide accurate weather conditions on event day (temperature, humidity, wind speed…). Weather condition data will be part of various weather-dependent prediction models in future.

Event Router module routes collected medical information into the event's database. Collected information is kept in a separate database for each event.

The processor module processes all collected medical data after the event is finished, and all medical units are closed. Processing is done offline, and collected data is exported from the Event database to the Central Database.

Central Database is a central repository that stores medical information related to all events (i.e., list of diagnoses, runners' complaints, ...). It is also archiving all events' medical history and runners' medical info.

Event specific databases are relational databases that store all event-related medical information history.

Reporting & Notification module provides real time information on the event side, such as bed occupancy in medical units, patient medical information, etc. It also raises notifications about language assistance or alerts and warnings if a patient is waiting for treatment too long or is waiting for transportation. The critical time period for warning and alert levels is event-based. This component also shall be used for two-way communication with medical staff in the field.

Communication between server and client applications implements interfaces described below.

ISet interface

Authenticate - method for authentication and authorization users from the field. By providing credentials, the system determines one of user levels: staff, manager, EMS staff, ARC staff, system admin.

Check In - method through which field staff submit patient/runner check in information: patient personal information (wristband number, BIB number), in which medical unit patient is admitted, in which bad, patient initial complaints, does patient need language assistance and does runner's emergency contact need to be alert. In case elite runners check in, the system automatically notified event management (predefined list of contacts).

Check Out – the method by which check out info is submitted: patient diagnoses, attending doctor info, is

Figure 2 - MPTS medical questionnaire UI

patient discharged or transferred to a medical unit or transported to a hospital.

IGet interface

Get Patient List - return all patients to a specific medical unit (tend or aid station) and patient's statuses (active, discharged, transferred, transported), which bed is occupied at a moment and time period passed from runner check-in (visit duration). Thus, real time bed occupancy information is available.

Get medical record - provide all medical information runner submitted during registration for the event which could be relevant in case of emergency and also all runner's medical history from previous events (if there is permission)

Get patient details - get all patient/runner medical visit info: status, check-in and check-out info.

Get Transferred Patients - return a list of patients transferred to other medical units.

6. CONCLUSION

The proposed architecture is one of the solutions for the MPTS system which is conceived to implement the requirements of the RACER project. The described solution expands the functionality of the medical archive with the ability for real time medical data acquisition and reporting. MPTS became a useful tool for medical staff on running-race events. It is used in real world events, and the concept proves itself to be helpful and valuable for emergency situations. However, the system could be a subject for many improvements in the future.

Further development could be classified into several groups. The first one concerns improving the comprehension and quality of all data acquired by the system. Pre-event data of runners' training and health conditions could be aggregated through integration with most of the existing running gears and accessories in the market - like Nike Plus API. This will give additional insights into the runner's general medical conditions on the event day in case of urgency.

The second one concerns specific pace related data. Additional information could be collected on race day based on runner pace (time is measured each 5km) through integration with timing technology companies.

MPTS has been in use for some time. During the usage, system generated a large amount of data. Challenge will be to utilize those data for the prediction and management of medical emergency situations. For example, race organizers could introduce telemetry for the highly risky runners to monitor them continuously on the event day.

Finally, an additional effort should be made for improving data security and runner privacy by implementing formal medical data governance standards (HIPAA, GDPR) and other security standards.

7. ACKNOWLEDGEMENTS

We want to acknowledge the help of the company EMOS1 LLC, a leader in developing systems for supporting large event organizations, which is in charge of developing the MPTS system.

8. REFERENCES

[1] M. Basdere, G. Caniglia, C. Collar, C. Rozolis and G. Chiampas, "SAFE: A Comprehensive Data Visualization System," I*NFORMS Journal on Applied Analytics*, 2019.

[2] J. Kim, R. Malhotra, G. Chiampas, P. d'Hemecourt and C. Troyanos, "Cardiac Arrest during Long-Distance Running Races," *The New England Journal of Medicine*, 2012.

[3] C. Ross, M. Başdere, J. Chan, S. Mehrotra and K. Smilowitz, "Data Value in Patient Tracking Systems," *Department of Industrial Engineering and Management Sciences, Northwestern, IL*, 2015.

[4] B. Parker, P. Thaker, S. Chan and G. Chiampas, "Medical Tent Usage From Bank of America Chicago Marathon 2015-2017," *Sports Health: A Multidisciplinary Approach*, p. 431–436, 2021.

[5] M. J. Marino, J. B. Delaney and E. R. Smith, "Patient Tracking and Victim Reunification," *Journal of Emergency Medical Service*, 2021.