DATA SCIENCE AND APPLICATIONS SESSION

UTILIZE DIGITAL TRANSFORMATION TO CREATE EVENT DIGITAL TWINS FOR MARATHONS AND LONG-DISTANCE RACES

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Abstract:

In recent years, the world of long-distance races has experienced a digital revolution, leveraging technology to enhance various aspects of the event. Marathons and other long-distance races have embraced digital technologies to improve organization, streamline staff and volunteer coordination and management, optimize equipment and merchandise management, enhance medical infrastructure, implement efficient runner tracking systems, and address event security protocols and safety measures.

The digital transformation of marathons and long-distance races has resulted in an exponential increase in event data, preparing for the creation of event digital twins. This paper explores how the larger digital footprint generated by these events can be leveraged to develop event digital twins, virtual representations that mirror the physical event environment. Based on this research, two digital twins were proposed - Event Organization DT and Race DT. The proposed models of digital twins include enhanced event planning, risk mitigation, staff and volunteers' engagement, and post-event analysis, ultimately contributing to safer, more engaging, and well-organized race experiences.

Keywords:

Digital Twin, Digital Twin in Sport, Marathon races, Marathon digital data, Marathon organization.

INTRODUCTION

The digital twin paradigm today attracts the attention of numerous researchers due to its capacity for applications in various specific domains. Currently, it is most often applied in the production industry [1], but also in healthcare [2] and in sports [3]. In addition, there are attempts at generalization that seek to provide the support that enables the development of DTs for different domains of application like the one presented in [4].

Marathons and long-distance races have embraced digital transformation, utilizing technology to improve various aspects of event planning, execution, and analysis. The increase in the number of digital tools and platforms has resulted in a significant expansion of the event's digital footprint, encompassing participant data, event management and execution data, environmental metrics, staff and volunteer data, communication data and more.

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This paper explores how the wealth of data generated by these events can be used to create event digital twins, virtual replicas that offer real-time insights and predictive capabilities to optimize event operations and enhance participant experiences. [5]

The marathon event is something very complex with many different business lines and many different activities – each marathon event has its internal dynamic. It is a system that is not always under full control and the data sources are not unified, thus organizers don't have accurate data in one place to make a real-time decision or to simulate and predict different scenarios.

The construction of the digital twin of the event in this paper is based on the following basic principles:

- An event is a dynamic system with variable structure and behavior.
- The basis for building a digital twin is a model of a dynamic system that includes the structure and behavior of a real physical event, a marathon race.
- A digital twin of an event is a digital implementation of the event model.
- The model itself and its implementation should meet the following conditions:
- To enable different views of the system for different target user
- To be extensible in structure and behavior
- To ensure full interoperability of processes and data

These principles can be applied if Event digital twins are built upon a foundation of integrated data streams from different sources. In this paper, existing data from real sources (marathon races) were identified and characterized with the aim of defining the basis for the integration of data from different sources. In doing so, the following aspects were considered: primary sources of data, methods of data collection and data contents generated within the marathon event as a whole.

2. MARATHON EVENT DIGITAL DATA

Digitalization in the organization of long-distance races involves using software platforms, data analytics, and communication tools to streamline event planning and logistics. All collected data are standardized among the events by utilization of multiple event organizers. Thus, all data could provide a standardized event metric to be used by digital twins.

An analysis of nearly 100 races from 10 marathon events in the US over the past 10 years resulted in the following systematization of data about marathon events available in digital form. Data contents, collection locations and methods are:

- Volunteer and staff's check-in location points (laptops, mobile apps)
- Aid station among the course (mobile app)
- Medical tents (mobile app)
- Equipment distribution locations (web and mobile app)
- Security zone access points (mobile devices)
- Communication logs (messaging providers, radio communication logs)
- Event timeline execution (web, mobile app)
- Runner timing system (RFID readers in the course)
- Weather conditions (3rd party API and sensors along the course)

Integrating IoT devices, different data streams, and sensors along the race course and event production area enables real-time monitoring of various parameters based on data belonging to seven categories: Event Organizer data, Communication data, Medical infrastructure data, Staffing - Planning phase data, Logistic data, Staffing - Execution Phase data, and Security data. The detailed contents of the categories are given below.

2.1. EVENT ORGANIZER DATA

- Number of events per year
- Number and type of races per event (5K, 10K, half, marathon)
- Number of participants/runners per race
- Runner data (demography, measured time, real-time pace, previous race history, injury and treatment during race data)

2.2. COMMUNICATION DATA

- Number and type of messages exchanged per event (email, text messages)
- Message templates used (intent and urgency),
- Number of messages (and templates) per team (traffic analysis)
- Time when messages are sent

2.3. MEDICAL INFRASTRUCTURE DATA

- Number and type of medical staff (doctors, nurses, massage therapists, podiatry, lab technician)
- Number and type of medical volunteers (medical students,)
- Number of medical tents and beds capacity
- Number of aid stations and locations along the course
- Number and type of medical staff in medical tents and aid stations,
- Number and details of course interventions (in aid stations)
- Number and details of medical tent interventions
  - » Number and type of Complaints,
  - » Number and type of Diagnosis,
  - » Number and type of Treatments
  - » Number and duration of intervention
- Course weather conditions (temperature, wind speed, humidity...)

2.4. STAFFING - PLANNING PHASE DATA

- Staff organization
  - » Number and type of teams (staff, volunteers, vendors…)
  - » Number of staff positions (per team),
- Position details:
  - » Position description (SOW),
  - » Number and type of associated equipment,
  - » List of required skills & certification
  - » Security zone access
  - » Number of tasks and timetable
  - » Number of shifts, shift duration
- List of certificates & skills
- Recruitment flow data Standardise actions (invite, accept, reject, confirm, cancel...)
- Recruitment dynamics (times between actions, peak time)
- Event Timetable data
  - » Number of tasks and details (status, duration)
- Number of volunteers,
- Volunteers' management:
  - » Volunteer group where they are coming from (school, university, company,)
  - » Volunteer type (medical, general…)

2.5. LOGISTIC DATA

- Number of equipment items per type (merchandise, medical equipment, communication equipment, signage & print materials, security equipment...)
- Equipment distribution metric
  - » Number of equipment assigned to staff
  - » Number of equipment used (checked out)
  - » Number of equipment returned
- Usage metrics (when and how long equipment is used?)
- Number of vehicles (i.e. golf cart)
- Vehicle usage metric (how many times and how long is used, and by whom)
- Hospitality data
  - » Metric of airfare & hotel requests (number of requests, usage per team…)

2.6. STAFFING - EXECUTION PHASE DATA

- Number of checks-in location
- Tasks dynamic:
  - » Task status reported (time and location)
- Staff checks-in metric (coming to the event):
  - » Duration between checks-in, event location
  - » Number of staff checks-in per location

2.7. SECURITY DATA

- Number of Security zones (SZ)
  - » Number of security zones check-in points
  - » Number of accesses to SZ
  - » Who (position, team) and when accessed SZ
- Number of securities guards (staff position) and shift duration
- Number of radio channels for communication
- Number and type of credentials

3. BUILDING EVENT DIGITAL TWINS

A large amount of data is generated during event organization through the interaction between staff and volunteers, participants, event resources and event infrastructure. All interactions are “multidimensional” – they happen at different times, physical locations, and event phases (planning, execution and post-event analysis).

Also, the race itself generates a large amount of digital data by runner tracking, integration with weather data sources and tracking real-time medical data.

Having collected data in mind, the current work of digital twins in sport and the advantage digital twins bring to a particular domain, we proposed the architecture of digital twins, related to marathon event organization and race execution. [1]

3.1. EVENT ORGANIZATION DIGITAL TWIN

Event organization digital twin is built upon a foundation of integrated data streams, including staff and volunteer registration data, GPS tracking data and operational metrics. By aggregating diverse data sources, the event organization digital twin provides a comprehensive view of event dynamics and participant behavior.

As previously noted, data are generated by interaction between staff participating and/or organizing events, event resources and event infrastructure. Based on that interaction, the proposal of the digital twin of the marathon event is shown in Figure 1.

The event organization digital twin should help enhance event planning and logistics management by providing real-time insights into staff and volunteer flows (procedures), venue layouts (infrastructure), and resource allocation. Implementing the proposed digital twin of a marathon event organization can significantly impact event organization.

3.2. RACE DIGITAL TWIN

Digital Twin of marathon race should be used to optimize course design, identify potential bottlenecks and simulate runners’ density on the course, detect runners prone to injury, predict injury types and allocate course resources more efficiently to ensure a smooth and well-coordinated event experience.

Runners’ medical injury data are collected in the past 10 years from several large marathons organized in the USA. Data collected contains 500.000 runners' demographic and pace data (time measured every 5 km) and around 15.000 corresponding injuries data for the same

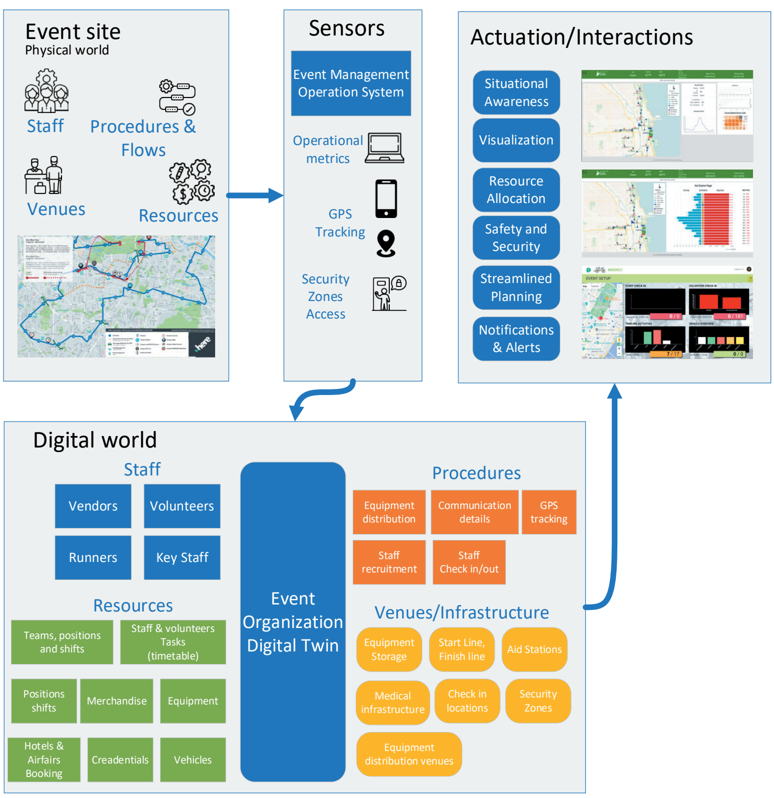

Figure 1. Event organization DT.

races – which allows cross-references of those data and the ability to find a pattern in runners' injuries. [6]

Based on that data, the proposal of the digital twin of the marathon race is shown in Figure 2.

Marathon race digital twin should combine multiple data sources to train the race model. Integrated data sources are:

- Runners' medical history and current medical data (real-time data from medical tents),
- Runners' pace (race tempo) – data acquired from the timing system (RFID reads along the course)
- Marathon weather conditions – data from 3rd party systems and sensors along the course
- Course characteristics – measurement and certification of road race [7]

4. PRACTICAL IMPLEMENTATION OF MARATHON DIGITAL TWINS

There are many potential benefits that the proposed digital twin offers. The following section covers some of the most important of them.

4.1. STREAMLINED PLANNING

Event organizers can use the Event Organization digital twin to visualize the entire event planning site, allowing them to plan more effectively. They can identify potential bottlenecks in planning, optimize the layout of aid stations and medical support areas, and make informed decisions about logistics such as resource allocation and staff control. For example:

- Planning event infrastructure based on the number of participants and number of races. DT should suggest the optimal number of staff, volunteers, staff organization (teams), needed equipment and event infrastructure (number of checks-in locations, equipment distribution venues, medical infrastructure).

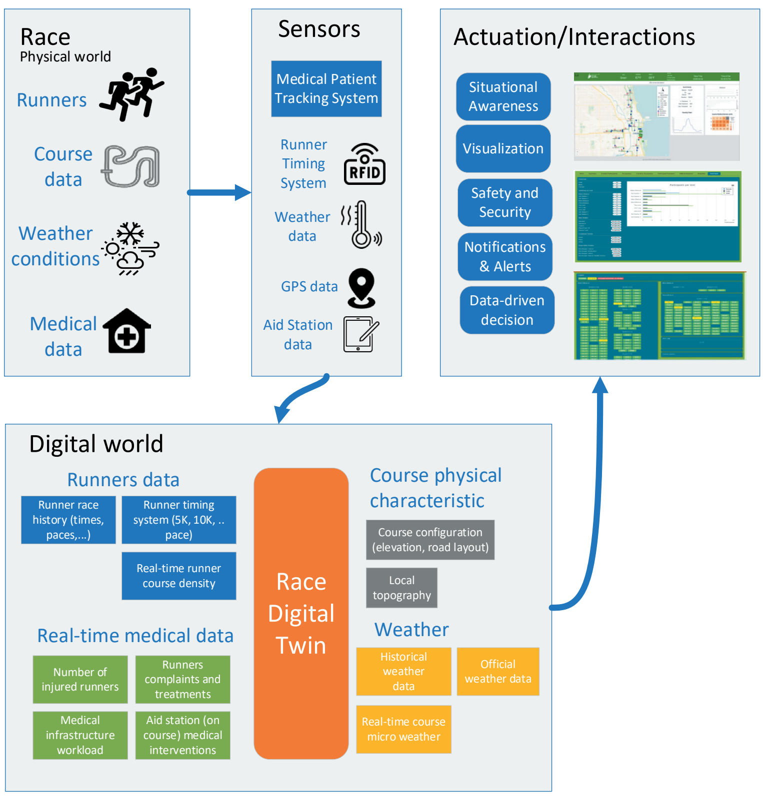

Figure 2. Race DT.

- Streamline staff and volunteers' recruitment process. Being able to define needed positions with appropriate equipment, shifts, skills and tasks. Then predict the best time to start recruitment and optimal communication which will lead to the quickest way to recruit the optimal number of staff and volunteers. Also, combining volunteers' groups (where volunteers are coming from) and other parameters (what volunteers are getting, shift duration, position location) ensures the best ratio of the number of registered volunteers and the number of volunteers that eventually will come on the event day.

4.2. EFFICIENT RESOURCE ALLOCATION

By simulating different scenarios within the digital twin, organizers can better allocate resources such as volunteers, medical personnel, and equipment. Organizers can anticipate where additional support may be needed and adjust staffing levels accordingly. Some practical examples are presented below:

- Organization and optimization of event day staff and volunteer check-in process. Determine the optimal number of check-in locations to optimize time to check-in and time to get gear/equipment for staff and volunteers
- Data-driven decision for allocation of volunteers and staff. Based on real-time information and prediction/simulation, the organizer could i.e. re-allocate medical volunteers from one aid station to another on the race course, if realize that a particular aid station will be overloaded with runners. Similarly, the organizer could optimize the recruitment process and recruit an optimal number of medical volunteers. Also, an optimal number of doctors per aid station or other medical location could be simulated and later implemented.

4.3. SAFETY AND SECURITY

The Race digital twin can be used to simulate emergency scenarios and develop contingency plans. Race digital twins could play a crucial role in risk mitigation and safety management by identifying potential safety hazards, such as overcrowding, extreme weather conditions, or medical emergencies, in advance. Organizers can use predictive analytics to assess risk levels, implement proactive safety measures, and coordinate emergency response efforts to ensure participant safety.

By analysing historical data and real-time inputs, race digital twins can anticipate potential issues and inform proactive decision-making strategies. Some practical implementations of race DT are:

- Detect runners (BIB – runner unique number) who are prone to specific injuries. This will allow medical staff on the course and/or finish line to pay attention to a specific runner
- Predict injuries that are more likely to happen during a particular event. This could help with better organization of medical infrastructure and medical staff training.
- Organizer can carry out a stress test which is not possible on event days. For example, the organizer could test the optimal approach for 45,000 runners should start the race – to reduce the crowd and time waiting to start the race. Also, how runners will adapt and will there be enough places in medical tents if during a race the temperature goes to plus 40° C?

4.4. IMMERSIVE VISUALIZATION & ANALYSIS

The value of visualizing a marathon was viewed more broadly, shifting from only a situational awareness tool to a comprehensive system that assists organizers in making decisions during the planning and implementation phases of the event.

Utilizing various IoT devices and sensors along the race course enables real-time monitoring of various parameters such as lead runner location, weather conditions, and medical infrastructure allocation. Event organizers can quickly respond to incidents, and medical injury trends (i.e. dehydration), re-route runners if necessary, and ensure a safer overall experience. [8]

After the event is finished, the event digital twin could offer valuable insights for post-event analysis and evaluation. Organizers can analyse participant performance data and operational metrics to identify areas for improvement, refine event strategies, and inform future event planning efforts, ensuring continuous innovation and enhancement of the race experience. Overall, implementing a digital twin of a marathon race can improve the efficiency, safety, and overall experience for both organizers and participants.

5. CONCLUSION

The digital transformation of marathons and long-distance races has created a new opportunity to develop event digital twins that offer real-time insights, predictive capabilities, and immersive visualization experiences. By utilizing the wealth of data generated by these events, event digital twins empower organizers to optimize event planning, mitigate risks, enhance participant engagement, and drive continuous improvement in the race experience. As technology continues to evolve, marathon event digital twins will play an increasingly integral role in shaping the future of endurance events, ensuring safer, more engaging, and well-organized race experiences for participants, spectators, and stakeholders alike.

In this paper, we proposed, based on analysed digital data, an abstract architecture of two digital twins: Event organization DT and Race DT and stated several practical use cases of DT implementation in live events.

Our future research will follow two main directions. The first one is an implementation of the proposed DT and testing the performance on suggested use cases in live events. This direction also includes the plan to integrate new data sources and digital data into the proposed DT as well as building a federation of the proposed digital twins (event organization DT and race DT) and other DTs handling runner conditions and training will allow the organizer to predict potential security and organization issues, to better organize existing resources and have better situational awareness of the whole event. Concerning this direction, one task is to collect data from runner wearable devices (running watches or fitness trackers) which could be a valuable data source. Moreover, a lot of work is done in implementing digital twins in sports involving creating virtual replicas or simulations of athletes' training, and their performance. [3], [9]

The second direction should include research that will enable the development and use of the digital twin paradigm in the field of athletic disciplines. We intend to use the results published in [4].

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