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Mobile Augmented Reality Traffic Management Center (MAR-TMC)

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FINAL RESEARCH REPORT

Award # 362

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Final Report

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Abstract

Traffic Management Centers (TMC) play an essential role in daily mobility and Emergency Support Functions (ESF). They are centralized with a massive amount of live data. In this project, we explore a decentralized TMC with Augmented Reality (AR) that integrates geographically accurate 3D terrain and building models with live mobility IoT data from open sources. The AR TMC system is portable and can run on a laptop, or an AR/VR device. We have built a virtual medical helicopter communication center and tested the launchpad on fire and remote fire extinguish scenarios.

Introduction

Traffic Management Center (TMC) is a hub of transportation management systems where information about transportation networks is collected and combined with other operational and control data to manage mobility to produce traveler information. It is the focal point for communicating transportation-related information to the media and the motoring public, a place where agencies can coordinate their responses to transportation situations and conditions. The TMC also links various elements of Intelligent Transportation Systems such as variable message signs, closed circuit video equipment, roadside count stations, etc., enabling decision-makers to identify and react to an incident in a timely manner based on real-time data.
TMCs encounter incidents on a daily basis. The operators are often overwhelmed with the flood of real-time data. For example, the TMC in PennDOT's District 11 in Bridgeville, PA has over 200 CCTV cameras that are streamed to 50 monitors at any time. During disastrous events, such as snow storms, power outages, floods, major accidents, and tornadoes, the TMC provides Emergency Support Functions (ESF) to first responders and the public. In many cases, mobile field command posts are necessary for emergency responders.

Many existing TMCs are located in fixed locations with massive wiring cables from sensors and a wall of monitors. The operators are overwhelmed by the massive isolated 2D data without a holistic view of the 3D reality. For example, many urban traffic jams are three-dimensional (3D), such as Fort Pitt Bridge, Pittsburgh International Airport, and subway systems in NYC and DC. Some emergency medical systems (EMS) often operate in a 3D space, for example, medical helicopters need to navigate through 3D structures, find landing zones, and avoid obstacles like power lines and utility poles. Furthermore, future mobility would include multimodalities such as drones and autonomous driving vehicles that depend on 3D lidar data to navigate through the city.

Augmented Reality (AR) has emerged as a next-generation intelligent interface that integrates cutting-edge sensors, vision, and data communication. AR devices overlay the critical information to the surrounding environment, merging the virtual world with live data and interaction. It is portable for field use. In the wake of the pandemic, an AR device can turn an operator's living room into a TMC including the video wall and live data through a high-speed Internet connection.

In this project, we explore a new kind of Traffic Management Center (TMC) with Augmented Reality (AR) technology that integrates geographically accurate 3D terrain and building models with the live mobility IoT data from open sources such as highway CCTV, Google Map, USGS, DHS, and NOAA. The AR TMC system is portable and it can run on a laptop or a heads-up-display (HUD) device for AR or VR such as HoloLens 2 and Magic Leap ML2. It can also be projected to a holographic screen for stereo vision from a pair of affordable polarized lens glasses.

Our Approach

1. AR City Models

We created geographically accurate city models that can be shared with TMC applications and GIS communities such as OpenStreetMap. Although there are 3D maps from iPhone Maps, Google Earth, and Google Maps, they are not accurate enough for close-up views, especially the spaghetti-like bridges and warped streets, when you view them from a driver or pedestrian's point of view. Developing 3D models of a city is a time-consuming, expensive, and technical process. In many cases, the extracted 3D models are not geo-referenced and noisy.

In this project, we first set the geographical boundaries for the map and extract the 3D models of a city from open sources such as Google Earth for infrastructures and buildings and USGS for elevation models. Then we developed a middleware to register the texture, GPS coordinates, and elevation models into an integrated AR model. This middleware is critical to building an accurate physical 3D model, for example, the details under a bridge, inside the tunnel, and the street views of buildings from the driver's and pedestrians' viewpoint. To incorporate water transportation or flood models, the middleware enables merging the river elevation models with the 3D models from Google Earth because it doesn't contain the profile of rivers. Google Earth and USGS models use different resolutions. The middleware fuse the multiresolution and multimodal models so that additional physical data can be integrated, e.g. flood water level and thermal imaging data, and so on. The libraries of the 3D articulated models are exported in standard formats such as GLB, OBJ, STL, DXF, PLY, and XYZ that can be readable to web browsers, Unity, and many AR/VR/MR devices.

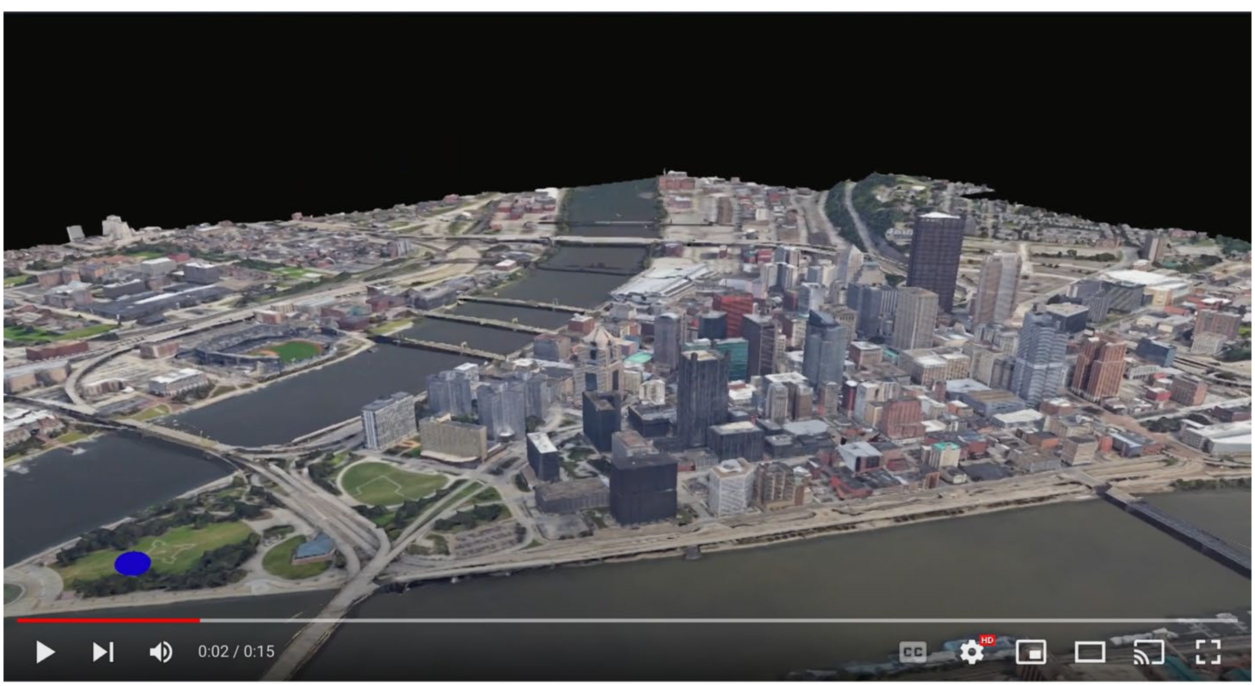

Figure 1. The 3D model of downtown Pittsburgh (https://youtu.be/CsDtk6U5UnA)

2. Real-Time Data Overlay.

The live streaming IoT (Internet of Things) data are registered onto the AR city model. The real-time IoT data come from open sources such as the CCTV video feed from PennDOT traffic camera websites and live traffic data from Google Map, air quality data from Allegheny County Health Department (ACHD), etc. For the CCTV video feed, we use RTMP (Real-Time Messaging Protocol) for transmission. For live sensor data, we use the MQTT (Message Queuing Telemetry Transport) protocol. The live CCTV videos can be registered to the 3D city model based on their locations and orientations. They also provide important mobility IoT data to the AR TMC. We have developed an algorithm to extract the IoT data from live videos. Many of the live video feeds are in lower frame rates, which is challenging to estimate the vehicle speed. We combine multiple camera data to obtain a more accurate estimation.

Our innovations in the system include:

1. Geographically accurate 3D terrain and building models registered with the live IoT data
2. Adjustable Spotlight for the hotspot in each scenario
3. Compressing IoT data to minimize cognitive overflow, e.g. values of non-essential sensors
4. Rotating text toward the viewer always
5. Surrounding soundscape for an immersive experience
6. The user can switch between the hologram and HUD views
7. Vertical stack for co-locational data to avoid visual congestion

Figure 2. The 3D model of a simulated traffic management center with real-time traffic camera data from PennDOT District 11. https://youtu.be/QnsO0i5K_rI

Figure 3. Example of the AR model and registered MQTT IoT Data Format

3. Mobility Scenarios in Normal and Extreme Conditions

The AR TMC system is portable and can run on a laptop or a heads-up-display (HUD) device for AR or VR such as HoloLens 2 and Magic Leap. It can also be projected to a holographic screen (with a sprayed-on coating) for stereo vision from a pair of affordable polarized lens glasses. In this project, we studied a few scenarios: the Pittsburgh model with the real-time traffic data from Oakland to the Pittsburgh International Airport in a normal day-to-day condition. We created the virtual traffic management center with live traffic data from open sources such as CCTVs of PennDOT and Google Map. We also simulated the Emergency Management System, and MedEvac Dispatch Center with live data from helicopters and hospitals, weather, and traffic data services. Our model would help to coordinate the mobilities in a 3D space: inside the hospital, on the ground, and in the air. The mobile AR TMC enables dispatch working in extreme conditions such as the disastrous field or working from home. In addition, we superimposed extreme conditions on the AR city model, specifically, the downtown Pittsburgh area. We simulated extreme scenes such as fire on the helicopter launchpad. These scenarios can be used for training emergency responders and traffic management operators, including firefighters, emergency medical doctors, police, and SWAT teams. Furthermore, this system can be used for coordinating with multiple response teams for disaster rescues and humanitarian assistance, for example, the massive pileup accident on I-80 in a snowstorm. The MAR TMC can be deployed in the field and connected with the cellphone networks or satellite Internet with helicopters, hospitals, and existing TMC. The system is able to record the user's response and the data logs for training purposes.

Furthermore, the AR city models can be used to create immersive driving experiences, for example, driving on the most dangerous spot Fort Pitt Bridge in Pittsburgh, or on the icy and hilly road during a snowy day. The system may also help to train the autonomous vehicle AI systems and drone pilots with immersive and live data.

Figure 4. AR 3D hologram of Richmond, VA with simulated live IoT data (left) and the live CCTV data registered to the 3D highway network in a simulated earthquake (right). Demo video: https://www.youtube.com/watch?v=aEzewo6xDMU

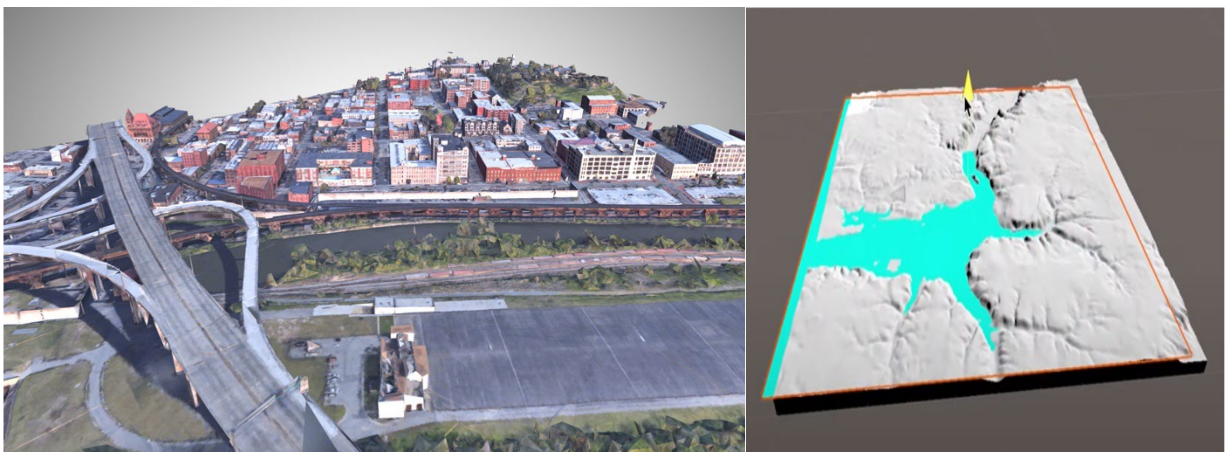

Figure 5. The geo-referenced 3D model of Richmond, VA, and the USGS flood model (Animation video on YouTube: https://www.youtube.com/watch?v=MZyZqUObOTg

We have scanned the UPMC STAT MedEvac Dispatch Center, built the 3D model of the helicopter launchpad, and tested the helicopter on fire and remote fire extinguish scenarios.

Figure 6. Helicopter launchpad on fire and remote fire extinguish scenarios

News about the project:

Engineering meets extreme reality, by Sherry Stroke, Inside CIT, Feb 17, 2022
https://engineering.cmu.edu/news-events/news/2022/02/17-extreme-reality.html

Publications:

Yang Cai, Haocheng Zheng, Mel Siegel, and Lenny Weiss, Extreme Reality (EXR) Telemetry Interfaces. In "Human Factors in Robots, Drones and Unmanned Systems," Vol. 57, 2022, 138–145, AHFE Open Access. AHFE Conference, NYC, July 26-28, 2022.
https://doi.org/10.54941/ahfe1002321

Yang Cai, Tomas Vancura, Haocheng Zheng, Lenny Weiss, and Mel Siegel. Real-Time Breath Pattern Detection from a Helmet. In "Human Factors and Wearable Technologies", Vol. 29, 2022, 1–9, AHFE Open Access. AHFE Conference, NYC, July 24-28, 2022.
https://doi.org/10.54941/ahfe1001468

Sean Hackett, Florian Alber, Haocheng Zheng, and Yang Cai. Sensor Fusion for Remote Multi-Body Temperature Monitoring. In "Human Factors and Wearable Technologies", Vol. 29, 2022, 63–72. AHFE Open Access. AHFE Conference, NYC, July 24-28, 2022.
https://doi.org/10.54941/ahfe1001475