Digital Twin for Emergency Traffic Management

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The contents of this report reflect the views of the authors, who are

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Accomplishments

The goals of this project include building Digital Twin city models, implementing real-time traffic overlays, and rendering mobility scenarios in extreme conditions.

We have built digital twin models of downtown Pittsburgh, the UPMC STAT MedEvac helicopter launchpad, and the EMS commanding center. These models were based on 3D scanning of real-world scenes and rendered in Unity (a cross-platform computer game engine) and C++ environments. We have overlaid ambulance routing sample data on Digital Twins via the MQTT protocol, and we have tested it on our 3D visualization platform. We tested the helicopter launchpad model with normal pre-flight checklist procedures, and in extreme situations such as escaping fire incidents and deploying the fire-extinguishing-cannon. Small affordable IMU (Inertial Measurement Unit) based 6-DOF sensor modules attached to the user's foot are used to implement realistic gait detection and avatar motion in the VR simulator.

In 2022 we also developed a mobile incident command dashboard prototype. We implemented a demo for wildfire protection called Cold Trialing with this mobile command dashboard.

In April 2022, after the Pittsburgh (Squirrel Hill – Regent Square) Fern Hollow Bridge collapsed into the valley below, we started building 3D models of the site. Our goal was to create a digital twin of the disaster site for training first responders, recovery planning, and forensics. Even our rough model was able to provide situational awareness from multiple perspectives. This rapid development and deployment exemplifies the possibilities for virtual training-on-demand responses to unexpected scenarios.

We have demonstrated our training system at the UPMC Emergency Medicine Communication Center, and the Center Director acknowledged the simulation system value and suggested additional features for training. We completed this software and integrate it into the training program for public safety.

In this project, we have trained over 4 graduate students and 6 undergraduate students from CMU, as well as a full-time intern from TU of Vienna.

Impacts

We anticipated our proposed system would have an impact on the day-to-day operations and professional training of future transportation systems, such as traffic management for medical helicopters and drones. It would also benefit other governmental agencies such as NIST PSCR (Public Safety Communication Research), USFS (Forest Service), HHS, and FEMA. Based on current outcomes, it appears feasible to launch a startup to commercialize the technology.

In addition, the team launched an outdoor graduate course in the Heinz School, called Drone Information Systems, that attracted over 8 graduate students from their MIS major. The feedback from the FCE was positive, and the several students stated that it was one of their best classes at CMU.

Outcomes

PI Mel Siegel participated in the 10th IEEE International Symposium on Inertial Sensors & Systems (INERTIAL 2023: https://2023.ieee-inertial.org/). Emerging high-precision low-drift inertial sensors and systems are poised to launch a "sealed-cabin navigation" revolution of magnitude not seen since the GPS/GNSS revolution that launched three decades ago. Technologies include cold atom interferometry and other atom-level sensors, ultra-narrow-line spectroscopy, nanoscale optomechanical and piezoelectric ICs, and integrated multi-modality sensor fusion software implemented in commercially packaged hardware. Applications range from precision integrated management of traffic in heavily congested scenarios to allowing first-responders to work in zero-visibility GPS-denied environments. The conference proceedings, now online, illustrate opportunities and stimulate cutting-edge possibilities for future Traffic21 / Mobility21 applications and projects.

We published four papers:

1. Yang Cai and Mel Siegel, Tangible extended reality with sensor fusion, Electronic Imaging Conference, San Francisco, January 2023

   [Abstract] Many extended reality systems use controllers, e.g. near-infrared motion trackers or magnetic coil-based hand-tracking devices for users to interact with virtual objects. These interfaces lack tangible sensation, especially during walking, running, crawling, and manipulating an object. Special devices such as the Tesla suit and omnidirectional treadmills can improve tangible interaction. However, they are not flexible for broader applications, bulky, and expensive. In this study, we developed a configurable multi-modal sensor fusion interface for extended reality applications. The system includes wearable IMU motion sensors, gait classification, gesture tracking, and data streaming interfaces to AR/VR systems. This system has several advantages: First, it is reconfigurable for multiple dynamic tangible interactions such as walking, running, crawling, and operating with an actual physical object without any controllers. Second, it fuses multi-modal sensor data from the IMU and sensors on the AR/VR headset such as floor detection. And third, it is more affordable than many existing solutions. We have prototyped tangible extended reality in several applications, including medical helicopter preflight walking around checkups, firefighter search and rescue training, and tool tracking for airway intubation training with haptic interaction with a physical mannequin.
   https://www.imaging.org/IST/IST/Conferences/EI/EI2023/Conference/C_MOBMU.aspx

2. Yang Cai, Mobile incident commanding dashboard (MIC-D), Electronic Imaging Conference, San Francisco, January 2023

   [Abstract] Incident Command Dashboard (ICD) plays an essential role in Emergency Support Functions (ESF). They are centralized with a massive amount of live data. In this project, we explore a decentralized mobile incident commanding dashboard (MIC-D) with an improved mobile augmented reality (AR) user interface (UI) that can access and display multimodal live IoT data streams in phones, tablets, and inexpensive HUDs on the first responder's helmets. The new platform is designed to work in the field and to share live data streams among team members. It also enables users to view the 3D LiDAR scan data on the location, live thermal video data, and vital sign data on the 3D map. We have built a virtual medical helicopter communication center and tested the launchpad on fire and remote fire extinguishing

scenarios. We have also tested the wildfire prevention scenario “Cold Trailing” in the outdoor environment.

https://www.imaging.org/IST/IST/Conferences/EI/EI2023/Conference/C_MOBMU.aspx

3. Yang Cai, Real-time imaging processing for low-vision users, Electronic Imaging Conference, San Francisco, January 2023

   {Abstract] We have developed an assistive technology for people with vision disabilities of central field loss (CFL) and low contrast sensitivity (LCS). Our technology includes a pair of holographic AR glasses with enhanced image magnification and contrast, for example, highlighting objects, and detecting signs, and words. In contrast to prevailing AR technologies which project either mixed reality objects or virtual objects to the glasses, our solution fuses real-time sensory information and enhances images from reality. The AR glasses technology has two advantages: it’s relatively ‘fail-safe.” If the battery dies or the processor crashes, the glasses can still function because it is transparent. The AR glasses can also be transformed into a VR or AR simulator when it overlays virtual objects such as pedestrians or vehicles onto the glasses for simulation. The real-time visual enhancement and alert information are overlaid on the transparent glasses. The visual enhancement modules include zooming, Fourier filters, contrast enhancement, and contour overlay. Our preliminary tests with low-vision patients show that the AR glass indeed improved patients' vision and mobility, for example, from 20/80 to 20/25 or 20/30.
   https://www.imaging.org/IST/IST/Conferences/EI/EI2023/Conference/C_MOBMU.aspx

4. Yang Cai, Wearable spectrum imaging and telemetry at edge, Electronic Imaging Conference, San Francisco, January 2023

   [Abstract] We present a head-mounted holographic display system for thermographic image overlay, biometric sensing, and wireless telemetry. The system is lightweight and reconfigurable for multiple field applications, including object contour detection and enhancement, breathing rate detection, and telemetry over a mobile phone for peer-to-peer communication and incident commanding dashboard. Due to the constraints of the limited computing power of an embedded system, we developed a lightweight image processing algorithm for edge detection and breath rate detection, as well as an image compression codec. The system can be integrated into a helmet or personal protection equipment such as a face shield or goggles. It can be applied to firefighting, medical emergency response, and other first-response operations. Finally, we present a case study of "Cold Trailing" for forest fire prevention in the wild.
   https://www.imaging.org/IST/IST/Conferences/EI/EI2023/Conference/C_MOBMU.aspx

Our project was reported by College of Engineering, CMU, “Engineering Meets Extreme Reality,” by Sherry Stokes,2022 https://engineering.cmu.edu/news-events/news/2022/02/17-extreme-reality.html

Our related work was also reported by NIST Public Safety and Communication Division: “Extreme Reality (EXR) Telemetry Interface for Real-Time Operation and Training”, in 2023.
https://www.nist.gov/ctl/pscr/funding-opportunities/past-funding-opportunities/psiap-augmented-

reality/extreme-reality

Our AR glasses for low-vision users have been tested by three patients from AGH Vision Lab. So far, the feedback has been positive.

Our VR Emergency Medical Helicopter Launchpad simulation training system has been demonstrated at the NIST PSCR Innovation Summit, June 28-30, San Diego, CA.

Our Extreme Reality (EXR) systems were demonstrated at the NIST PSCR Annual Meeting at San Diego, June 2022. Dr. Yang Cai was also invited to be the panelist of Future of AR/VR for Public Safety panel session.

New Partners

CMU Software Engineering Institute (SEI)
Visual Intelligence Studio, University of California, San Diego
US Air Force Research Lab
McCandless Fire Department
City of Pittsburgh Fire Department
University of Pittsburgh, Emergency Medicine Communication Center

Issues
N/A