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Enhancing Public Safety, crowd monitoring and Socio-cultural Event Management by generating a Digital-Twin by Drone Photogrammetry and Immersive Media.

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Abstract: This study examines the efficacy of immersive media and photogrammetry in enhancing security and safety, assessing its potential for future implementation. User perceptions and integration challenges are evaluated through the testing of various established methods. This research encompasses the implementation of a Digital Twin model on a large-scale public event, the Rathyatra. The research demonstrates how modernising public event security has enhanced the decision-making capabilities of state police. The methodologies were developed with a human-centred design approach and are scalable to meet custom requirements. The research incorporates design for social innovation and impact, covering public infrastructure integration and public service integration. The Digital Twin is generated using immersive media and photogrammetry as the medium. Conducted UX research, behavioural insights, formal and informal interviews, and field studies to comprehensively understand the project's scope. Developed resilient design approaches that align with HCI and HFI principles, such as workload and stress assessment, safety-critical system design, and risk assessment. Considered integrating sustainable technology into the existing ecosystem of tools and devices to facilitate digital transformation and the development of a digital twin that ensures future-proof security systems for large-scale public domains. Interoperability among digital systems, including immersive media, HCI, HFI, and advanced design methodologies, plays a pivotal role in this research.

Introduction

In the era of emerging technology, we can upgrade the application of technology to the field level. Photogrammetry is a technique that generates 3D models and visuals with the aid of 2D photos or videos. There are several methods to create photogrammetry outcomes. Methodology varies with the purpose and scale of the work. Mobile photogrammetry can be utilised for tangible product scanning and reverse engineering. For larger-scale implementations, professional cameras can be employed, and aerial field of view can be achieved using drone photos and videos.

The Old City of Ahmedabad, a UNESCO World Heritage Site, is a historic urban core renowned for its rich cultural heritage, traditional pols (gated communities), and vibrant festivals. Founded in 1411 by Sultan Ahmad Shah, the Old City comprises numerous neighbourhoods, each imbued with distinct architectural and cultural significance. (UNESCO World Heritage Centre, n.d.).

The Ahmedabad Rath Yatra is a prominent annual festival celebrated in Ahmedabad, Gujarat, India that honours Lord Jagannath, his brother Balabhadra, and his sister Subhadra. Commencing in 1878 under the auspices of Mahant Narsinhdasji Maharaj, the festival has transformed into a grand spectacle, attracting numerous devotees annually. Rathyatra is a socio-cultural event that presents an ideal opportunity for the implementation of a digital twin. The establishment of crowd monitoring, security, and safety measures can be achieved through the utilisation of photogrammetry techniques (Ahmedabad Mirror, 2021).

Keywords: Digital Twin, Immersive Media, Photogrammetry, Drone Data Capturing, Point Cloud Data Processing.

1 Overview of the Rathyatra event

India is a culturally diverse country that hosts numerous cultural and religious festivals throughout the year. Rathyatra is one of the most prominent socio-cultural festivals and events that takes place according to the Vikram Samvat calendar, a Hindu lunisolar calendar. As per the Vikram Samvat calendar, Rathyatra is observed on the second day of the bright fortnight of the Ashadha month.

The Jagannath Rath Yatra in Ahmedabad is a prominent annual religious procession organised by the Jagannath Temple in Jamalpur. The chariot procession of Lord Jagannath, Balbhadra, and Subhadra traverses the densely populated streets of the Old City, traversing historic localities.

Jamalpur, the commencement of the Rath Yatra, houses the venerable Jagannath Temple. This region encompasses a diverse blend of religious, commercial, and residential establishments.

Kalupur, a prominent historical neighbourhood, is renowned for the Kalupur Swaminarayan Temple and its bustling traditional markets. The Rath Yatra traverses this area, drawing in thousands of devotees.

Dariyapur, one of the city's older Muslim-dominated areas, exemplifies the harmonious coexistence of diverse cultures. It is an integral part of the Yatra route, necessitating robust security measures.

Shahpur, another historically significant area along the Yatra route, is characterised by its ancient havelis and the communal harmony that prevails during the festival.

Prem Darwaza, a historic gateway, marks the procession's approach towards the inner sanctum of the walled city.

Manek Chowk, a central marketplace, transforms from a bustling bazaar during the day into a culinary hub at night. Located near the Yatra route, it holds historical significance.

Teen Darwaza, one of the oldest and most iconic gateways of Ahmedabad, has witnessed the traditional passage of processions for centuries.

Raipur, another locality on the route, exudes an old-world charm and proximity to several pols.

Ghee Kanta and Astodia, the procession continues through these densely populated areas, which comprise a fusion of commercial and residential hubs.

Procession Details:

The Rath Yatra, a revered religious procession, traverses approximately 16 kilometres through various localities of Ahmedabad, including the Old City and sensitive communally designated areas. The procession comprises 18 ornately decorated elephants, 100 trucks adorned with thematic tableaux, 30 akhadas (traditional gymnasiums), and bhajan mandalis (devotional singing groups). A notable highlight is the halt at Saraspur, revered as the deities' maternal uncle's abode, where a Maha Bhoj (grand feast) is organised for devotees.

Security and Logistics:

Given the massive turnout, elaborate security measures are implemented to ensure the safety of

Participants:

Personnel Deployment: Over 22,000 security personnel, including 12,000 from the regular police force, 6,000 Home Guards, 11 companies of Central Armed Police Forces (CAPF), and 35 companies of the State Reserve Police (SRP), are deployed along the route.

Surveillance: The procession is monitored using 1,733 body-worn cameras linked to a control room, 20 drones, and 96 surveillance cameras installed at 47 locations. Additionally, approximately 1,400 CCTV cameras installed by local shopkeepers provide live surveillance.

Medical Facilities: To address any medical emergencies, 16 ambulances and medical teams at five government-run hospitals are on standby. Seventeen help desks are also set up along the route to assist citizens (Shree Jagannathji Mandir Trust, n.d.).

Ahmedabad Rathyatra, the third-largest Rathyatra in the country, after Puri, Odisha, and Serampore, West Bengal, the first and second, respectively, necessitated the adoption of technology immersion to ensure the safety and security of the event amidst the extensive security monitoring measures. Traditional event monitoring methods, such as CCTV and manual surveillance, are insufficient to meet the demands of such a large-scale event, Ahmedabad Mirror. (2021, July 3).

2 Objectives

This project was developed in collaboration with the Gujarat Police and Crime Branch, Gujarat. Objectives were defined by the higher authority of the Gujarat Police, Crime Branch, Gujarat and technology experts. The objective aims to provide a solution that is politically acceptable, socially desirable, technologically feasible, financially viable, administratively doable, judicially tenable, emotionally relatable and environmentally sustainable.

Fig. 1 - Rathyatra Crowd Visuals

List of precise objectives for project Rathyatra,

- Identify an optimised system to capture data through photographs, videos, and manual data generation.
- Develop a seamless workflow to create a digital twin of the city by testing multiple pathways for photogrammetry.
- Capture 360 videos for the Rathyatra path debriefing event, incorporating digital milestone tags for reference.
- Construct a standalone system to integrate the digital twin of the city into the police control room.
- Design a user interface that collaborates the necessary data for security, safety, crowd monitoring, geotagging, 360 visual feeds, and transitions between three Raths.
- Develop a decision-making system for state police with seamless integration with the state crime branch.

3 Methodology

Photogrammetry is the science of obtaining reliable measurements from photographs and digital imagery. The output of the photogrammetric process is often orthomosaic maps, symbolic maps, GIS layers, or three-dimensional (3D) models of real-world objects or scenes. Parenthetical citation: (Esri, n.d.) There are two general types of photogrammetry, aerial photogrammetry and close-range photogrammetry (Quintero et al., 2017).

Photogrammetry on a larger scale to scan and create a digital twin was the very first of its kind attempt for an event like Rathyatra. There were numerous challenges, including understanding the geography, city areas, localities, Rathyatra route, congested areas of the city, crowd monitoring, technological upgrades, understanding the role of each management committee, etc.

Key points before starting the ground-level methodology implementation were:

A comprehensive team formation ceremony was held, attended by three professors, eleven students, the DCP Cyber Crime unit, and the state police force.

The team conducted multiple traversals of the 17 km route to familiarise themselves with the terrain, and engage with various individuals to gain insights into the route, schedules, and crowd behaviour at the Rathyatra.

Understood and comprehend the communally sensitive areas and assess potential situational challenges through technical assessments of technology adoption and the identification of necessary considerations.

The solution comprises three interconnected layers of ecosystems synchronised to monitor the event and establish a decision-making framework. (A) Drone photogrammetry, (B) 360-degree ground visuals captured by an advanced 360 camera, and (C) a decision-making interface located in the control room. These three solutions are integrated and constitute a unified parent ecosystem.

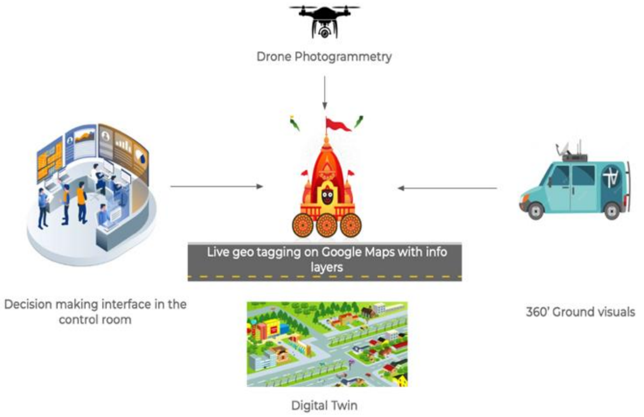

Fig. 2 – Methodology Implementation

Experimental Setup: This step includes processes like site selection based on the Rathyatra path, key areas of safety concerns, communal sensitive areas and precautions, and available technological bandwidth and gadgets. Trial and error of drone photography and videography are also included in this procedure to capture the most optimised field of view. Including LiDAR sensors as a point cloud data-capturing device was the key trial of this experimental setup.

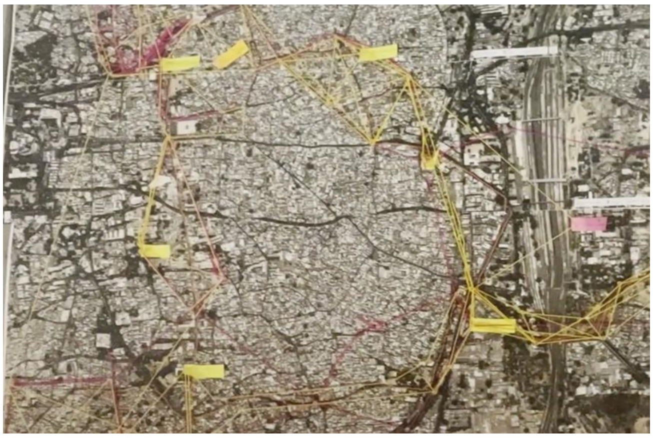

Fig. 3 - Manual Mapping of areas and route

Data acquisition and processing: Drone photogrammetry was deemed an optimised data collection method. It offered a comprehensive field of view to capture intricate structural details and complexities (Kong & Hucks, 2023). Subsequently, data processing presented a formidable challenge, necessitating the conversion of videos to high-resolution images for enhanced image processing capabilities. Dense Point Cloud data generated through this process facilitated detailed mesh refinements and texturing (Bujakiewicz et al., 2006).

Fig. 4 – Drone flights with visual monitoring for data acquisition

(A) Drone photogrammetry

Here are the attributes of the data acquisition and processing:

- 145 Drone flights were conducted to identify the optimised orientation and capture the photo.
- A total of 4 Lacs photos were captured with 0.5 inch CMOS sensor – DGI Maverick 2 Pro.
- 1000+ man-hours spent to generate a digital twin with layers, modelling, texturing and making it virtual reality enabled.
- 200 m area covered on both sides from the central route of Rathyatra.
- A total of 21 km was mapped with drone photogrammetry and 360 video capturing with an Insta 360 camera.

Fig. 5 – 360 video capturing of the route with Insta 360

Ground-level 360 video capturing necessitated video editing for the purpose of information tagging and labelling. Post-editing, the video required conversion to a virtual reality-compatible format, ensuring compatibility with virtual reality applications (Agnello et al., 2019).

Fig. 6 – Visuals of optimised drone path for photogrammetry

Drone photogrammetry is a series of numerous software and trial-and-error to generate a digital twin of the city. Multiple pathways were attempted for better outcomes. (McKee & Yuan, 2019) Texture and rendering quality directly depend on the density of the point cloud, the higher the dense the point cloud data, the higher the refined results and the lesser the lead time for processing the data. (Streilein et al., 1994) (Ergun, Şahin, & Bilücan, 2024).

Data processing has multiple considerations and standards to be followed. Here are some considerations:

- All the data was mapped with the same or similar lighting conditions for accurate light and shadow.
- 45-degree drone inclination provided maximum field of view and data capturing.
- Cloudy but well-lit weather provided soft lighting with sharp shadows that enhanced the processing of the point cloud data and reduced lead time. (Garrett & Anderson, 2018)

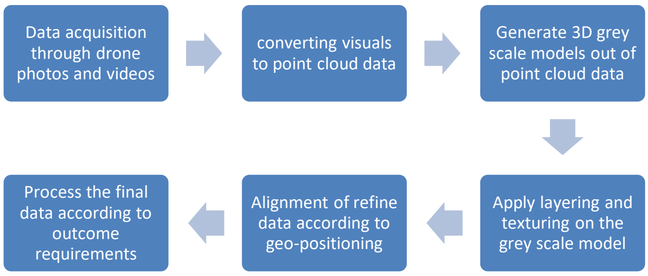

Fig. 7 - Process flow of Data acquisition and processing

Fig. 8 – High-res digital twin through drone photogrammetry

(B) 360-degree ground visuals

Insta360 cameras employ dual fisheye lenses to capture seamless 360° images and videos, seamlessly stitched together using AI-powered software. Their FlowState Stabilisation ensures ultra-smooth footage without the need for a gimbal. Features such as reframing enable users to edit perspectives post-recording, while the invisible selfie stick creates a floating camera effect. Advanced modes like TimeShift, Bullet Time, and HDR enhance creative possibilities. (Marín-Buzón et al., 2021) Insta360 also supports live streaming and VR compatibility, making it ideal for immersive content creation. Its combination of hardware innovation and AI-driven processing ensures high-quality results. (Hardin & Jackson, 2005)

Fig. 9 – Custom-fabricated 360 camera mount

This recorded 360 video was used for briefing and virtual reality visuals on the Oculus Quest 2 headset. Due to the high crowd density, network connectivity was severely compromised. Consequently, a separate network connection was established with the assistance of the police force to transmit the data to the control room for live 360 visualisations.

(C) a decision-making interface located in the control room

Making AIRAVAT - Artificial Intelligence Reconnaissance And Virtual Adaptivity Toolkit: As it is named, AIRAVAT is the decision-making system for state police that integrates AI reconnaissance data monitoring interface with virtual reality adaptive supports. The State police and crime branch can have live visuals of Rathyatra being present in the control room only. It provided drone footage and 360 ° audio-visual feed for crowd monitoring. A digital twin of the city provided a gamified version of the city in the control room that allowed one to manoeuvre everywhere in the point cloud data. Prime data was labelled in the digital twin as per the requirements of the police department. It included Police station details, reporting police officer details, zonal details, forward and return path details, fire brigade locations, CCTV locations, key landmarks of the route, approaching roads, swagat points on the route, watch towers, sensitive area information, turn indications, etc.

Fig. 10 – Decision-making system for Police authorities at Police Headquarters, Ahmedabad

AIRAVAT, the decision-making system, offers solutions at multiple layers of security and access to multiple crucial pieces of information, enabling the identification and resolution of bottlenecks to facilitate informed decision-making.

Here are the elaborated purposes of each window of the AIRAVAT interface.

- Window A was a customised map of the route, complete with all required labelled information, accessible to the smartphone of field police personnel in the format of a clickable PDF.
- Window B presented a comprehensive 360-degree visual of the route, accompanied by annotated information indicating zones, police presence, and sensitive areas.
- Window C provided live audiovisual footage from a single point-of-view camera positioned in front of Lord Jagannath Chariot, ensuring continuous monitoring.
- Window D accessed the digital twin of the city in real time in sync with the live location of three chariots. All the necessary information is anchored in the digital twin, including officer on duty, zone, area, Swagat points, CCTV points, entry-exit points, ambulance locations, fire station locations, police stations, watch towers, sensitive areas, approaching and returning routes, dhaba (terrace) points and landmarks provided by Gujarat police and Crime Branch Ahmedabad.
- Window E provided detailed information regarding the precise location and the officer in charge, as well as zonal, range, and area data. This vital information proved instrumental in making informed decisions and facilitating contact with the appropriate zonal police officers.
- Window F served as a crucial point of reference for monitoring the lead time of the Rathyatra procession. Airavat collaborated with a time calculation algorithm that indicated whether the Rathyatra procession was proceeding on time or not.
- Window G provided a live television channel that displayed various visual content and facilitated simultaneous monitoring of telecasting activities.

Fig. 11 – Solution implementation used for Police briefing

The AIRAVAT decision-making system played a pivotal role in the briefing process preceding the Rathyatra event, educating police personnel about the intricacies of the event with meticulous details and the procession. 5000 police officers were initially presented with the information, followed by multiple briefing sessions for a subsequent batch of officers. This project not only created a digital repository of the digital twin of the old city of Ahmedabad for future reference but also revolutionised the conventional method of presentation.

4 Result

- Enhancing public safety, crowd monitoring, and socio-cultural event management by developing a digital twin and its successful implementation.
- Designed the decision-making system for state police through the integration of advanced design techniques, including immersive media and photogrammetry.
- Developed and optimised workflows to capture data for photogrammetry using drone photographs and videos.
- Developed an optimised method to process point cloud data into a digital twin.
- Implemented social welfare measures for crowd monitoring, ensuring safety and security during large-scale public events such as Rathyatra.
- The development and establishment of AIRAVAT provided a single-point resource for data, resulting in a proficient decision-making system.

5 Conclusion

The research successfully demonstrated the potential of digital twins in enhancing public safety, crowd monitoring, and socio-cultural event management. By integrating immersive media and photogrammetry, an advanced decision-making system was developed for the state police, enabling efficient real-time monitoring and response. Optimised workflows for drone-based photogrammetry and point cloud processing ensured high accuracy and efficiency in digital twin generation. Implementing AIRAVAT as a centralised data resource enhanced decision-making and improved event security and management. This study underscored the transformative impact of digital twins in public safety, presenting a scalable model for future large-scale events.

6 Reference

1. Fig – 1: https://www.ahmedabadmirror.com/for-ahmedabad-residents-rath-yatra-an-occasion-to-bephilanthropic/81837743.html
2. UNESCO World Heritage Centre. (n.d.). Historic city of Ahmadabad. UNESCO World Heritage Centre. https://whc.unesco.org/en/list/1551/
3. Shree Jagannathji Mandir Trust. (n.d.). Rath Yatra. Shree Jagannathji Mandir Trust. https://www.jagannathjiahd.org/rath-yatra/
4. https://theprint.in/india/over-22000-cops-to-guard-lordjagannath-rath-yatra-in-ahmedabad-on-july-7/2160380
5. Quintero, M. S., et al. (2017). CIPA’s mission: Digitally documenting cultural heritage. APT Bulletin: The Journal of Preservation Technology, 48(4), 51–54.
6. Streilein, A., et al. (1994). Digital photogrammetry for heritage recording. APT Bulletin: The Journal of Preservation Technology, 26(1), 40–46. JSTOR. https://doi.org/10.2307/1504434.
7. McKee, A., & Yuan, M. (2019). A high-resolution multi-scalar approach for micro-mapping historical landscapes in transition: A case study in Texas, USA. In T. Coomans, et al. (Eds.), Mapping landscapes in transformation: Multidisciplinary methods for historical analysis (pp. 199–216). Leuven University Press. JSTOR. https://doi.org/10.2307/j.ctvjsf4w6.11.
8. Hardin, P. J., & Jackson, M. W. (2005). An unmanned aerial vehicle for rangeland photography. Rangeland Ecology & Management, 58(4), 439–442.
9. Garrett, B., & Anderson, K. (2018). Drone methodologies: Taking flight in human and physical geography. Transactions of the Institute of British Geographers, 43(3), 341–359.
10. https://www.researchgate.net/publication/351473042_Photogrammetry_as_a_New_Scientific_Tool_in_Archaeology_Worldwide_Research_Trends.
11. Bujakiewicz, A., Kowalczyk, M., Podlasiak, P., & Zawieska, D. (2006). 3D reconstruction and modelling of the contact surfaces for the archaeological small museum pieces. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XXXVI(22), 56–61. https://doi.org/10.1111/j.1477-9730.2007.00418.x.
12. Agnello, F., Avella, F., & Agnello, S. (2019). Virtual reality for historical architecture. In ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLII-2/W9 (pp. 9–16). International Society for Photogrammetry and Remote Sensing. https://doi.org/10.5194/isprs-archives-XLII-2-W9-9-2019.
13. Kong, X., & Hucks, R. G. (2023). Preserving our heritage: A photogrammetry-based digital twin framework for monitoring deteriorations of historic structures. Automation in Construction, 152, 104928.
14. Ergun, B., Şahin, C., & Bilücan, F. (2024). Digital twin base model study by means of UAV photogrammetry for the library of Gebze Technical University. In Proceedings Title (if available) (pp. 235–242). Springer. https://doi.org/10.1007/978-3-031-54376-0_21.