VISUAL 2026

The Eleventh International Conference on Applications and Systems of Visual Paradigms

ISBN: 978-1-68558-352-1

March 8th –12th, 2026

Valencia, Spain

VISUAL 2026 Editors

Petre Dini, IARIA, USA

VISUAL 2026

Forward

The Eleventh International Conference on Applications and Systems of Visual Paradigms (VISUAL 2026), held between March 8-th, 2026 and March 12-th, 2026 in Valencia, Spain, continued a series of events putting together complementary domains where visual approaches are considered in a synergetic view.

Visual paradigms were developed on the basis of understanding the functions of the brain and the eyes. They spread over computation, environment representation, autonomous devices, data presentation, and software/hardware approaches. The advent of Big Data, high speed images/camera, complexity and ubiquity of applications and services raises several requests on integrating visual-based solutions in cross-domain applications.

We take here the opportunity to warmly thank all the members of the VISUAL 2026 technical program committee, as well as all the reviewers. The creation of such a high-quality conference program would not have been possible without their involvement. We also kindly thank all the authors who dedicated much of their time and effort to contribute to VISUAL 2026. We truly believe that, thanks to all these efforts, the final conference program consisted of top-quality contributions. We also thank the members of the VISUAL 2026 organizing committee for their help in handling the logistics of this event.

We hope that VISUAL 2026 was a successful international forum for the exchange of ideas and results between academia and industry for the promotion of progress in the field of applications and systems of visual paradigms.

VISUAL 2026 Chairs

VISUAL 2026 Steering Committee
Irene Yu-Hua Gu, Chalmers University of Technology, Sweden
Sergio A. Velastin, Universidad Carlos III de Madrid, Spain
Marina Tropmann-Frick, Hamburg University of Applied Sciences, Germany
Sugata Banerji, Lake Forest College, USA

VISUAL 2026 Publicity Chairs
Francisco Javier Díaz Blasco, Universitat Politècnica de València, Spain
Ali Ahmad, Universitat Politècnica de València, Spain
José Miguel Jiménez, Universitat Politècnica de València, Spain
Sandra Viciano Tudela, Universitat Politècnica de València, Spain

VISUAL 2026
Committee

VISUAL 2026 Steering Committee

Irene Yu-Hua Gu, Chalmers University of Technology, Sweden
Sergio A. Velastin, Universidad Carlos III de Madrid, Spain
Marina Tropmann-Frick, Hamburg University of Applied Sciences, Germany
Sugata Banerji, Lake Forest College, USA

VISUAL 2026 Publicity Chairs

Francisco Javier Díaz Blasco, Universitat Politècnica de València, Spain
Ali Ahmad, Universitat Politècnica de València, Spain
José Miguel Jiménez, Universitat Politècnica de València, Spain
Sandra Viciano Tudela, Universitat Politècnica de València, Spain

VISUAL 2026 Technical Program Committee

Ana Paula Afonso, Universidade de Lisboa, Portugal
Samson Adebisi Akinpelu, University of Kwazulu-Natal, South Africa
Marco Angelini, University of Rome "La Sapienza", Italy
Keivan Ansari, Institute for Color Science and Technology, Iran
Danilo Avola, Sapienza University, Italy
George Baciu, The Hong Kong Polytechnic University, Hong Kong
Sugata Banerji, Lake Forest College, USA
Hans-Peter Bischof, Rochester Institute of Technology, USA
Liudmila Bredikhina, Geneva University, Switzerland
Vittoria Bruni, Sapienza Rome University, Italy
Maria Beatriz Carmo, Universidade de Lisboa, Portugal
Satish Chand, Jawaharlal Nehru University, New Delhi, India
Haeyong Chung, University of Alabama in Huntsville, USA
Stefano Cirillo, Università degli Studi di Salerno, Italy
Gennaro Costagliola, University of Salerno, Italy
Tobias Czauderna, Hochschule Mittweida, Germany
Antonina Dattolo, University of Udine, Italy
José Mario De Martino, University of Campinas, Brazil
José Joaquim de Moura Ramos, University of A Coruña, Spain
Cosimo Distante, CNR / University of Salento, Italy
Pierre Drap, Aix-Marseille University, France
Omar Elharrouss, College of Engineering - Qatar University, Qatar
Ben Falchuk, Peraton Labs, USA
Ana Figueiras, Universidade Nova de Lisboa, Portugal
Valentina Franzoni, University of Perugia, Italy
Marnim Galib, University of Texas at Arlington, USA
Manuel González-Hidalgo, University of the Balearic Islands, Spain

Table of Contents

Forensium – The Digital Twin in Forensic Casework

Dirk Labudde
FoSIL – Forensic Science Investigation Lab
University of Applied Sciences Mittweida
Mittweida, Germany
e-mail: labudde@hs-mittweida.de

***Abstract*— The concept of the digital twin is revolutionizing forensic work and opening completely new possibilities for crime scene documentation, evidence collection, and reconstruction of the course of events. This paper highlights the development, application, and prospects of this transformative technology in a forensic context. The convergence of digital data, digitized material, the crime scene as a digital twin, and intelligent systems can be understood as a further development of the Free Agents in a Cellular Space (FACS) concept and transferred to forensics. The Forensium as a coupled system consisting of a digital twin and various simulation rooms offers the possibility of mapping the center of the hypothesis-driven investigation process.**

Keywords – Forensium; digital twin; simulations; coupled systems; crime scene.

I. INTRODUCTION

The idea of the digital twin originated at NASA in the 1960s and 1970s. A striking example is the Apollo 13 mission in 1970, during which ground technicians used an identical physical model of the spacecraft to analyze critical problems and develop life-saving solutions. This early form of twin technology laid the foundation for later developments.

However, the term “digital twin” was first coined around 2002 by Michael Grieves [1] and was initially used primarily in product development and lifecycle management. With the advent of Industry 4.0 [2][3], the Internet of Things (IoT) [4][5], and advanced Product Lifecycle Management (PLM) approaches [6] (engineering/industrial context), the concept spread increasingly across a wide range of industries from 2010 onwards [7]. Technological advances over the last decade now also enable its use in highly specialized areas such as forensic science.

This methodology, which has proven itself in space travel, is now the conceptual foundation for the application of digital twins in forensic work. Just as NASA engineers had to work with their model without having direct access to the spacecraft, investigators today can work with a digital twin of a crime scene long after it is no longer physically accessible. The fundamental concept of the digital twin will bring about profound changes in forensics. These range from understanding forensic documentation to reforming crime scene work. This transformation will be presented here in a compact form, and the digital twin will be classified within the concept of the Forensium. The Forensium can be understood as a coupled system consisting of a 3D space (crime scene model), the digital twin, and a special multi-agent system, whereby the associations between the components are mediated by analog and digital evidence and form the basis for simulations.

The rest of the paper is structured as follows. In Section II, we present the transformation from classical crime scene photography to the concept of the digital twin and discuss the methodological shift in forensic documentation. In Section III, we examine evidence as an information carrier in digital space and describe its structured representation within the digital twin. Section IV introduces the conceptual foundations of the Forensium and its relation to hybrid simulation models such as Free Agents in a Cellular Space (FACS). In Section V, we describe the architecture and functionality of the Forensium, including the integration of simulation technologies and Large Language Models. Finally, in Section VI, we outline future developments and discuss the potential impact of digital twin technology on forensic investigation.

II. FROM CLASSIC CRIME SCENE PHOTOGRAPHY TO DIGITAL TWIN

The development of forensic documentation reflects technological progress. Traditionally, crime scene work was based on forensic photography, a method that has been in use for over a century [8] and follows clear, unchanging principles. Descriptive photography aimed to document the crime scene objectively, completely, and to scale. Forensic photography used special techniques. Scales and number cards were systematically placed to document proportions and clearly identify individual evidence. This approach made it possible to transport documented objects from the crime scene to the laboratory for further examination under controlled conditions. Each photo became a carrier of information that captured specific attributes of a piece of evidence. However, this approach had fundamental limitations: the crime scene was gradually “dismantled” in the course of securing evidence. Each piece of evidence removed irreversibly changed the situation. The spatial relationships between the evidence were partially lost because they were only documented by two-dimensional photos from different perspectives. Integrating all the information into a coherent overall picture required human interpretation and remained susceptible to errors or misunderstandings [9][10]. They are complex carriers of information.

But today, holographic 3D scans with data overlays and real-time forensic analysis can serve as a modern addition

 ISBN: 978-1-68558-352-1

and help bridge the gap between descriptive and advanced exploratory documentation.

Exploratory forensic reconstruction is a special approach within forensic imaging. It differs significantly from descriptive photography. While the descriptive method documents what is visible and known, exploratory photography aims to make the invisible visible or to test hypotheses. The digital twin combines both methods and goes beyond the goals of descriptive and exploratory reconstruction.

III. THE EVIDENCE AS AN INFORMATION CARRIER IN THE DIGITALE SPACE

Evidence plays a special role in digital twins. In forensic science, evidence is much more than physical objects. It is a complex carrier of information. Evidence can be understood mathematically as a function: $S = f(x,t)$, where it depends on spatial coordinates (x) and temporal parameters (t). This abstract view illustrates that every piece of evidence carries information about its place of origin, time of origin, and the circumstances of its origin. The concept of the "evidence container" expands on this understanding: traditionally, this was understood to mean the physical packaging in which evidence was secured and transported. In the digital age, however, this term must be broadened. An evidence container is now the secured medium that stores the information contained in the evidence and protects it from alteration, regardless of whether the evidence is physical or digital [11][12].

The documentation requirement no longer applies only to physical packaging, but also to the secured information itself. In the digital twin, every piece of evidence becomes a structured data object with defined attributes and values (Table 1). A fingerprint, for example, is not only stored as an image, but is enriched with metadata such as position, orientation, quality, analysis results and links to other evidence. The systematic structuring of evidence information follows a clear pattern. Each piece of evidence is characterized by specific attributes, which in turn take on concrete values. This approach enables machine processing and analysis of large amounts of data while creating a uniform basis for communication between different investigation teams and specialist disciplines [13].

A practical example illustrates this principle: DNA traces are not simply documented as 'present' but are described based on numerous attributes. These include the exact 3D position at the crime scene, the sample volume, the quality of the DNA, the result of the genetic match, the probability of a match, and many other parameters. Each attribute contributes to the overall information and can be related to data from other evidence. These relationships can be understood as associations.

This structured approach forms the basis for the transfer of patterns and information between objects during the course of events. These information flows can be visualized and analyzed in the digital twin. If, for example, a textile fiber was transferred from the perpetrator to the victim, this relationship can be represented as a directed information flow in the system and correlated with other evidence.

TABLE I. STRUCTURAL LEVELS AND POSSIBLE CONTENT

STRUCTURAL LEVEL	CONTENT
EVIDENCE	THE OBJECT ITSELF (EXAMPLE: SHOE PRINT)
ATTRIBUTE	CHARACTERISTIIC OF THE EVIDENCE (EXAMPLES: LENGTH, PATTERN, POSITION)
VALUE	SPECIFIC CHARACTERISTICS (EXAMPLES: 28.5 CM, PROFILE-TYPE X, COORDINATES)

A central concept in working with digital twins is semantic association, the meaningful linking of different pieces of information. Evidence never stands alone but is part of a complex network of relationships. Recognizing, documenting and analyzing these relationships is crucial for understanding and reconstructing the course of events. Semantic associations can be visualized in various ways: as graphs representing relationships between objects, as 2D or 3D models illustrating spatial relationships, or as simulations reconstructing temporal sequences. The digital twin makes it possible to switch seamlessly between these forms of representation while always retaining the full depth of information. An important aspect is the partial or complete automation of this association generation. Modern AI systems can recognize patterns in the evidence and data and suggest potential connections that human investigators might overlook. However, it should be noted that a loss of information is not synonymous with a loss of detail. In abstraction and modelling, details are deliberately omitted or summarized without losing essential information.

IV. FROM DIGITALIZATION TO DIGITAL TWIN – THE FOUNDATION FOR FORENSIUM

It is important to distinguish between a mere digital copy of a crime scene and a true digital twin. A digital copy is a digital replica or representation, such as a 3D scan of a room. It is static, represents a specific point in time and allows for measurements and visualizations, but not dynamic analyses or simulations. A digital twin, on the other hand, is much more than just documentation. It is a living, evolving system that is continuously enriched with data and integrates various levels of analysis. It combines geometric data with semantic information, physical models and forensic findings to form a coherent whole [14].

Digital copy

- Static 3D image
- Geometric information
- Time-related

Digital twin

- Dynamic model
- Multi-modal data integration

- Cross-period
- Active analysis and simulation.

This distinction has direct practical implications for forensic work. Whereas a digital copy mainly functions as high-quality documentation, a digital twin supports the examination of complex investigative questions, such as whether a witness could have observed the described event from a specific position or which movement sequences are consistent with the available evidence. The transformation from a digital copy into a digital twin occurs through the systematic enrichment of the model with additional information layers, including evidence locations, material analyses, lighting conditions, and temperature profiles. As these data layers accumulate, the analytical value of the system increases, enabling more precise analyses and more reliable reconstructions.

Free Agents in a Cellular Space (FACS) is a hybrid model between agent-based simulation and cellular automata. The FACS approach was developed by Israeli urban researcher Juval Portugali as part of his work on the self-organization of cities and was first presented in 2000 in his work 'Self-Organisation and the City' [15]. It describes a model in which individual, autonomous agents, move within a discrete spatial structure to simulate complex social and spatial processes.

The FACS model thus forms a link between two central modelling approaches in complexity research:

- Cellular Automata (CA) – for modelling spatial structures.
- Agent-Based Models (ABM) – for modelling individual behaviors.

Portugali views cities as self-organizing systems in which macroscopic patterns (e.g., residential areas, traffic flows, social clusters) emerge from microscopic interactions. The FACS model attempts to capture these processes computationally, without central control or deterministic planning [16][17].

The space is divided into a grid of cells, similar to classic CA models (e.g., Conway's Game of Life). Each cell can contain information about the state of the environment (e.g., land use, density, attractiveness).

Agents (free agents) are mobile entities that move between cells. They have internal states (e.g., income, preferences) and decision-making logic (e.g., 'move to where the neighborhood is attractive'). Unlike CA cells, agents are not location-bound but interact dynamically with their environment.

A typical FACS simulation cycle consists of three steps:

1. Perception: Agents gather information from their environment – e.g., neighborhood characteristics or agent density.

2. Decision: Each agent applies decision rules (e.g., utility maximization, neighborhood preference, social attractiveness).

3. Movement/interaction: Agents move within cellular space, thereby changing local conditions.

The interactions of many such agents lead to emergent patterns, e.g., social segregation, spatial clustering or economic concentration.

FACS is primarily used in spatial and urban sociological research, but also in related fields such as:

• Urban development & urban dynamics: simulation of growth processes, land use changes.

• Segregation analyses: investigation of social divisions (similar to the Schelling model but spatially expanded).

• Mobility & migration: analysis of how people respond to spatial and social attractiveness factors.

• Planning & governance: Decision-making support for politics and urban planning by testing scenarios.

FACS is now a cornerstone of urban complexity research and is considered a precursor to modern hybrid models (e.g., multi-agent systems with spatial embedding). The FACS model combines the spatial logic of cellular automata with the autonomous decision-making capabilities of agent-based systems [18].

The basic idea behind hybrid simulation models is transferred to the Forensium and embedded in the forensic context.

V. The Forensium

The digital twin in forensics builds on established technologies from other fields, in particular Geographic Information Systems (GIS), Building Information Modelling (BIM) and the Internet of Things (IoT). These technologies provide the foundation for spatial data integration, detailed object modelling and real-time data acquisition. Geographic Information Systems have proven themselves in cartography, urban planning and environmental monitoring. They enable the management of large spatial data sets, the analysis of geographical relationships and the visualization of complex spatial information. In forensic applications, GIS systems provide the spatial context: Where is the crime scene in relation to roads, buildings and surveillance cameras? What escape routes were available? What public transport was accessible?

The scanned 3D location/space forms the system to be located. Building Information Modelling originates from architecture and construction. BIM models contain not only the geometry of buildings, but also extensive metadata: materials, installations, intended uses of individual rooms, technical systems. If a crime scene is located in a building for which a BIM model exists, this information can be transferred directly to the digital twin. This provides valuable contextual information: Which rooms were locked? Where did power cables or water pipes run? What surveillance systems were installed? The Internet of Things adds a temporal dimension to the digital twin. IoT devices, from smart home systems to vehicle telematics and wearables, continuously generate data streams. This data documents not only conditions, but also how they change over time. When was a door opened? How did the temperature in the room change? What movements did sensors register? The integration of such real-time data turns the digital twin into a living model that not only depicts a point in time but also documents processes and changes.

Copyright (c) IARIA, 2026. ISBN: 978-1-68558-352-1

Figures 1 and 2 show the basic structure and creation of a digital twin (Figure 1) and the transition to the Forensium (Figure 2).

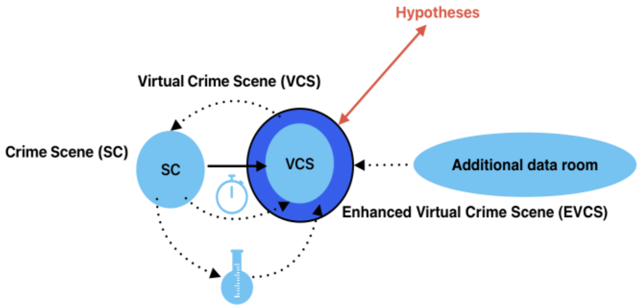

Figure 1. Forensium: A virtual crime scene is created from a crime scene, containing all objects, including future evidence carriers. The evidence relevant to the case is transferred to the laboratory, and the information obtained is used to construct an extended virtual crime scene. By enriching it with additional data and information, the extended virtual crime scene can obtain further information and serves as the basis for falsifying and verifying forensic hypotheses in the hypothesis-driven investigation cycle.

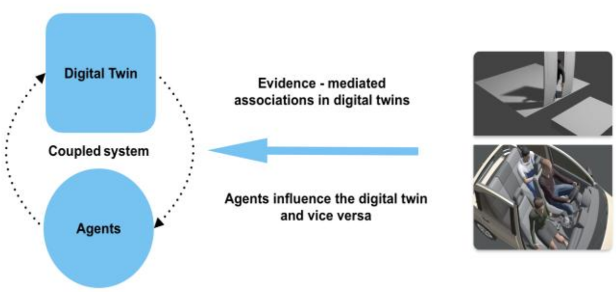

Figure 2. Representation of the Forensium as a coupled system. (analogous to FACS). FRE3 – free agents in 3D enviroment.

A particular challenge when working with digital twins in forensics is the integration of subjective content, especially witness statements. The digital twin strives for objectivity and is based on measurable physical data. Witness statements, on the other hand, are subjective perceptions that are influenced by memory errors, interpretations and emotional states.

Large Language Models (LLMs), as representatives of foundation models, offer new possibilities here. Their main field of application lies in the automated collection, structuring and semantic interpretation of unstructured data. Witness statements are typically available in text form, as interrogation transcripts, free descriptions or memory logs. LLMs can analyze these texts, extract relevant information and convert it into structured data formats that can be integrated into Forensium [19].

One of the biggest challenges in lengthy investigations is the fading of memories. Witnesses who were able to provide precise information immediately after the event often cannot remember important details months or years later. Forensium cannot completely solve this problem, but it does offer tools for dealing with uncertain or incomplete witness statements. The central question is often not ‘Who saw what?’ but ‘Who could have seen what?’.

The digital twin enables a systematic analysis of this question: based on the known or presumed position of a witness, lines of sight can be calculated. Which areas of the crime scene were visible from this position? At what times, under what lighting conditions? Were there any obstacles blocking the view?

These analyses are particularly valuable when different witnesses give contradictory statements. Forensium can show that both statements may be correct if the witnesses observed events from different perspectives, or it can reveal that a statement is incompatible with the spatial conditions. Such objective checks help to assess the credibility of witnesses without accusing them of dishonesty. Contradictions are often simply the result of different perspectives or cognitive distortions.

The concept of a coupled system makes it possible to connect the actors with the digital twin in the Forensium. This allows simulations to be carried out for individual agents or groups of agents. The use of physics engines enables the description and calculation of interactions between agents and the digital twin, providing new insights for ongoing investigation. A physics engine is a computer program or module that ensures that objects behave realistically in simulations, animations or Virtual Reality (VR). Among other things, it calculates gravity, collisions between objects, friction, elasticity, masses, movements (speed, acceleration, momentum) and fluid or particle simulations. One such simulation (falling from a train) is shown in Figure 2 (top right).

VI. Outlook – The Future of Forensic Digital Twin and the Forensium

Digital twin technology is still in its infancy in forensic applications. The coming years will bring significant advances in several areas that will further revolutionize its possibilities. The integration of artificial intelligence, the standardization of interfaces and the increasing availability of real-time data will make the digital twin an indispensable tool in modern investigative work, the Forensium. One promising approach is to record the crime scene with evidence in different layers. Various recording modalities, thermal imaging, different light spectra and acoustic measurements can be used in parallel to create a multidimensional image of the crime scene. Thermal imaging cameras document temperature distributions, which allow conclusions to be drawn about the sequence of events. Multispectral cameras capture evidence that is invisible to the naked eye. Acoustic analyses can capture room geometries and simulate sound propagation. The relationship between the different layers forms the input for the association layer, in which the semantic relationships between the evidence for the specific course of events reflect the entire case.

The increasing interconnectedness of our environment through IoT devices will make automatically collected data the norm. Smart buildings, connected vehicles and wearable technology continuously generate data trails that can be used in investigations. The challenge will no longer be data collection, but rather intelligent filtering and analysis of the flood of data. Machine learning will help to recognize relevant patterns and identify anomalies. Legal and ethical issues will become increasingly important. Comprehensive digital documentation raises questions of data protection and data security.

The first steps in development have already been taken. An example of this is the work of Volkmann et al. [19]. The paper examines the potential of digital twins in combination with Large Language Models (LLMs) and Building Information Modelling (BIM) for police investigations. The focus is on how immersive, data-driven reconstructions of crime scenes can help to systematically analyse and verify gaps in perception, memory distortions and uncertainties in witness statements. The case study involves a sexual offence against a six-year-old girl, in which an older man is suspected. The child witness belongs to a particularly vulnerable group, which is why gaps in perception and memory are to be expected. Among other things, the child remembers:

- a 'shiny object' in the perpetrator's right ear
- sunny lighting conditions, without being able to specify the time of day.

Further witness statements also provide only vague details ('sunny day'). Even a forensic psychological assessment was unable to clarify these open questions. LLMs are described in the paper as a linguistically intelligent extension of the digital twin. LLMs thus function as cognitive partners, not as autonomous decision-makers. Using real weather and geodata, a sun position analysis is carried out in the digital twin. The aim is to check at what times of day a reflective object in the perpetrator's ear may have been visible from the child's perspective. These changes in perspective can be used to show when and why certain perceptions were possible or impossible. At present, 'individual parts' of the Forensium are being analysed to combine the concept presented here in the near future.

In conclusion, it can be said that the Forensium and the digital twin represent a paradigm shift in forensic work. They transform evidence collection from a destructive to a conservative process. They enable the integration of heterogeneous data sources into a coherent overall picture. They make complex spatial-temporal relationships visualizable and analyzable. And they create a basis for more objective, transparent and comprehensible reconstructions of criminal events. The journey has only just begun, but the potential is enormous.

ACKNOWLEDGMENT

The author would like to thank Mr. Dirk Volkmann for his expert discussions and critical comments.

REFERENCES

[1] M. Grieves and J. Vickers, Digital Twin: Mitigating Unpredictable, Undesirable Emergent Behavior in Complex Systems, 2002. [Online]. Available: https://www.researchgate.net/profile/Michael-Grieves/publication/307509727_Origins_of_the_Digital_Twin_Concept/links/57c6f44008ae9d64047e92b4/Origins-of-the-Digital-Twin-Concept.pdf [rerieved: 11, 2025]

[2] H. Lasi, P. Fettke, H.-G. Kemper, T. Feld, and M. Hoffmann, "Industry 4.0," Business & Information Systems Engineering, vol. 6, no. 4, pp. 239–242, 2014.

[3] H. Kagermann, W. Wahlster, and J. Helbig, Recommendations for Implementing the Strategic Initiative INDUSTRIE 4.0. Berlin: acatech, 2013.

[4] K. Ashton, "That 'Internet of Things' Thing," RFID Journal, 2009.

[5] J. Gubbi, R. Buyya, S. Marusic, and M. Palaniswami, "Internet of Things (IoT): A Vision, Architectural Elements, and Future Directions," Future Generation Computer Systems, vol. 29, no. 7, pp. 1645–1660, 2013.

[6] M. Grieves, Digital Twin: Manufacturing Excellence through Virtual Factory Replication, White Paper, 2014. [Online]. Available: https://theengineer.markallengroup.com/production/content/uploads/2014/12/Digital_Twin_White_Paper_Dr_Grieves.pdf [retrieved: 11, 2025]

[7] S. Sabri, K. Alexandridis, and N. Lee, Digital Twin: Fundamentals and Applications. Cham: Springer, 2024. doi: 10.1007/978-3-031-67778-6.

[8] S. L. Weiss, Handbook of Forensic Photography, Boca Raton, FL: CRC Press, 2022.

[9] N. D. N. A. Mendis, "Forensic Photography: Concepts and Applications for Better Crime Scene Examination," Medico-Legal Journal of Sri Lanka, vol. 9, no. 1, pp. 47–49, 2021.

[10] A. Bell, "Crime Scene Photography in England, 1895–1960," Journal of British Studies, vol. 57, no. 1, pp. 53–78, 2018. doi: 10.1017/jbr.2017.182.

[11] T. Trejos, S. Koch, and A. Mehltretter, "Scientific foundations and current state of trace evidence—A review," Forensic Chemistry, vol. 18, 2020, Art. 100223. doi: 10.1016/j.forc.2020.100223. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2468170920300114 [retrieved: 11, 2025]

[12] H. van Beek, C. van den Pol, and J. van der Weerd, "Criminalistic zoom levels: Unravelling the hierarchy of forensic traces," Forensic Science International, vol. 372, 2025, Art. 112498. doi: 10.1016/j.forsciint.2025.112498.

[13] S. Francese, Emerging Technologies for the Analysis of Forensic Traces. Cham: Springer, 2020. doi: 10.1007/978-3-030-20542-3.

[14] G. Galanakis et al., "A Study of 3D Digitisation Modalities for Crime Scene Investigation," Forensic Sciences, vol. 1, no. 2, pp. 56–85, 2021. doi: 10.3390/forensicsci1020008

[15] J. Portugali, Self-Organization and the City, Berlin: Springer, 2000, ch. 5, "Free Agents in a Cellular Space." doi: 10.1007/978-3-662-04099-7_5.

[16] I. Benenson and P. M. Torrens, Geosimulation: Automata-Based Modeling of Urban Phenomena. Hoboken, NJ: Wiley, 2004.

[17] J. Portugali, Complexity, Cognition and the City. Heidelberg: Springer, 2011.

[18] M. Batty, The New Science of Cities. Cambridge, MA: MIT Press, 2013.

[19] D. Volkmann, S. Schildein, R. Povalej, and D. Labudde, *A Case Study for Immersive Technology-Based Evidence Representation*, 2025. [Online]. Available: https://link.springer.com/book/10.1007/978-3-032-07986-2 [retrieved: 11, 2025].