Parallel Exhibition: An ACP-Based Framework for Organization and Management of MICE Systems

SANGTIAN GUAN[1], SIJI MA[1], JUN HUANG[1], WEN DING[2]
[1]Faculty of Innovation Engineering, Macau University of Science and Technology, Macao 999078, China
[2]QAII, Shandong 266111, China
Corresponding author Sangtian Guan (e-mail: sangtian.guan@ieee.org).

ABSTRACT The MICE (Meetings, Incentives, Conferences, and Exhibitions) industry serves as a critical infrastructure of the global service economy, combining huge economic scale with an irreplaceable knowledge spillover function. However, the essential characteristics of temporary organizations give rise to multidimensional management challenges, including multi-participant conflicts, spatiotemporal uniqueness, rigid regional constraints, and emergent crowd behavior. Existing project management tools, isolated technologies, and digital twin methods are all insufficient to address these complex challenges. In this paper, we propose a parallel exhibition intelligent management framework based on the ACP (Artificial systems, Computational experiments, Parallel execution) approach. We design a collaborative mechanism among three types of humans—biological humans, digital humans, and robotic humans—to enable virtual-real closed-loop management. The framework aims to achieve coordination among participants, transferable experience accumulation, and real-time dynamic regulation through the ACP approach, addressing systemic management challenges in the MICE industry through a system-level approach and offering a reference for the intelligent management of complex social systems.

INDEX TERMS Parallel Exhibition, ACP, Parallel Intelligence, MICE Management, Complex Systems, Digital Human

I. INTRODUCTION

THE MICE (Meetings, Incentives, Conferences, and Exhibitions) industry is a critical link connecting production with consumption and enabling industrial coordination and knowledge innovation. The global MICE market size reached \$598.2 billion in 2022 and is projected to grow at 11.6% annually through 2032 [1], with direct GDP contributions exceeding \$662.6 billion [2]. Beyond direct economic contributions, MICE industries function as "temporary clusters" that facilitate tacit knowledge exchange, cross-organizational trust building, and innovation catalysis through face-to-face interaction [3], [4], making MICE events essential nodes in global knowledge pipelines.

Nevertheless, MICE industries are fundamentally temporary organizations characterized as "spatiotemporal phenomena" [5], whose management involves multiple participants subject to regional infrastructure constraints and nonlinear emergent crowd behavior, creating coupled systemic challenges. Current MICE management approaches lack the capacity to model multi-participant complex interactions; technologies such as agenda recommendation and crowd monitoring exhibit fragmented and open-loop characteristics, making it hard to react to unforeseen on-site emergencies; and digital twin technology cannot adequately adapt to human-dominated MICE social systems due to its reliance on reductionist high-fidelity physical modeling. These limitations call for a fundamentally new management paradigm.

The ACP (Artificial systems, Computational experiments, Parallel execution) approach [6] provides a novel paradigm for managing complex systems: instead of pursuing precise prediction based on analytical models, it constructs functionally equivalent artificial systems, explores multiple possible development paths through computational experiments, and steers real systems toward desired outcomes through parallel execution, establishing effective prescription as its core objective. Based on this approach, we propose the concept of parallel exhibition as an intelligent management framework for MICE systems.

The main contributions of this paper are as follows:

- We propose the concept of parallel exhibition, establishing a systematic intelligent management framework for the MICE industry based on the ACP approach, which

aims to transcend the limitations of existing reductionist and fragmented approaches.
- We construct the parallel exhibition system architecture, integrating the ACP approach with a collaborative mechanism among three types of humans—biological humans, digital humans, and robotic humans—to enable virtual-real closed-loop management.
- We present an illustrative academic conference scenario to show the intended workflow and potential applicability of the proposed framework.

The remainder of this paper is organized as follows. Section II reviews MICE industry challenges, existing management methods, and parallel intelligence applications. Section III presents the parallel exhibition system architecture, including the three types of human collaborative mechanism and the application of the ACP approach for MICE. Section IV provides scenario validation. Section V concludes the paper.

II. RELATED WORK

A. MICE INDUSTRY CHARACTERISTICS AND MANAGEMENT CHALLENGES

Given the strategic importance of the MICE industry, there exists a series of research trying to capture its key characteristics. For instance, Bathelt and Schuldt proposed the "global buzz" mechanism, demonstrating that temporary co-presence generates high-frequency information and knowledge spillovers, while Maskell et al. defined exhibitions as critical nodes in global knowledge pipelines, where tacit knowledge exchange, cross-organizational trust building, and innovation catalysis drive knowledge creation [7], [8].

However, exhibitions are fundamentally temporary organizations whose time-limited and spatially non-replicable nature creates distinctive management challenges. Getz defined planned events as spatiotemporal phenomena, where each event presents a unique combination under specific conditions [5]. This spatiotemporal uniqueness aligns with the 4T framework [9] and gives rise to four core management challenges. First, multi-participant conflicts: MICE management involves multiple actors—governments, venue operators, exhibitors, sponsors, and attendees—with significantly different objectives, and the dynamic interactions and information asymmetry among these objectives increase coordination difficulty [10]. Second, spatiotemporal uniqueness and fragmented experience: each event's host city, venue layout, and participant composition differs, making it difficult to transform past experience into systematic, reusable knowledge. Third, rigid regional infrastructure constraints: exhibition operations rely on local infrastructure with rigid upper limits on traffic capacity, accommodation, catering supply, and security resources, where misjudgment can trigger chain reactions. Fourth, nonlinear emergence of attendee behavior: small individual behavioral differences are continuously amplified through local interactions, producing unpredictable macroscopic emergent phenomena [11], [12], and macroscopic crowd behaviors cannot be predicted through simple aggregation of individual behaviors.

These challenges are intertwined and mutually amplifying. Perrow argued that in systems with high complexity and tight coupling, accidents are a normal, inevitable feature [13]. The Duisburg Love Parade stampede (2010), where inadequate crowd management at a narrow tunnel entrance led to 21 deaths, and the Itaewon crowd crush (2022), where coordination failures in a dense urban district resulted in 159 fatalities, both demonstrate that multi-party coordination failures, exacerbated by rigid regional constraints and emergent crowd behavior, can lead to systemic collapse [14], [15]. These real-world pain points demand constructing a holistic, closed-loop intelligent management framework that simultaneously addresses multi-participant strategic interaction, experience transfer, regional adaptation, and emergent behavior.

B. EXISTING MANAGEMENT METHODS AND THEIR LIMITATIONS

Gantt charts and Work Breakdown Structures (WBS) decompose MICE projects into linear task hierarchies and schedule dependencies and remain the core tools in MICE management. However, their linear decomposition cannot capture the dynamic interactions of multi-participant games; for instance, a government's increased security requirement may trigger venue layout changes cascading into exhibitor adjustments and logistics rearrangements—such nonlinear chain reactions fall outside the scope of traditional linear planning tools [10], [16].

AI and internet of things (IoT) technologies have produced isolated solutions including agenda recommendation, crowd monitoring, and smart check-in, improving efficiency to some extent. However, isolated technologies suffer from two core problems: fragmentation, where technologies operate independently with non-interoperable data creating "information silos" [17]; and open-loop operation, lacking real-time feedback and dynamic calibration [18].

Many crowd management studies rely on individual-level models such as the Social Force Model [11] to simulate pedestrian movement through force-based interaction rules. While these models can reproduce certain microscopic movement patterns, crowd behavior may also exhibit nonlinear emergence, meaning that individual-level models alone are often insufficient for reliable macro-level prediction [19], limiting prediction accuracy and providing insufficient support for management decision-making.

Digital twin technology constructs high-fidelity replicas of physical entities and achieves sensor-based closed loops, with notable success in manufacturing [20], [21]. However, several core variables in MICE systems—especially human decisions and participant interactions—are difficult to model precisely, difficult to observe directly, and likely to exhibit emergent dynamics, limiting the effectiveness of digital twin approaches in behaviorally rich MICE settings [22]. In contrast, parallel intelligence emphasizes functional equivalence and system-level coordination, which may be more suitable for such settings [6].

In summary, existing methods either employ linear thinking to address nonlinear systems, focus on isolated problems while ignoring system coupling, or rely on reductionist modeling that cannot adapt to human-dominated social systems. A new framework must satisfy core design requirements: transcending reductionist modeling, achieving systematic integration of multi-participant strategic interaction, constructing closed-loop feedback mechanisms, and accommodating different scales through tiered deployment.

C. PARALLEL INTELLIGENCE

Parallel intelligence, first proposed by Wang [23], is an intelligent theory oriented toward complex social systems. Its core is to address the three fundamental challenges of complex systems, difficulty in precise modeling, inability to repeat experiments, and difficulty in real-time regulation, through the ACP approach. Philosophically, parallel intelligence is grounded in holism and Popper's three-world theory, which posits the coexistence of the physical world (World 1), the subjective mental world (World 2), and the objective world of human creations such as theories and artifacts (World 3); artificial systems can be understood as knowledge-bearing constructs in World 3, which provides a philosophical foundation for the parallel exhibition framework.

The ACP-based parallel intelligence methodology has been applied to a growing range of complex social systems, providing a theoretical foundation for the parallel exhibition framework. In transportation, parallel transportation systems construct artificial traffic environments to achieve real-time regulation of urban traffic flow through computational experiments and parallel execution, effectively addressing nonlinear congestion dynamics and multi-participant coordination in urban mobility [24]. In manufacturing, parallel manufacturing systems introduce foundation models and parallel workers into smart factories, improving production flexibility through virtual-real collaboration [25]. More recently, parallel tourism systems integrate foundation models and DAOs to address challenges in personalized service delivery and intelligent management of complex travel ecosystems [26]; parallel museums construct virtual museums for computational experiments to optimize exhibition design, visitor flow control, and safety management—challenges that directly parallel those faced in exhibition venues [27]; parallel art proposes computational frameworks for artistic creation that extend the parallel intelligence paradigm into cultural production [28]; and parallel theaters leverage immersive simulation environments for collective decision-making within CPSS, offering a model for multi-participant coordination under uncertainty [29].

These applications demonstrate the ACP approach's cross-domain potential in complex social systems characterized by multi-participant dynamics, human behavioral uncertainty, and spatiotemporal constraints. Notably, parallel museums and parallel theaters address challenges—visitor flow optimization, safety management, and multi-participant coordination—that directly parallel those encountered in exhibition venues, suggesting that the ACP approach is particularly well-suited for the MICE domain. However, the application of parallel intelligence to MICE management remains unexplored, and the proposed parallel exhibition framework is intended to address this gap.

III. PARALLEL EXHIBITION SYSTEMS

Based on the ACP approach, we construct the parallel exhibition systems framework. The three components progressively build upon each other and cycle continuously, forming the intelligent management systems covering the full lifecycle of exhibitions. Figure 1 illustrates the overall framework.

The parallel exhibition is centered on the ACP approach, with a collaborative mechanism among three types of humans—biological humans, digital humans, and robotic humans—as its operational carrier. The three ACP components are deeply coupled and operate collaboratively, with core inputs including regional constraint parameters, participant requirements, and exhibition data, and primary outputs including optimized exhibition plans, emergency rule libraries, and management knowledge bases. The architecture possesses three core characteristics: comprehensiveness: covering the full lifecycle of exhibition preparation, execution, and conclusion while integrating multiple participants and multi-process management; closed-loop capability: enabling synchronized bidirectional feedback between virtual and real systems through parallel execution; and adaptability: calibrating model parameters, supplementing rule libraries, and updating knowledge bases through real data feedback to support continuous system evolution.

A. THREE TYPES OF HUMANS

The three types of humans—biological humans, digital humans, and robotic humans—collectively constitute a functionally stratified working system for parallel exhibition management. Biological humans fulfill governance, decision-making, cross-party coordination, and responsibility attribution; digital humans provide cognitive processing, computational support, interactive services, and continuous online operation; and robotic humans handle on-site perception, execution, guidance, and physical manipulation. This functional stratification reflects the ACP philosophy at the operational level: biological humans serve as the governance layer for goal-setting and accountability; digital humans construct and run the artificial systems that enable computational experiments; and robotic humans translate virtual decisions into physical execution. Together, they form a collaborative mechanism that constitutes the multi-agent system for virtual-real collaboration across physical and cyber dimensions.

Biological humans are higher-order governance entities within the exhibition system, including conference chairs, organizing committee members, program committee mem-

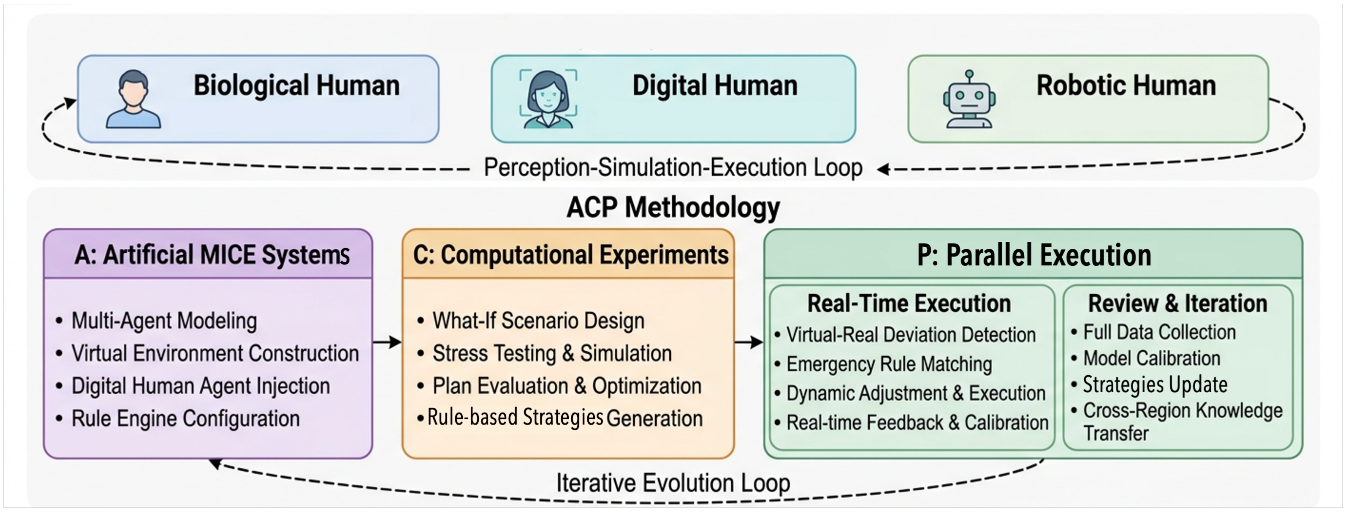


FIGURE 1: Overview of parallel exhibition framework.

bers, operations managers, venue managers, sponsorship and partnership managers, security and medical personnel, and key volunteer supervisors. They are responsible for objective-setting, rule formulation, resource allocation, cross-party coordination, conflict adjudication, risk management, and ultimate responsibility attribution. In academic conferences, their core tasks include topic design, peer review policy, speaker invitations, budget approvals, on-site decisions, and emergency response; in exhibitions, they govern booth planning, brand partnerships, audience strategy, business matchmaking, operations coordination, and safety governance. The value of biological humans lies in situational judgment, value trade-offs, organizational authorization, and closing accountability loops.

Digital humans are cognitive and service agents operating within the cyber domain, manifesting as digital conference secretaries, digital peer review assistants, digital customer service agents, digital guides, digital business matching assistants, digital scheduling optimizers, digital publicity agents, and virtual venue operators within the artificial exhibition. In academic conference scenarios, digital humans continuously perform large-scale, high-frequency cognitive labor including submission inquiry response, initial paper format screening, agenda scheduling recommendations, attendee profiling analysis, review progress coordination, schedule reminders, multilingual consultations, and integrated online-offline coordination. In exhibition scenarios, they manage exhibitor matching, buyer recommendations, visitor guidance, booth inquiry response, transaction lead collection, promotional content generation, and operational data analysis. The significance of digital humans lies in depositing scalable, replicable, and real-time-responsive intelligent service capabilities that would otherwise require prohibitive human labor.

Robotic humans are embodied execution agents within the physical exhibition system, including check-in verification devices, service robots, guide robots, security inspection robots, logistics handling robots, cleaning robots, intelligent recording equipment, intelligent access control terminals, and other automated devices capable of performing on-site tasks. They bear responsibility for physical space execution, environmental perception, process implementation, and operational feedback. In academic conferences, robotic humans can be deployed for check-in guidance, venue inspection, equipment coordination, material delivery, and venue order maintenance; in exhibitions, they can manage booth guidance, sample handling, route direction, security monitoring, environmental maintenance, and interactive demonstrations. The significance of robotic humans lies in translating virtual-layer scheduling and decision-making into concrete actions within venue spaces, forming a complete closed loop from information processing to physical execution.

The operational coordination among the three types of humans follows an event-driven three-mode structure: Autonomous Mode, Parallel Mode, and Expert/Emergency Mode. These three modes dynamically invoke different human configurations based on task standardization, anomaly complexity, and risk level, collectively forming the organizational foundation for parallel exhibition management.

Autonomous Mode (AM) handles the majority of exhibition operations over 80% of total workload, where processes are clear-cut and rule-based. In this mode, digital humans manage cognitive processing and workflow orchestration, robotic humans execute physical tasks on-site, and biological humans exercise overall supervision and quality control. In academic conferences, this covers routine operations such as submission inquiries, registration verification, agenda notifications, venue guidance, and basic attendee services; in exhibitions, it covers visitor registration, booth navigation, lead collection, standard inquiries, and traffic monitoring. AM bears the primary operational load of the system.

Parallel Mode (PM) addresses the remaining operational scenarios, which occupy lower than 15% of total workload, that involve uncertainty, cross-departmental coordination, or moderately complex anomalies. In this mode, digital humans and robotic humans continue operating at baseline, while biological humans enter the loop remotely through parallel participation. For academic conferences, this includes manuscript review conflicts, speaker schedule adjustments, sub-forum agenda rescheduling, online-offline venue synchronization failures, multilingual complex communications, and VIP attendee customization; for exhibitions, this includes urgent client matchmaking, dynamic booth resource adjustments, key exhibitor coordination, on-site crowd redistribution, and real-time communication strategy corrections. PM embodies the principle of "virtual-real parallel operation, human-machine coordination, and remote participation in the loop."

Expert/Emergency Mode (EM) handles low-frequency but high-consequence critical events under 5% of total workload, that carry significant risk or strong scenario dependence. In this mode, biological humans become the on-site leaders, digital humans provide intelligence aggregation, case retrieval, scenario analysis, and decision support, and robotic humans assist through sensing, isolation, guidance, and physical execution. For academic conferences, this covers medical emergencies, VIP protocol changes, critical system failures, major public opinion incidents, security threats, and venue-scale disruptions; for exhibitions, this covers equipment accidents, fire hazards, crowd safety incidents, core business disputes, and major operational interruptions. EM bears low-frequency but high-value critical tasks.

B. ARTIFICIAL EXHIBITION

Artificial exhibition is the concrete realization of the artificial systems component of the ACP approach in the MICE scenario. The core principle is the construction of computational models functionally equivalent to real systems, focusing on "how the system operates" rather than replicating the hardware details of physical components one-to-one. This functional equivalence principle reduces computational cost while effectively adapting to sociological variables that are difficult to quantify in complex social systems. In the MICE context, this means constructing virtual exhibition environments that capture the essential dynamics of participant interactions, crowd movement, and resource constraints without requiring precise physical replication of venue infrastructure.

Based on this principle, the artificial exhibition constructs a virtual exhibition environment using multi-agent modeling technology, introducing multi-role digital humans to simulate the full-process operation and evolution of the exhibition, combined with the Social Force Model by Helbing and Molnár for spatial movement modeling to ensure simulation validity [11].

The construction process includes three steps: first, inputting core parameters including exhibition plans, regional constraint parameters, and participant requirements; second, constructing the virtual environment based on multi-agent modeling technology, incorporating virtual mapping of regional constraints; third, introducing multi-type, multi-objective digital humans with corresponding behavioral patterns, decision logic, and objective functions.

The core innovation of the artificial exhibition lies in transforming exhibition planning from "preset input" to "experimental output": through initialization, construction, and agent connection phases, the system inputs physical spatial parameters, regional rigid constraints, and participant demand functions; builds a virtual venue with interactive capabilities and dynamic mapping of regional constraints; and configures access protocols, interaction rules, and payoff distribution algorithms via a flexible rule engine, so that the final exhibition plan emerges through iterative experiments, stress tests, and game equilibria within the artificial systems rather than manual drafting. The artificial exhibition captures behavioral patterns at the macroscopic level rather than pursuing precise individual-level modeling, which is both computationally infeasible and practically unnecessary for MICE management decision-making. This macroscopic focus distinguishes the parallel exhibition approach from digital twin methods that emphasize high-fidelity physical replication: rather than attempting to reproduce the exact physical attributes of venue infrastructure, the artificial exhibition aims to capture the essential dynamics, where participant interaction patterns, crowd flow regularities, and resource constraint effects, that govern exhibition system behavior, enabling computational tractability while preserving managerial relevance.

C. COMPUTATIONAL EXPERIMENTS

Computational experiments constitute the core exploratory component of the ACP approach. Since physical-world MICE events are irreversible and management experience cannot be acquired through destructive testing, computational experiments leverage the repeatability of artificial systems to provide a safe virtual testing ground, exploring the possibility space of evolution under multiple constraints. Through massive exploration, the system distills scattered trial-and-error results into standardized strategy libraries, transcending the theoretical barrier of non-repeatable experimentation in complex social systems.

In the MICE scenario, computational experiments run massive *"WHAT-IF"* scenario experiments on the artificial exhibition, enabling plan evaluation, stress testing, and generation of transferable knowledge. The operational process follows four steps: designing experimental scenarios (normal operation, participant gaming, crowd congestion, and emergency scenarios); running simulations under different scenarios to collect experimental data; evaluating and optimizing plans based on results; and extracting "scenario-to-optimal response strategy" associations into a standardized rule library that abstracts away venue-specific topological data, retaining only the mathematical mapping between crowd dynamics parameters and evacuation strategies for cross-regional reuse.

The computational experiment mechanism anticipates execution effects and potential risks before exhibition execution, enabling ex-ante optimization, and accumulates systematic management experience for knowledge reusability and cross-regional transfer [30]. This directly addresses the "inability to repeat experiments" barrier in complex social systems by providing a virtual environment where destructive testing and extreme scenario exploration become feasible without real-world consequences.

D. PARALLEL EXECUTION

Parallel execution is the implementation and validation component of the ACP approach, aiming to establish dynamic bidirectional mapping between virtual models and physical entities. The system continuously extracts real-time states from the physical side and compares them with expected trajectories from the virtual side, forming a deviation detection mechanism. This dynamic feedback compensates for the unidirectional execution limitation of traditional open-loop management, ensuring that management strategies can track and respond to system evolution in real time. In the MICE context, parallel execution achieves real-time synchronous operation between the artificial and real exhibitions, enabling bidirectional closed-loop management during exhibition execution through deviation detection, emergency rule matching, and execution effect feedback [31].

The operational process forms a continuously cycling closed loop. First, virtual-real synchronization and deviation detection: real-time data from the real exhibition is collected through sensors, IoT, and mobile terminals, and injected into the artificial exhibition to detect operational deviations. Second, contingency matching and decision generation: deviations within rule library coverage trigger direct strategy matching; deviations exceeding coverage trigger real-time computational experiments to explore new strategies. Third, instruction dispatch and physical execution: adjustment instructions are dispatched to attendees and staff via mobile terminals, to robotic humans as physical execution instructions, and to participants via communication platforms. Fourth, effect feedback and virtual-real calibration: execution effects are fed back in real time, and parallel execution calibrates the artificial exhibition's model parameters accordingly.

After the exhibition concludes, parallel execution processes the full dataset through three steps: comprehensive data collection and structuring; model calibration and rule library supplementation by fitting real data to digital humans' behavioral parameters; and knowledge base updating for cross-regional and cross-scenario transfer. Together, the artificial exhibition provides the virtual foundation, computational experiments explore the possibility space, and parallel execution achieves real-time virtual-real synchronization and accumulates transferable knowledge, with each exhibition cycle designed to refine the systems intelligence.

IV. SCENARIO VALIDATION: ACADEMIC CONFERENCE SCENARIO

To demonstrate the practical applicability of the parallel exhibition framework, we present a scenario validation using an academic conference setting. The framework operates through three event-driven modes: AM, PM and EM. Figure 2 illustrates the key stages of scenario validation.

Consider an annual computer science conference at a large conference center with approximately 8,000 attendees, spanning three days of main forums, twelve parallel sub-forums, poster sessions, and an industry exhibition. Participants include the academic committee, local MICE authorities, the venue operator, the event company, sponsoring enterprises, and attending scholars. This scenario exemplifies the core management challenges identified in Section II: multi-participant conflicts among the academic committee, venue operator, and local government; spatiotemporal uniqueness as a one-time event in a specific city; rigid regional constraints from local infrastructure; and nonlinear emergence of crowd behavior during session transitions.

Ex-ante preparation phase The system receives venue layout data (hall dimensions, passage widths, fire code occupancy limits), regional constraint parameters provided by the local government (hotel bed capacity in the vicinity, peak-hour capacity of the nearest metro station, parking capacity, deployable security personnel limits), a draft agenda from the academic committee, and exhibitor requirements from sponsoring enterprises. These data constitute the initial input for the artificial exhibition system. The artificial exhibition constructs a virtual venue mirroring the real conference center, incorporating spatial constraints such as corridor widths and room capacities, while generating multiple types of digital human parameterized by historical data.

Multiple types of digital humans are generated in the artificial exhibition. Attendee digital humans are parameterized by historical data: senior scholars tend to attend keynotes and specific sub-forums, doctoral students move more frequently between poster areas and multiple sub-forums, and industry participants concentrate in the exhibition area. When these attendee digital humans navigate the virtual venue, their movement trajectories follow the Social Force Model, producing emergent crowd patterns at corridor intersections and bottlenecks that reveal potential congestion points before the real event occurs. Organizational-level digital humans simulate each participant's decision logic: the government authority's digital human prioritizes public safety, automatically triggering flow restrictions when crowd density approaches fire safety thresholds; the venue operator's digital human pursues a balance between facility utilization and operational efficiency; the academic committee's digital human focuses on knowledge dissemination effectiveness and attendee academic experience; and the sponsoring enterprise's digital human monitors brand exposure and attendee visit rates.

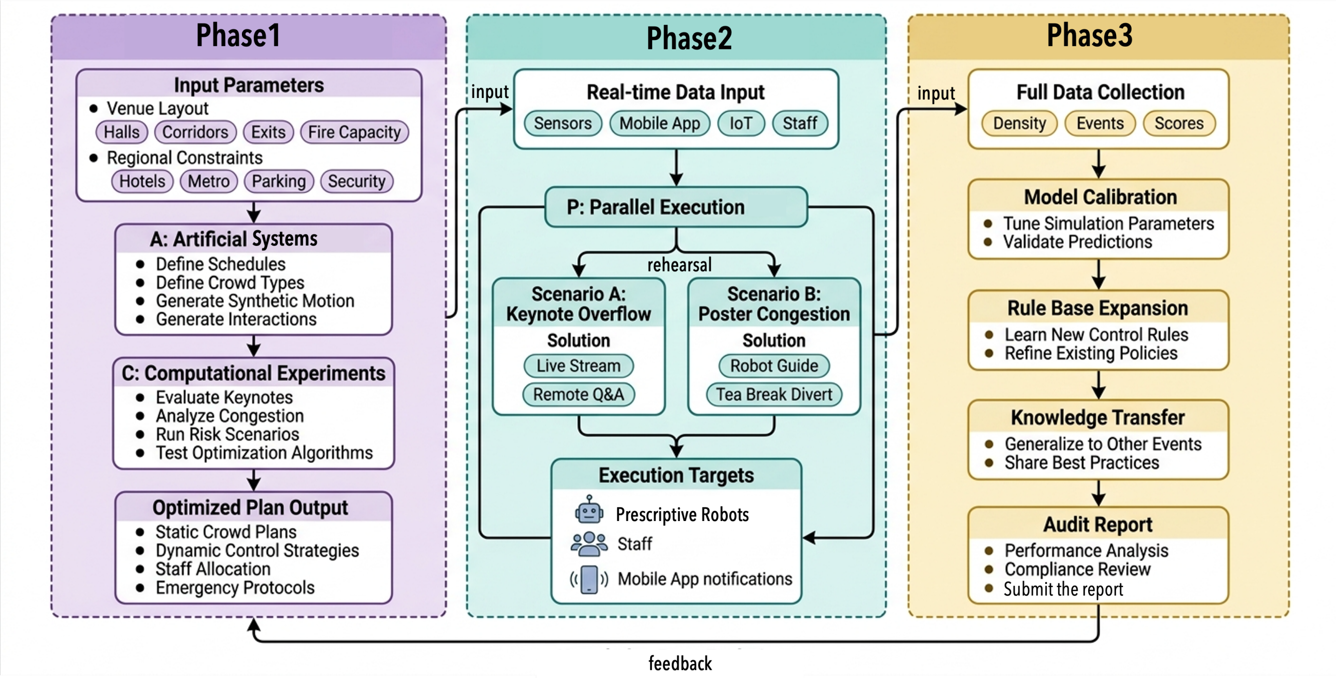


FIGURE 2: Scenario validation of the parallel exhibition framework in an academic conference setting.

The interaction among these organizational digital humans produces dynamics. For instance, the academic committee's preference for large-capacity keynote halls conflicts with the government authority's safety-driven capacity limits, and the system captures these tensions as multi-objective optimization problems rather than treating them as independent constraints.

The computational experiment module identifies critical issues: after the keynote speech, thousands of attendees must transition to sub-forums, yet corridor passage capacity is insufficient, causing sustained high-density congestion; hotel bed capacity shows a significant gap; and metro passenger flow is near saturation. The system generates and evaluates multiple alternative plans through thousands of simulation runs: for accommodation, delaying the main forum opening to avoid morning peak, relocating low-relevance workshops to nearby universities, and adding shuttle services; for corridor congestion, staggering sub-forum start times into two batches interspersed with tea breaks, significantly reducing peak density. Additionally, the system simulates deploying prescriptive robots at corridor intersections to further disperse crowd flow. Multi-participant satisfaction is quantitatively evaluated through digital humans' objective functions, and multi-objective optimization algorithms select the plan with the highest composite score. This transforms multi-participant coordination from experience-based manual negotiation into quantifiable computational experiments, directly addressing the multi-participant conflict and regional constraint challenges.

During-conference execution phase The parallel execution module maintains virtual-real synchronization through sensors and the conference application, continuously injecting real-time data into the artificial exhibition to detect operational deviations. Routine operations proceed under AM: digital humans handle submission inquiry responses, agenda updates, and attendee notifications, while robotic humans manage automated check-in, guided navigation, and standardized service delivery, with biological humans providing overall supervision.

When deviations exceed rule library thresholds, the system switches to PM: biological humans enter the loop remotely alongside digital and robotic humans for coordinated real-time adjustment. When a keynote speech attracts unexpectedly large attendance approaching fire code occupancy limits, the system detects the anomaly and explores response options in the artificial exhibition: opening adjacent halls for synchronized livestreaming with remote question priority. A biological human coordinator (e.g., the operations manager) approves the response strategy remotely; digital humans generate specific diversion ratios and timeline parameters; and robotic humans execute the physical redirection. The solution is dispatched to three human types: prescriptive robots direct arrivals to the livestream venue; staff set up equipment; the application pushes sub-venue information. Within minutes, crowd density drops to safe levels with no disruption to academic exchange. This example illustrates the PM deviation detection–strategy generation–remote approval–instruction dispatch loop.

When a critical emergency occurs—such as a medical incident, fire alarm, or security threat—the system escalates to EM: biological humans become on-site leaders with direct situational command authority, digital humans provide rapid case retrieval, scenario analysis, and decision support, and robotic humans execute isolation, guidance, and physical assistance. For instance, upon detecting a fire alarm, a biological human safety officer takes immediate command; the digital human system instantly retrieves the venue evacuation plan, identifies the nearest safe exits based on real-time crowd density, and generates optimal evacuation routing; prescriptive robots navigate toward hazard zones to assist with evacuation while security robots cord off dangerous areas. This EM response ensures that high-consequence emergencies receive the immediate, authoritative human leadership they demand.

During routine poster sessions, sensor data occasionally reveals crowd clustering in a popular area. The module deploys prescriptive robots at adjacent corridors and pushes tea-break information to nearby attendees via the application, gently dispersing crowd flow without forced restrictions. This intervention demonstrates the framework's capability to detect emergent crowd behavior in real time and implement non-invasive crowd management strategies under AM, with digital notification systems coordinating robotic humans. Throughout these interventions, the parallel execution module continuously compares virtual predictions with real outcomes, calibrating digital human behavioral parameters and updating the rule library, so that the system's response accuracy is designed to improve progressively during the event.

Ex-post iteration phase After the exhibition concludes, the framework transitions to post-event analysis and knowledge accumulation, which is primarily AM work: digital humans automatically process and structure the full event dataset—crowd density time series, deviation detection and response records, actual versus expected attendance comparisons, attendee feedback, and participant satisfaction scores—into a structured format; robotic humans report execution logs and post-event equipment status. Biological humans review significant deviations identified by digital humans (e.g., doctoral student mobility patterns during poster sessions that exhibited concentrated visits during specific periods rather than the simulated uniform distribution), validate the calibration direction, and approve the finalized rules before they enter the knowledge base. New scenarios and response strategies are abstracted into general rules: the "keynote overflow" scenario and its livestreaming response are encoded as a rule retaining only core parameters (crowd density thresholds, diversion ratios, response times), abstracting away venue-specific layout data. When the conference moves to another city the following year, the system invokes this rule and automatically adapts without needing to accumulate experience from scratch. EM is activated on-demand only if post-event disputes, contractual disagreements, or legal liability issues arise that require biological human decision-making authority.

V. CONCLUSION AND FUTURE PERSPECTIVES

Addressing the multidimensional management challenges faced by exhibitions as complex social systems, this paper explores the potential of parallel intelligence in addressing the inherent complexity of temporary organizations. We propose the parallel exhibition intelligent management framework, constructed upon the ACP approach and operated through the three types of human collaborative mechanisms. The framework is designed to integrate multi-participant strategic interaction demands, accumulate cross-regionally transferable management experience, and achieve macroscopic crowd dynamic regulation.

The proposed framework includes the artificial exhibition as the virtual foundation, computational experiments as the exploratory engine, and parallel execution as the real-time regulation and knowledge accumulation mechanism. Each component addresses a specific barrier identified in complex social systems: the artificial exhibition overcomes the difficulty of precise modeling through functional equivalence; computational experiments overcome the inability to repeat experiments through virtual scenario exploration; and parallel execution overcomes the difficulty of real-time regulation through dynamic virtual-real feedback. The scenario validation illustrates how these components work together in an academic conference setting, demonstrating the framework's potential applicability to real-world MICE management.

The large-scale deployment of the parallel exhibition framework requires the construction of unified industry standards and implementation systems. In the future, collaboration among MICE industry associations, research institutions, and MICE enterprises can jointly establish technical standards, data standards, and management standards for parallel exhibition, while constructing the framework's implementation system and talent cultivation system, promoting the large-scale adoption of the parallel exhibition framework in the MICE industry. Additionally, the framework's applicability to other temporary organization domains warrants further investigation, potentially extending the impact of parallel exhibition beyond the MICE sector.

ACKNOWLEDGMENT

This work was partially supported by The Science and Technology Development Fund, Macao SAR (0093/2023/RIA2, 0145/2023/RIA3, 0157/2024/RIA2), and the Distinguished Program of Obuda University and the De-Sci Center for Parallel Intelligence at the Obuda University, Hungary.

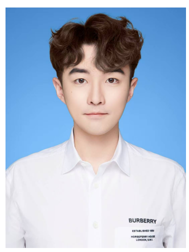
REFERENCES

[1] Allied Market Research. MICE industry market report. Market Report, Allied Market Research, 2023.

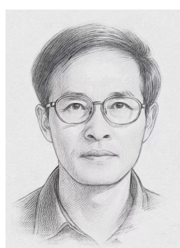
[2] Events Industry Council. Global economic significance of business events. Oxford Economics, 2018.
[3] Harald Bathelt and Nina Schuldt. International trade fairs and global buzz, Part I: ecology of global buzz. European Planning Studies, 19(1):122, 2010.
[4] Peter Maskell, Harald Bathelt, and Anders Malmberg. Building global knowledge pipelines: the role of temporary clusters. European Planning Studies, 14:9971013, 2006.
[5] Donald Getz. Event tourism: definition, evolution, and research. Tourism Management, 29(3):403428, 2008.
[6] Fei-Yue Wang. Toward a paradigm shift in social computing: the ACP approach. IEEE Intelligent Systems, 22(5):6567, 2007.
[7] Michael Polanyi. The Tacit Dimension. Doubleday, Garden City, NY, 1966.
[8] Ikujiro Nonaka and Hirotaka Takeuchi. The Knowledge-Creating Company. Oxford University Press, 1995.
[9] Rolf A. Lundin and Anders Söderholm. A theory of the temporary organization. Scandinavian Journal of Management, 11(4):437455, 1995.
[10] Kevin Wallace and Eleni Michopoulou. Building resilience and understanding complexities of event project stakeholder management. Event Management, 27(4):499517, 2023.
[11] Dirk Helbing and Péter Molnár. Social force model for pedestrian dynamics. Physical Review E, 51(5):42824286, 1995.
[12] Mehdi Moussaïd, Niriaska Perozo, Simon Garnier, Dirk Helbing, and Guy Theraulaz. The walking behaviour of pedestrian social groups and its impact on crowd dynamics. PLoS ONE, 5(4):e10047, 2010.
[13] Charles Perrow. Normal Accidents: Living with High-Risk Technologies. Basic Books, New York, 1984.
[14] Dirk Helbing and Pratik Mukerji. Crowd disasters as systemic failures: analysis of the Love Parade disaster. EPJ Data Science, 1:7, 2012.
[15] Minseok Kim, Jinsoo Yoon, and Jung-Kyu Park. 158 deaths at Halloween Night: an AcciMap analysis of 2022 Itaewon crowd crush. Safety Science, 170:106385, 2024.
[16] Project Management Institute. A Guide to the Project Management Body of Knowledge (PMBOK Guide). Project Management Institute, 7th edition, 2021.
[17] Karen Celuch. Event technology for potential sustainable practices: a bibliometric review. International Journal of Event and Festival Management, 12(3):314330, 2021.
[18] Norbert Wiener. Cybernetics: Or Control and Communication in the Animal and the Machine. MIT Press, 1948.
[19] Philip W. Anderson. More is different. Science, 177(4047):393396, 1972.
[20] Fei Tao, He Zhang, Ang Liu, and Andrew Y. C. Nee. Digital twin in industry: state-of-the-Art. IEEE Transactions on Industrial Informatics, 15(4):24052415, 2019.
[21] Michael Grieves and John Vickers. Digital twin: mitigating unpredictable, undesirable emergent behavior in complex systems. In Transdisciplinary Perspectives on Complex Systems, pages 85113. Springer, 2017.
[22] Barbara Rita Barricelli, Elena Casiraghi, and Daniela Fogli. Towards the Human Digital Twin: definition and design. arXiv preprint arXiv:2402.07922, 2024.
[23] Fei-Yue Wang. Steps toward parallel intelligence. IEEE/CAA Journal of Automatica Sinica, 3(4):345348, 2016.
[24] Fenghua Zhu, Yisheng Lv, Yuanyuan Chen, Xiao Wang, Gang Xiong, and Fei-Yue Wang. Parallel transportation systems: toward IoT-enabled smart urban traffic control and management. IEEE Transactions on Intelligent Transportation Systems, 21(10):40634071, 2020.
[25] Jing Yang, Xiaoxing Wang, and Yandong Zhao. Parallel manufacturing for industrial metaverses: a new paradigm in smart manufacturing. IEEE/CAA Journal of Automatica Sinica, 9(12):20632070, 2022.
[26] Jun Huang, Yonglin Tian, Tengchao Zhang, Qinghua Ni, Fei Lin, Timothy J. Lee, Naiqi Wu, and Fei-Yue Wang. Parallel tourism system with foundation models and decentralized autonomous organizations. International Journal of Tourism Research, 27(2):e70008, 2025.
[27] Chunfa Wang, Fei-Yue Wang, Yue Lu, Huabiao Li, and Chao Guo. Parallel museums: intelligent management and control of museum operations in the new era. Chinese Journal of Intelligent Science and Technology, 3(2):125136, 2021.
[28] Chao Guo, Yue Lu, Yong Dou, and Fei-Yue Wang. Can ChatGPT boost artistic creation: the need of imaginative intelligence for parallel art. IEEE/CAA Journal of Automatica Sinica, 10(4):835838, 2023.
[29] Qinghua Ni, Buday Viktória, Fei Lin, Jun Huang, Levente Kovács, Nan Zheng, and Fei-Yue Wang. Parallel theaters in CPSS: from shadows of ISDOS to intelligence of decision theaters. IEEE/CAA Journal of Automatica Sinica, 12(6):10591062, 2025.
[30] Fenghua Zhu, Zhe Wang, and Fei-Yue Wang. A Parallel Transportation System for Urban Traffic Management. IEEE Transactions on Intelligent Transportation Systems, 20(11):41594169, 2019.
[31] Hairong Dong, Hainan Zhu, Yidong Li, Yisheng Lv, Shigen Gao, Qi Zhang, and Bin Ning. Parallel intelligent systems for integrated high-speed railway operation control and dynamic scheduling. IEEE Transactions on Cybernetics, 48(12):33813389, 2018.

SANGTIAN GUAN received the ME degree in intelligent technology from Macau University of Science and Technology, China, in 2023. He is currently pursuing the PhD degree at Department of Engineering Science, Faculty of Innovation Engineering, Macau University of Science and Technology, Macao, China. His research interests include DeEco, blockchain, DAO, and parallel management.

SIJI MA received his master's degree from the Faculty of Innovation Engineering at Macau University of Science and Technology in 2024. He is currently pursuing the Ph.D. degree at the same faculty. His research interests include parallel intelligence, blockchain, reinforcement learning, and DAOs.



JUN HUANG received his Master's degree from the Faculty of Science and Engineering, The University Of Manchester, Manchester, UK. He is currently pursuing the Ph.D. degree at the Department of Engineering Science, Faculty of Innovation Engineering, Macau University of Science and Technology. His research focuses on deep learning algorithms and reinforcement learning, including autonomous vehicle trajectory prediction and planning, parallel intelligence, and prompt engineering.



WEN DING is currently a researcher at QAII. His research interests cover parallel intelligence, blockchain, parallel management, and Agentic AI.