

REAL-TIME SMILE SYNCHRONIZATION AS A MECHANISM FOR EMOTIONAL CONTAGION IN PUBLIC INTERACTIVE DISPLAYS

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ABSTRACT

*Emotional contagion refers to the psychological and behavioral phenomenon in which individuals unconsciously mimic the facial expressions, vocal patterns, postures, and movements of others during social interactions, resulting in corresponding changes in their own emotional states. With the rapid development of digital media and networked communication platforms, emotional transmission is no longer limited to face-to-face interaction, but increasingly mediated through multimodal digital signals such as symbolic icons, animated feedback, visual imagery, and auditory cues. This transformation has positioned emotional contagion as a critical research topic in the fields of Human-Computer Interaction (HCI) and Affective Computing. This study focuses on the transmission of positive emotions, specifically investigating the contagion effect of happiness through an interactive installation titled *Quartic Smile*. The system was designed to construct a real-time emotional feedback environment in which users can perceive and respond to the emotional expressions of others within a shared interactive space. By integrating real-time facial expression recognition, the system captures smiling behaviors as emotional triggers and translates them into visualized interactive responses, thereby facilitating emotional resonance and collective engagement among participants. To quantitatively evaluate the effectiveness of emotional contagion, two core metrics were defined in this study. The first is the contagion level, which is calculated based on the frequency of smiles and reflects the intensity and distribution of emotional transmission among users. The second is the contagion speed, measured by the cumulative duration of smiling behaviors between participants, representing the temporal dynamics and responsiveness of emotional propagation. The experimental results indicate that *Quartic Smile* effectively enhances positive emotional interaction and demonstrates the potential of real-time interactive systems to shape collective emotional atmospheres and social engagement patterns. This study is based on research and data from 2017, which have been reorganized and revised.*

KEYWORDS

Smile Detection, Emotion Recognition, Real-Time System, Public Interactive Installation.

1. INTRODUCTION

With the rapid development of the Internet and real-time communication technologies, the relationship between humans and computers has undergone a fundamental transformation. Networked environments have not only expanded the scale and density of social connections, but have also reshaped the structure of emotional communication, enabling emotions to propagate rapidly across highly connected digital networks. Psychological studies have demonstrated that emotions exhibit strong social transmissibility and dynamically influence individual cognition and behavioral responses within group interactions [1][2].

The theory of mood-congruent processing proposed by Bower (1981) indicates that emotional states within a group tend to reinforce one another. When individuals collectively display positive expressions such as smiling, participants are more likely to experience elevated levels of positive affect. Conversely, emotional inconsistency within a group may induce anxiety and psychological discomfort [1]. Building upon this perspective, Hatfield et al. (1994) introduced the concept of emotional contagion, explaining how individuals automatically mimic the facial expressions, vocal patterns, and bodily movements of others during social interactions. Through unconscious behavioral imitation, emotional states gradually synchronize among participants, a phenomenon referred to as primitive emotional contagion [2].

In contemporary digital environments, these psychological mechanisms are no longer confined to face-to-face interpersonal interactions but increasingly extend to human-computer relationships. According to the Computers Are Social Actors (CASA) paradigm proposed by Nass and Reeves, users unconsciously apply social norms and interpersonal expectations to computational systems, perceiving digital interfaces as socially responsive agents [3].

Based on this theoretical foundation, the present study designed an interactive installation as an experimental platform to investigate emotional contagion mechanisms within human-computer interaction contexts. The system integrates the CASA framework [3] with Hatfield's emotional contagion model [2], positioning the interactive installation not merely as a technical interface, but as an emotionally responsive medium capable of eliciting social projection and affective engagement. Post-interaction surveys and semi-structured interviews were conducted to analyze emotional experiences, behavioral changes, and their influence on users' willingness to interact with the system.

2. RELATED WORK

With the advancement of Internet technologies, real-time interaction systems, and affective sensing algorithms, emotional contagion has become a significant research topic in the fields of Human-Computer Interaction (HCI), Affective Computing, and interactive media art since 2010. Recent studies have shifted their focus not only toward improving emotion recognition accuracy, but also toward understanding how emotional feedback mechanisms influence user behavior, engagement, and social perception.

In the domain of interactive installations, the *Chameleon* system [4] employs facial expression detection to capture users' emotional responses in real time and retrieves corresponding emotional video portraits from a database to provide affective feedback to observers. Through this design, the system establishes an emotional dialogue between the user and the interface. By presenting users with a visual reflection of their own emotional state, the system creates an emotional mirroring effect, which encourages emotional introspection and enhances self-awareness during interaction.

In game design and virtual social simulation research, emotional contagion has also been widely adopted as a mechanism to enhance immersion and social engagement. The game *I'm Happy If You Are Happy* [5] integrates an emotional influence model into virtual characters and compares user interactions with emotionally responsive agents and non-responsive agents. Based on the Emotional Contagion Scale (ECS), multiple social scenarios with varying susceptibility levels were constructed to simulate diverse virtual social environments. Experimental results indicate that emotionally responsive characters significantly increase perceived enjoyment and friendliness of the gaming experience, highlighting the importance of emotional contagion in virtual interaction design.

Furthermore, interdisciplinary approaches combining physical modeling and social emotion simulation have been proposed in interactive systems. The installation developed by Jérémie Bordas [6] introduces a computational framework that integrates the OCC emotional model, which assigns 22 emotional states to virtual characters, with the ASCRIBE model to construct social relationships among agents. Inspired by heat dissipation models in physics, the system treats emotional transmission as a dynamic diffusion process and computes emotional propagation based on environmental factors, social relationships, and event-driven interactions. This approach enables a more realistic simulation of emotional contagion in complex social contexts.

Collectively, these studies demonstrate that emotional contagion can be mediated through a wide range of platforms and media forms, including video portraits, virtual characters, robotic systems, textual interfaces, and visual content. Emotional contagion is inherently cyclical: individuals are influenced by the emotions of others, and their emotional responses, in turn, affect surrounding participants, forming a continuous feedback loop. Moreover, emotional contagion exhibits strong propagation properties, with positive emotions being the most rapidly transmitted and socially amplified, making them particularly valuable for interaction design and collective emotional atmosphere construction.

3. CONCEPT OF THE WORK

In the digital era, emotional contagion has been shown to be strongly associated with online social networks, and the majority of existing studies have focused on large-scale social media platforms such as Facebook and Twitter. However, most of these studies rely primarily on passive data collection and large-scale behavioral analysis, while relatively few have investigated real-time emotional interaction through physically deployed interactive systems in public spaces.

To address this research gap, the present study designed and implemented a dual-terminal interactive installation as an experimental platform. Two terminals were deployed at separate outdoor locations, referred to as Point A and Point B, and connected via a real-time network communication system. Through this remote connection, users at both locations were able to view each other's live images, enabling synchronous cross-location interaction. In addition, interaction-generated images were automatically uploaded to Facebook, allowing on-site emotional interactions to extend into online social networks and further amplify emotional dissemination through secondary sharing mechanisms.

The experimental installation was deployed on the campus of National Taiwan University, with terminals located at the College of Social Sciences and the Main Library—two high-traffic public spaces that provide diverse user participation and realistic social interaction conditions. This spatial configuration enabled the construction of a distributed interaction environment that overcomes geographical distance and transforms emotional contagion from a localized phenomenon into a dynamic, multi-node networked interaction process.

Furthermore, the system emphasizes real-time reciprocal influence between participants. Instead of limiting interaction to a conventional one-to-one human–computer relationship, users are able to perceive emotional feedback from remote participants and respond instantaneously, forming a continuous emotional feedback loop across physical space. This interaction model aligns with Pugh’s concept of facilitating emotional contagion through realistic interaction contexts [7], highlighting that emotional transmission should not rely solely on mediated images or symbolic representations, but should be grounded in embodied interaction and real-time social feedback mechanisms to better approximate authentic social dynamics.



Figure 1. Quartic Smile interactive installation on A and B.

3.1. Installation Design

The interactive installation is titled *Quartic Smile*, a name derived from the Chinese term “sì fāng,” which refers both to the geometric form of a cube and to the four cardinal directions, symbolizing omnipresence and spatial extension. This conceptual framework reflects the core objective of the project: to transcend the constraints of physical distance by connecting two separate physical spaces through networked interaction, thereby constructing a metaphorical fourth-dimensional interaction channel.

In terms of physical design, a cubic structure was adopted as the primary architectural form of the installation. Two identical cubes were interconnected via real-time Internet communication, transforming each individual object from an isolated physical artifact into a node within a distributed interaction system. This configuration establishes a spatial metaphor of a fourth dimension, in which geographically separated spaces become perceptually linked through digital mediation. Two identical interactive units were deployed at Point A and Point B to ensure symmetrical interaction conditions and consistent user experience.

Each cube measures 215 cm × 215 cm × 215 cm and is constructed using an aluminum framework combined with wooden panels to achieve structural stability and modular assembly. The exterior surfaces of the cubes are covered with large mirror panels, enabling environmental reflection and self-referential visual feedback, while LED light strips are embedded along the structural edges to outline the cubic geometry and enhance spatial visibility, particularly under low-light conditions.

On the front façade of each cube, a viewing window measuring 110 cm × 68 cm allows users to observe the interior space. The interior layout is designed to resemble a cozy study room, creating a familiar and approachable interaction environment that reduces psychological barriers for first-time users. A 65-inch high-resolution display is mounted on the front wall of the study, functioning as an extension of visual depth. This display simulates the experience of looking

through an interior window that opens into another remote space. This interface is defined in the present study as the “Virtual Window” [8].

The display system operates at a resolution of 2000×4000 pixels, enabling high-detail visual rendering that approximates real-world window views. To enhance immersion and spatial realism, a depth-sensing camera is integrated to perform real-time head tracking. Based on the user’s viewing position, the system dynamically adjusts the perspective of the displayed content, generating a motion parallax effect that reinforces depth perception and spatial continuity within the virtual window environment [9].

To support bidirectional interaction between the two terminals, multiple sensing and input devices were integrated into the installation. An infrared camera installed at the base of the cube detects user presence within an approximate range of 500 cm, serving as an interaction trigger mechanism. A touch screen positioned in front of the viewing window provides a user interface for interaction selection and system control, while a microphone installed above the window captures audio input and transmits voice signals to the remote terminal in real time, enabling multimodal communication. A detailed description of the interaction workflow and user behavior design is presented in the following section

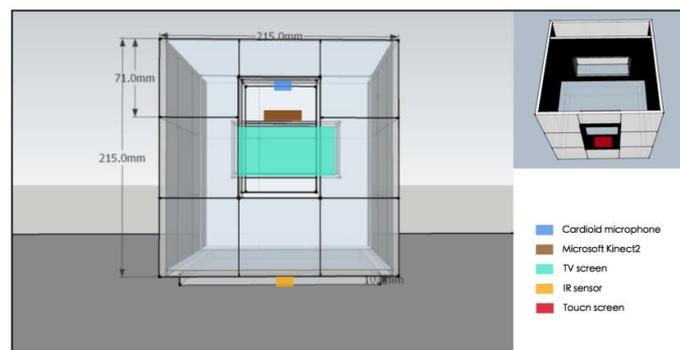


Figure 2. Design of Quartic Smile.

3.2. Interactive Design and Structure

The interaction design of this study was grounded in the theoretical frameworks of the Audience Funnel model [10] and Proxemics theory [11]. By integrating spatial distance with progressive engagement stages, the system guides passersby from peripheral awareness toward active participation and cross-location emotional interaction. The Audience Funnel model emphasizes multi-stage transitions from attention capture to deep engagement, while Proxemics theory highlights the influence of interpersonal distance on social behavior. In this study, both concepts were translated into a distance-driven, state-based interaction architecture.

Four interaction states were defined based on spatial proximity: Sleeping State, Attracting State, Interacting State, and Wormhole State. As the installation was deployed simultaneously at two physical locations (Point A and Point B), real-world interactions involved synchronized multi-node state transitions, enabling emotional contagion to propagate across distributed spatial contexts.

In the Sleeping State, the installation remains in a low-interference mode. Audio and dynamic visual outputs are deactivated, and only basic informational content related to the surrounding

environment is displayed, such as community bulletin boards. This state minimizes disruption to public space while serving as the system's standby mode. When no users are detected within a 500 cm radius, the system automatically returns to this state.

When a user enters the detection zone, the system transitions into the Attracting State. During this phase, LED light patterns along the cube edges are activated to draw visual attention. This design follows the principles proposed by Enns [12], which emphasize brightness contrast and dynamic visual cues as effective mechanisms for capturing human attention.

Once the user approaches the front interface and begins interaction, the system enters the Interacting State. Users can operate the system via a touch panel to access information or activate interactive functions. When the "Virtual Window" mode is enabled, a depth-sensing camera tracks the user's head position and dynamically adjusts the viewing perspective of the displayed content, generating a motion parallax effect that enhances spatial realism and immersive perception.

When both terminals simultaneously detect active users, the system activates the Wormhole State. This state establishes a real-time audiovisual communication channel between the two remote locations, enabling users to see and communicate with each other. Unlike conventional video conferencing interfaces, the immersive spatial framing of the wormhole interface reduces social awkwardness and shortens psychological distance between strangers.

To enhance emotional contagion, the Wormhole State integrates real-time smile detection and visual feedback mechanisms. When users smile during interaction, the system triggers auditory feedback and visualizes an energy scale representing the combined smile intensity of both participants. The magnitude of the smile directly influences the size of the wormhole opening: sustained positive expressions maintain the maximum opening, thereby encouraging prolonged interaction. Before terminating the session, users are invited to upload snapshots of their interaction to Facebook and optionally exchange contact information, extending offline emotional interaction into online social networks.

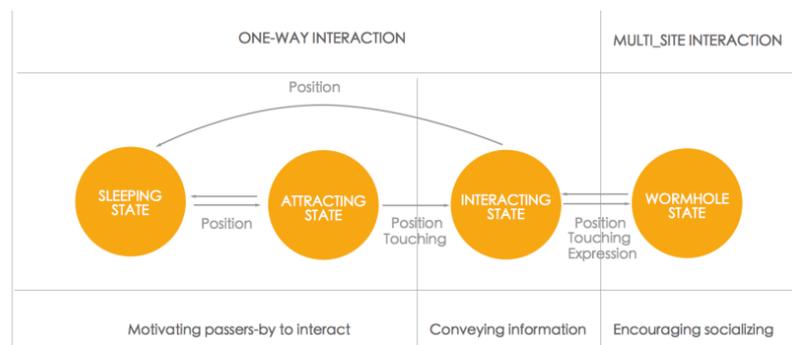


Figure 3. Four interaction states of Quartic Smile.

For facial expression recognition, Histogram of Oriented Gradients (HOG) was adopted as the primary feature descriptor [13], providing robust representation of facial structures. The extracted features were processed using a Support Vector Machine (SVM) classifier to perform binary classification between smiling and non-smiling states. To achieve both high classification accuracy and real-time performance, Logistic Regression was employed as the decision function [14], enabling probabilistic output that could be directly mapped to interactive feedback parameters within the system.

4. EXPERIMENT RESULTS

To evaluate system performance and user engagement, interaction logs from both installation sites were collected and analyzed over a long-term deployment period from October 12, 2016 to February 1, 2017. Synchronized log data from both terminals were examined to investigate spatial differences in user participation and emotional contagion effects.

During the Attracting State, Site A (located at the main entrance of the NTU Main Library) recorded substantially higher activation frequency than Site B (College of Social Sciences). A total of 2,228 users were detected at Site A compared to 453 users at Site B, representing approximately a fivefold difference. This discrepancy can be attributed to spatial characteristics: Site A is located at the geographic center of the campus, serves as a major pedestrian flow hub, and is positioned at the main gateway of the library, resulting in higher visibility and foot traffic. However, when examining the conversion rate from Attracting State to Interacting State, both sites exhibited remarkably similar proportions. At Site A, 992 users (44.5%) initiated direct interaction with the installation, while Site B recorded 195 users (43%). These results suggest that although baseline foot traffic differed significantly between locations, the interactive design maintained consistent engagement effectiveness across spatial contexts.

For synchronized cross-site interaction in the Wormhole State, the system recorded 77 successful activations at Site A and 85 at Site B. Since the wormhole mechanism requires simultaneous interaction at both terminals, successful activation depends heavily on temporal synchronization between users and network stability. In practice, scenarios were observed in which one terminal satisfied activation conditions while the remote participant had already disengaged, resulting in partial activation records. Network latency and real-time streaming stability also contributed to variations in successful synchronization.

When normalized by the number of active participants, Site B exhibited a relatively higher wormhole activation rate despite its lower total user volume, indicating that environments with lower crowd density but higher user attention may facilitate deeper engagement in cross-site interaction.

Regarding emotional contagion outcomes, log data showed that Site A generated a total of 494 smile events across 77 wormhole interactions, with an average of 15.5 smiles per session. Site B recorded 508 smile events across 85 interactions, with an average of 16.7 smiles per session. The close similarity between total smile counts and average values across sites demonstrates the stability and reproducibility of positive emotional responses elicited by the system.

Overall, under naturalistic deployment conditions without on-site facilitators and with daily operating hours from 9:00 AM to 6:00 PM, the installation achieved an interaction conversion rate of approximately 40% and successfully facilitated synchronized cross-location engagement and positive emotional contagion. These findings indicate that the proposed interactive system effectively supports emotional resonance and spontaneous social interaction among strangers in public spaces.

Table 1. Interaction frequency.

Status	NTU Main Library (Site A)	NTU College of Social Studies (Site B)
Attracting state	2228	453
Interacting state	992	195

Wormhole state	77	85
Total Smile Count	494	508
FaceBook OK	28	28

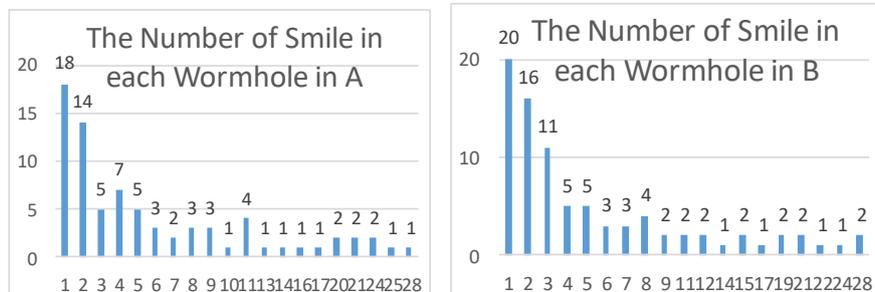


Figure 4. Smiling frequency.

To further examine the dynamic characteristics of emotional contagion, this study analyzed joint smile events during cross-site interaction sessions. In the system logs, the “total number of smiles” refers to all smile events independently generated by users at either site, whereas “joint smile frequency” is defined as the number of smile events that occur simultaneously within a predefined temporal window at both terminals. This metric represents a key indicator of emotional synchronization between remote participants.

Because joint smiles require simultaneous activation at both sites, their frequency is inherently lower than the total number of individual smile events. For example, although Site A recorded 494 total smile events, only 220 of these were classified as joint smiles. Similarly, Site B recorded 508 total smiles, of which only 216 occurred simultaneously with Site A users. This discrepancy highlights the structural difference between individual emotional expression frequency and successful emotional synchronization across remote participants.

In addition to frequency analysis, reaction time was calculated to quantify the speed of emotional contagion. Reaction time was defined as the temporal interval between the onset of interaction and the first occurrence of a joint smile event. The results indicate that emotional synchronization occurs rapidly in most interaction sessions. At Site A, 195 out of 220 joint smiles (88.6%) occurred within two seconds. At Site B, 194 out of 216 joint smile events (89.9%) were generated within the same time window.

These findings demonstrate that positive emotional contagion can propagate and synchronize across remote locations within a very short temporal scale when supported by real-time audiovisual interaction and affective feedback mechanisms. The results provide empirical evidence supporting Hatfield et al.’s theory of rapid and automatic emotional contagion, extending its applicability to digitally mediated interactive environments.

It should be noted that reaction time measurements may be influenced by several factors, including network latency, video streaming refresh rates, user attention allocation, and individual differences in emotional expressiveness. Nevertheless, the strong clustering of joint smile events within the two-second window indicates that the proposed system effectively facilitates fast emotional synchronization and real-time affective interaction across distributed spaces.

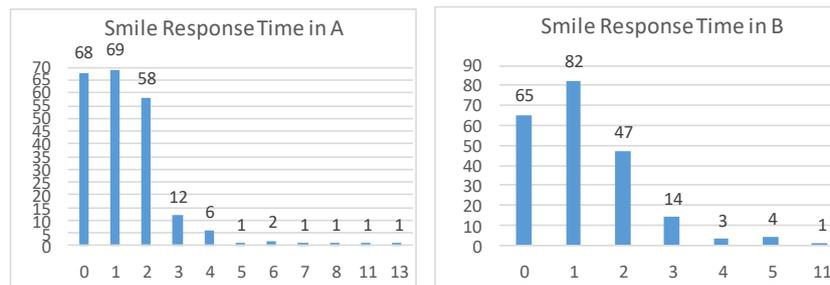


Figure 5. Joint smiling and reaction time.

Since *Quartic Smile* was deployed in an open public environment rather than a controlled laboratory or gallery exhibition space, the evaluation methodology was designed based on the framework proposed by Alt et al. in “How to Evaluate Public Displays” [15]. This framework emphasizes the importance of combining multiple evaluation approaches, including user inquiry, field observation, and in-situ interaction analysis, to capture authentic usage behaviors in real-world public contexts.

The installation was deployed at two major public locations on the National Taiwan University campus—the College of Social Sciences and the Main Library entrance—both characterized by high pedestrian flow and spontaneous social interaction. Therefore, an on-site questionnaire combined with semi-structured interviews was adopted as the primary evaluation method. Participants were randomly recruited from passersby and users in the vicinity of the installation to reduce sampling bias and improve the representativeness of the collected data.

During the interaction phase, participants were not provided with prior instructions regarding the interaction process. Instead, users were encouraged to interact with the installation intuitively, simulating natural encounters with public interactive displays. Researchers minimized intervention throughout the interaction process unless participants experienced significant operational difficulties or system malfunctions. This approach enabled observation of whether users could independently complete the full interaction sequence, from initial attraction to cross-site communication.

After completing the interaction session, participants were invited to fill out a questionnaire and participate in brief interviews. The questionnaire covered multiple evaluation dimensions, including usability, perceived immersion, emotional feedback awareness, sense of co-presence, and overall willingness to engage with the installation. The interviews provided qualitative insights into participants’ emotional experiences, perceptions of interacting with strangers, and reflections on the social impact of the system design.

All participants were informed of the research objectives and data usage policies prior to participation, and consent was obtained following ethical research guidelines. Personal information was anonymized during analysis to protect participant privacy. By adopting this mixed-method evaluation approach, the study integrates quantitative performance assessment with qualitative user experience analysis, thereby enhancing the reliability and interpretability of the evaluation results.

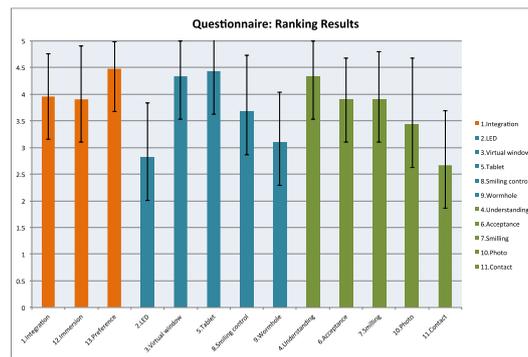


Figure 6. Questionnaire: Ranking Results (Score 1-5: ranges between 1-5 with 1 meaning strongly disagree while 5 meaning Strongly agree)

5. CONCLUSIONS

This study deployed the interactive installation *Quartic Smile* in an open public environment and implemented a four-stage interaction framework to investigate emotional contagion across distributed physical spaces. Long-term field data demonstrate that user participation decreases progressively at each interaction stage, reflecting the increasing engagement threshold associated with deeper interaction levels. This phenomenon highlights the inherent challenges of designing interactive installations for non-traditional exhibition environments and underscores the importance of balancing accessibility and engagement complexity in public interaction design.

From an affective perspective, the results confirm that smiling functions as a highly effective trigger for positive emotional contagion. More than half of participating users exhibited responsive smiling behavior influenced by remote interaction partners. Furthermore, over 90% of joint smile events occurred within two seconds, indicating that emotional synchronization across remote spaces can be achieved within a very short temporal window. These findings provide empirical support for existing emotional contagion theories related to rapid and automatic emotional mimicry, while extending their applicability to digitally mediated and spatially distributed interaction environments.

From a human-computer interaction design perspective, *Quartic Smile* demonstrates an interaction framework that integrates spatial installation design, real-time audiovisual communication, and affective feedback mechanisms. The results suggest that public interactive systems can function not only as information displays but also as social mediators that facilitate emotional resonance and spontaneous interpersonal connection between strangers. The visualization and quantification of emotional states further enhance user engagement and sustain interaction duration, offering practical implications for emotion-driven interaction design.

Despite these contributions, several limitations remain, including variations in pedestrian flow across deployment sites, the impact of network latency on real-time synchronization, and individual differences in emotional expressiveness. Future work may expand the system architecture to multi-node networks, incorporate multimodal emotion sensing such as vocal and bodily cues, and conduct longitudinal studies to further explore the role of emotional contagion in public interactive environments and remote social communication contexts.

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