Crowding Perceptions at Large Business Events: Insights from Beacons and Surveys

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Abstract We quantitatively assess how attendees perceive congestion based on survey responses compared to crowd levels measured by beacon data. Our findings show that attendees demonstrated better perception accuracy than random guessing for time and location, whereas density recognition from images was less effective. Additionally, we identified a temporal bias, with attendees tending to report congestion at times closer to when they filled out the survey. These insights contribute to enhancing crowd management strategies and the overall experience at large-scale events.

Keywords Crowd management, Beacon data, Survey analysis, Congestion perception, Crowd dynamics

Introduction

Managing the flow and density of people at large-scale events, such as international conferences and business exhibitions, is critical for maintaining a lively atmosphere while minimizing the negative effects of excessive congestion. To achieve this, it is essential to understand how attendees perceive congestion at these events. However, quantitative evaluations of congestion perception remain unclear, especially for large-scale gatherings.

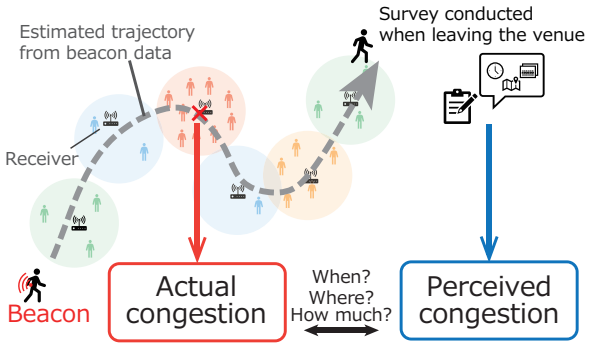

Figure 1: Schematic representation of the combined beacon and survey methodology used in this study.

Recent technological advances offer promising solutions: various sensors now enable real-time counting and tracking of people ' s movements [1, 2], while large-scale analyses of crowd dynamics, such as controlled laboratory experiments involving hundreds of participants [3] have revealed the complex phenomena involved. Despite these advancements, establishing a clear correlation between perceived and actual crowding at large-scale events has been challenging, particularly when drawing on extensive survey data collected in real facilities.

In this presentation, we introduce our recent study on the quantitative comparison of perceived congestion and measured crowd levels at events exceeding 10,000 participants [4]. Specifically, we investigated the relationship between measured and perceived crowding by analyzing how location, time, and crowd density affect individual attendees at large-scale events.

Methodology

To investigate discrepancies between how attendees perceive crowding and how it is actually measured, we combined questionnaire-based data collection with sensor measurements using beacon tags (Fig. 1).

Over two consecutive editions, we conducted surveys and Bluetooth-based mobility analyses at Tokyo Big Sight, one of Japan ' s largest exhibition and conference venues.

Survey respondents provided information about congestion in three ways: (1) They reported specific times they felt crowded through open-ended questions. (2) They marked perceived congestion locations on venue maps that were subdivided into smaller sections. (3) They selected photographs that most closely matched their personal sense of crowd density.

Simultaneously, beacon-based trajectory analyses tracked participant movement to capture the timing, location, and extent of crowding they encountered (Fig. 1). The beacon tags continuously recorded timestamps and estimated each participant ' s position within the venue. We assumed that the number of beacons detected by each receiver within specified time intervals would correlate with local crowd density. By cross-referencing each participant ' s trajectory with crowd data across various locations and times, we identified peaks in measured crowding in terms of time, location, and density.

Results

In 2022 and 2023, the number of visitors to the targeted events was 10,607 and 31,137, respectively. The higher attendance in 2023, roughly three times that of 2022, primarily reflected shifting attitudes toward COVID-19 [5].

To explore how participants qualitatively perceived congestion, we examined the ratio of responses to the crowding-time questions among those who provided answers. The data indicate that as the maximum crowd size increased, the proportion of participants who reported experiencing congestion also increased.

Next, we compared quantitative perceptions of crowding with measured crowd levels. Our findings indicate that while participants accurately identified the most heavily congested times overall, their reported congestion times tended to align more closely with their departure times than with actual peak crowding. This pattern suggests a recency bias in how participants recall congestion.

With regard to location, most participants displayed a fairly accurate understanding of which larger zones (approximately 100 m $\times$ 100 m) were crowded, although many mistakenly identified adjacent smaller zones (around 20 m in distance) as crowded. Moreover, participants ' selections of crowd-density photographs showed only a weak correlation with the measured congestion levels, implying that factors beyond spatial density (e.g., personal comfort thresholds or expectations) play a significant role in shaping perceived crowd intensity.

Discussion and Conclusion

By combining questionnaire data and beacon-derived crowd measurements, this study offers, to the best of our knowledge, the first attempt to compare perceived and actual crowding at an event attracting over 10,000 attendees. Our results reveal how and when attendees tend to notice or recall congestion and underscore the importance of psychological factors, such as recency bias, that can affect perceptions of crowd density.

These insights broaden our understanding of crowd perception and carry direct implications for event management and planning. For instance, by addressing congestion closer to expected departure times, organizers may be able to enhance overall attendee experiences without compromising safety or operational efficiency. Taken together, our findings provide a foundation for strategies aimed at optimizing crowd flow while preserving the many benefits of large-scale gatherings.

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