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学位論文題目	A STUDY ON AGENT-BASED MODELING AND SIMULATION FOR ANALYZING PEDESTRIAN URBAN SPATIAL SAFETY （歩行者の都市空間安全性分析のためのエージェント・ベースド・モデリングとシミュレーションに関する研究）
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論文内容の要旨

Agent-based modeling and simulation (ABMS) research of pedestrians is expected to solve spatial safety problems. Evacuation studies, focusing on unidirectional flows and evacuation time, have entered the practical stage of commercial software development and have built evaluation guidelines of verification and validation (V&V). However, for spatial safety problems where bi-directional flows and multi-directional flows are involved, such as crowd accident prevention and infection risk reduction, a research framework is still being formed. After the Shanghai Bund crowd accident in 2014, architects' discussion of improvement proposals has highlighted the importance of spatial design and management. The prevalence of Covid-19 adds a new challenge in addition to the above aspects with the requirements of physical distancing policies.

This thesis explores an ABMS framework for analyzing two specific spatial safety problems in urban public spaces related to crowd accidents and the Covid 19 pandemic infection. This thesis adds its significance in (1) summarizing an evaluation scheme for the above problems based on the review of crowd accidents, public health, and ABMS studies (2) describing structures and characteristics of the behavioral rule-driven

pedestrian agent (3) conducting an ABMS based on the records of the Shanghai Bund accident to study the spatial design and crowd management strategies and (4) conducting an ABMS based comparative study of pedestrian avoidance behavior before and during the Covid-19 pandemic to estimate the proximity probability between pedestrians. The scope of this thesis covers a general review of existing pedestrian-related problems and corresponding simulation development, and utilizing a developed ABMS framework for problem-solving.

Chapter one presents the research background, problem, purposes, significance, scope, structure, and explanation of the terminology.

Chapter two reviews existing studies on crowd accidents, public health under a pandemic condition, and the situation of ABMS. An evaluation scheme for the targeted spatial problems is then summarized. In addition, a general ABMS framework with the behavioral rule-driven pedestrian agent is explored.

In chapter three, the Shanghai Bund crowd accident is analyzed using publicly available videos and documents. A model is constructed reproducing a relatively high-density situation of 3 to 5 people/m^2. By comparing five replacement scenarios, including three improvement designs and two crowd management strategies in addition to the basic scenario, this chapter: 1) identifies several possible causes of the accident, 2) generalizes some common points to be avoided in designing public spaces, and 3) clarifies the importance of efficient crowd management.

In chapter four, an ABMS is applied to estimate pedestrian proximity probability during the Covid-19 pandemic in a station atrium. A video comparison analysis is conducted before and during the pandemic focusing on pedestrian avoidance behavior in a low-density space of 0.1 to 0.5 people/m^2. The result shows that the average starting distance of pedestrians' avoidance behavior is longer during a pandemic, which may reflect people's awareness of 'distancing'. Therefore, avoidance behavior is divided into two categories, personal spacing avoidance (PSA) and long-range avoidance (LRA). Based on the findings, the chapter develops Agent Simulator of Contagious Pedestrian Proximity (ASCPP), reflecting those two types of avoidance and has 16 behavioral rules. We simulates the counter flows in the atrium with five scenarios that deal with the 'distancing' awareness, facial masks, and the obstruction of flow by the presence of people standing still, and estimates the effect of each scenario on the probability of proximity assuming a ratio of 1% contagious people in the population.

Chapter five summarizes the research and findings, and discusses future issues.

論文審査結果の要旨

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