Simulation Model with Side Trips at a Large-Scale Event

Extended Abstract

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ABSTRACT

We propose the Side-trip model, a simulation model for the human flow of visitors leaving a stadium including stochastic side trips as an extension of existing models. The proposed model represents the stagnation and the congestion caused by side trips until the agent reaches his or her final destination. Experiments with real measured data show that the proposed model is estimated with lower errors than simpler models.

KEYWORDS

Crowd simulation; Data Assimilation; Optimization; Modeling

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1 INTRODUCTION

Crowd control is essential to improve comfortability, efficiency, and safety at large-scale events. Especially at the end of the events, the visitors start to move all at once, causing significant congestion. Overcrowded condition stresses the event visitors and increases the risk of crowd accidents and infectious diseases. For that reason, the event organizers at Tokyo Dome stadium instruct visitors to time lag exiting in some areas to reduce congestion.

To evaluate this instruction quantitatively, it is difficult to measure human behavior in a whole large-scale event. To solve this problem, crowd simulation is a helpful tool to estimate whole pedestrian trajectories only with data measured in a part of the stadium. Crowd simulators employ simulation models that estimate pedestrian trajectories considering the environment and other pedestrians. However, the similarity of the simulation model to the reality is low in the exiting phase at the end of the event if the target situation is complicated. The simulation models in two-dimensional space have been developed to adapt to complicated situations but are computationally intensive [2, 6–11].

CrowdWalk, a crowd simulator, can simulate a limited situation such as an evacuation with fewer computations by employing a one-dimensional simulation model (one-dim model) in Figure 1 [5]. Therefore, we extended CrowdWalk to reproduce more complicated situations with less computation. As an extension, this study proposes the Side-trip model, which simulates the detour behavior of the agent on the way to the final destination. Furthermore, this extension enables CrowdWalk to simulate the pedestrian trajectories including stagnation and congestion caused by side trips. The experiment performed data assimilation using crowd simulation and measured data from Tokyo Dome stadium, in which the maximum capacity is 43,000 people, to evaluate the model's performance.

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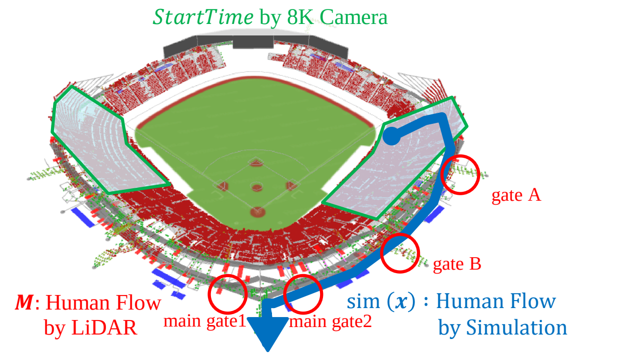

Figure 1: The simulation by CrowdWalk. Red circles are measurement points by cameras and LiDAR at Tokyo Dome stadium.

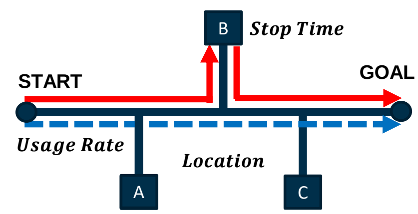

Figure 2: An example of side trips. Red and blue arrows are side trips used movement and a routing only movement.

2 SIDE-TRIP MODEL

The Side-trip model is the model to simulate stagnation and congestion by the detour behavior of the agent on the way to the final destination. It is based on the one-dim model used in CrowdWalk and the routing model. In Figure 2, the red line indicates the route

Table 1: Results of evaluating the model with NS.

	Side-trip	Routing	One-dim	default
main 1	**0.815**	0.215	**0.763**	-0.216
main 2	0.679	**0.803**	**0.786**	0.056
gate A	**0.922**	**0.864**	**0.931**	0.568
gate B	**0.702**	**0.785**	0.146	-0.545
mean	**0.779**	0.667	0.656	-0.034

including detours, and the blue dashed line indicates the direct route to the destination.

CrowdWalk can simulate the pedestrian trajectories by inputting the pedestrian information ($StartTime$, $StartPlace$, $Destination$). The one-dim model used on network maps consisting of nodes and links is the simplified model of the social force model (SFM) in the two-dimensional space [1]. The routing model sets the pedestrian's destination to the main gate with probability $\boldsymbol{Gate}$ and to the nearest gate with probability $1 - \boldsymbol{Gate}$. The routing and one-dim model cannot simulate stagnation and congestion on the way to the final destination because it cannot simulate the halting of pedestrians.

We define side trips as dropping by additional places before they reach the final destination. Additionally, the side-trip model composes of $UsageRate$, $StopTime$, and $Destination'$. $UsageRate$ is a value that determines the detour rate, $Destination'$ is the detour destination selected from all detour options, and $StopTime$ represents the time required for the detour. With these variables, The Side-trip model simulates behaviors including spontaneous stagnation.

3 EXPERIMENT

This section describes the experiment settings, the way to perform data assimilation, and evaluate the model.

The data assimilation follows the formula (1) and estimates the simulation parameters that minimize the error between the simulation result Sim and the measured data $\boldsymbol{M}$

$$\underset{\boldsymbol{x}}{\text{minimize}}\ \phi(Sim(\boldsymbol{x}), \boldsymbol{M}) \tag{1}$$

The loss function ϕ is the root mean squared error that is the error between the human flow rate Sim at the gate calculated by the simulation and the human flow rate $\boldsymbol{M}$ calculated by measuring the location indicated by the red circle in the figure 1 with LiDAR. $\boldsymbol{x}$ is the variable vector of the model.

Data assimilation estimates the following three variable vectors to compare the proposed model with existing models.

(1) One-dim model: $A_{0...2}, PersonalSpace$
(2) Routing model: $A_{0...2}, PersonalSpace, \boldsymbol{Gate}$
(3) Side-trip model: $A_{0...2}, PersonalSpace, \boldsymbol{Gate}, UsageRate$

$A_{0...2}$ and $PersonalSpace$ are the parameters which SFM in the one-dim model has, $\boldsymbol{Gate}$ and $UsageRate$ are the parameters which the routing model and the Side-trip model have, respectively.

The parameters required for the experiment are set as follows. $StartTime$ is determined by the departure time data measured in the green area in Figure 1. $StartPlace$ and $Destination'$ randomly arrange the seats where pedestrians leave and the restrooms on the sidewalk in four areas. $StopTime$ is set to 128 seconds based on the results of a station restroom usage survey by Nakagawa et al [3].

In the evaluation, this study uses The Nash-Sutcliffe efficiency (NS) proposed by Nash [4]. When NS is less than 0.0, the model is unusable, and when NS is greater than 0.7, the model is expected to be highly similar.

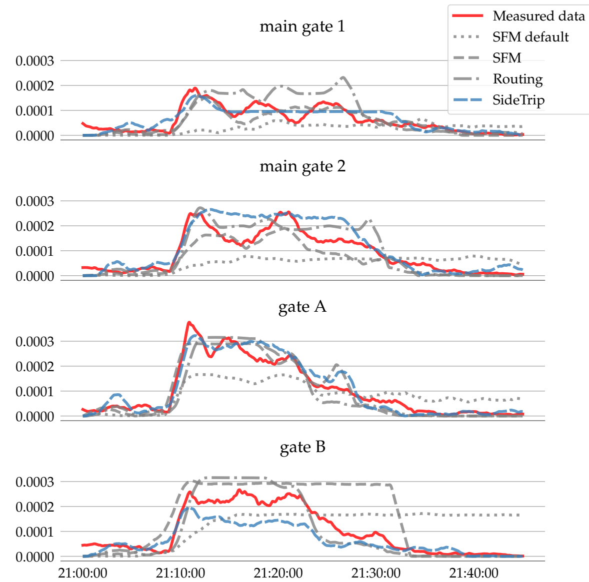

Figure 3: Human flow error by each measured point for each model. The vertical and horizontal axes are the number of people passing per total measured visitors and the time.

4 RESULTS AND DISCUSSIONS

Table 1 shows the NS for each model in each gate and the average NS in all gates. Bold numbers exceeding 0.7 indicate high similarity. When the Side-trip model is not included, some evaluation values are extremely low, while when the side-trip model is included, the values are more stable and better, which means that the model has high similarity performance.

In Figure 3, the red solid line is the human flow calculated by measured data at the gates, and the dashed other lines are the human flow computed by the simulation. The Side-trip model (the blue dashed line) can simulate measured data (the red solid line) with higher similarity than the other models (the grey dashed lines). The Side-trip model was successful for the following two reasons: The first reason is the reproduction of the human flow rate for each gate by the routing model and the second reason is the reproduction of the delay that occurred on the way to the final destination by the Side-trip model.

Future work will improve the Side-trip model and evaluate congestion with crowd-controlling methods. We hope that the development of this study will allow visitors to enjoy more comfortably and safely at a stadium such as Tokyo Dome stadium.

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