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Crowd Dynamics and Control in High-Volume Metro Rail Stations

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Abstract

Overcrowding in mass rapid transit stations is a chronic issue affecting daily commute in Metro Manila, Philippines. As a high-capacity public transportation, the Metro Rail Transit has been operating at a level above its intended capacity of 350,000 passengers daily. Despite numerous efforts in implementing an effective crowd control scheme, it still falls short in containing the formation of crowds and long lines, thus affecting the amount of time before they can proceed to the platforms. A crowd dynamics model of commuters in one of the high-volume terminal stations, the Taft Ave station, was developed to help discover emergent behavior in crowd formation and assess infrastructure preparedness. The agent-based model uses static floor fields derived from the MRT3 live feed, and implements a number of social force models to optimize the path-finding of the commuter agents. Internal face validation, historical validation and parameter variability-sensitivity analysis were employed to validate the crowd dynamics model and assess different operational scenarios. It was determined that during peak hours, when the expected crowd inflow may reach up to 7,500 commuters, at least 11 ticket booths and 6 turnstiles should be open to have low turnaround times of commuters. For non-peak hours, at least 10 ticket booths and 5 turnstiles are needed to handle a crowd inflow reaching up to 5,000 commuters. In the current set-up, the usual number of ticket booths open in the MRT Taft Station is 11, and there are usually 6 turnstiles open. It was observed that as the crowd inside the station increases to 200-250 commuters, there is a significant increase in the increase rate of the turnaround times of the commuters, which signifies the point at which the service provided starts to degrade and when officials should start to intervene.

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Keywords: Crowd Dynamics, Crowd Control, Complex Systems, Mass Rapid Transit

1 Introduction

Designing and planning public spaces such as transport terminals, airports, malls, and stadiums are becoming more challenging nowadays because of the increasing need to support large volume

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of people that exhibit different behavior and perform unconventional activities. It involves securing the safety of the people inside and near the area. In the Philippines, Metro Rail Transit has an average of 560,000 passengers daily. From 244 million passengers in 2004, to 415.5 million passengers in 2012, the passenger traffic in MRT stations increased by 71% in just a span of 8 years [2]. Aside from the increasing number of passengers, other contributing factors include its physical layout and various passenger behaviors. Thus, with the increasing instances of overcrowding in MRT3's terminal and high-volume stations, and interchanges, the Department of Transportation (DOTr) has been trying out different crowd control schemes to decrease overcrowding.

Crowd Dynamics is the study of how and where crowds form and move as the density of the crowd increases [10]. This involves modeling, simulating, and understanding the movement of individuals. Through knowing and predicting the movement of the commuters, how they use the space, and their activities in train stations, it will be easier to plan effective crowd control schemes, or floor layouts that could lessen crowd traffic. Currently, only an actual implementation of the plan can DOTC evaluate the effectiveness of a crowd control scheme. But through simulations, visualizing and understanding the crowd dynamics is easier since it offers a unique environment to test plans realistically by incorporating diverse traffic scenarios and human behavior [3]. Simulation results will lead to making informed design decisions. Although there are existing transportation models, there is a need for a model that considers the culture and environmental settings of the country.

This study aims to design and develop a crowd dynamics model of commuters in Metro Rail Transit or MRT3 stations that would help in evaluating their infrastructure preparedness. The agent-based model produced will be used to provide a tool that can aid in investigating the infrastructure preparedness of the MRT station. For the data gathering, the researchers developed a system called Swarm Plot, which allows the researchers and volunteers to annotate the data gathered from the MRT3 CCTV Live Feed. Swarm Plot produces floor field based from the annotations, and this floor field would be one of the factors that contributes to the behavior of the agents in the simulation system, SWARM-Simulation. Other factors that contribute to the behavior of the agents are the social forces adapted from [5] and some forces developed by the researchers.

The next section discusses some significant related works in creating crowd dynamics models. Section 3 details the data gathering method, as well as the annotation tool, SWARM Plot. Then, in Section 4, the architectural and detailed design of the SWARM simulation tool is discussed. Then, in Section 5, the results of the system validation and scenario analyses are explained. Lastly, Section 6 details a summary of the results and recommendations for future work.

2 Related Works

Many studies on crowd dynamics are currently focused on developed nations. One study [1] developed an agent-based model for public transportation which focuses on developing advanced driver assistance systems, semi- or fully autonomous buses, subway systems, and air transportation. Their agent-based model is able to capture the dominant socio-psychological factors operative within the presented Intelligent Transportation System context. This was inspired by the Metrobus system in Istanbul, Turkey. However, the study was not able to test emergent behavior in different simulation settings and compare the simulated data to real-world data.

Another study [7] developed a big model for transportation terminals which has individual models for rails, roads, general resources (human workers), pedestrians, trans-loading which is responsible for unloading and loading of freight between vehicles, vessels and storage, and lastly