Density Dependent Gait Patterns in Crowds

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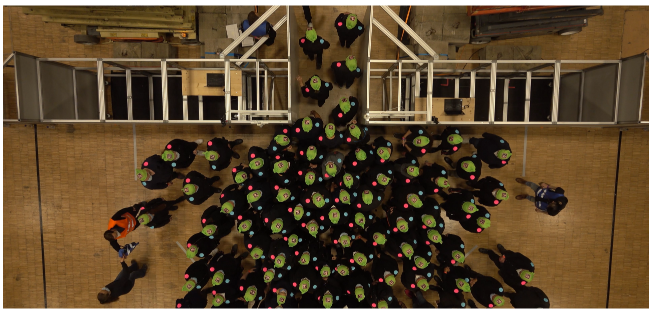
Abstract Ensuring safety in dense crowds remains a critical challenge, partly due to a lack of detailed understanding of 3D motion dynamics such as foot positioning and base of support, which are critical for gait stability and fall prevention. This study aims to address this gap by examining gait patterns in dense crowds using a 3D motion capture system. The research focuses on how individual characteristics influence gait patterns changing as crowd density increases, e.g. to be able to identify indicators of potential falls or injuries.

Keywords Gait pattern, 3D motion capturing, Bottleneck experiment, Crowd safety

Introduction

Crowd safety is important issue and limited understanding of crowd behavior and individual movement can lead to serious incidents, including falls [6]. The relationship between crowd density and falls, along with the mechanisms causing them, requires further investigation.

Previous studies have identified factors such as step length and speed as influential in determining the likelihood of falls. Studies such as those by Boomers et al. [1] on walking speeds near bottlenecks, Chatagnon et al. [3] on recovery strategies following external pushes have all contributed valuable insights. Furthermore, one-dimensional pedestrian flow experiments by researchers like Jelic et al. [4], Wang et al. [5], and Cao et al. [2] have provided information about the gait patterns during density changes. These studies have already considered some aspects, but none of them have examined subjects within a crowd. However, a more detailed and nuanced understanding of how individuals behave within dense crowds is essential. This study aims to address this need by examining the gait patterns of individuals in a crowd, employing a 3D motion capture system to precisely record and analyze their movements. Specifically, the study will focus on two key objectives: First, to identify patterns or trends in gait behavior in general and especially these that may serve as indicators of potential crowd-related falls or injuries. Second, to explore how individual characteristics like height, gender, and age influence changes in gait patterns as crowd density increases.



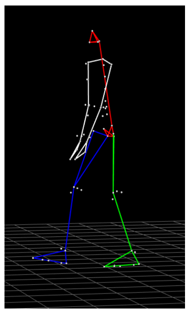


Figure 1: Experimental setup and motion capture data. (Left) Top camera view from bottleneck experiment, and (Right) corresponding motion capture data from one participant, illustrating the detailed movement patterns recorded.

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Method

A mixed-methods approach will be used to achieve the study objectives. The 3D motion capture system will be used to record gait patterns, while trajectory analysis will provide data on crowd density. The experimental setup involves a crowd passing a bottleneck, as shown on the left of Figure 1, with some participants wearing XSens MVN Link suits to capture their 3D movements in detail. The recorded data for one person 3.5m in front of the bottleneck is shown on the right of Figure 1. A range of conditions are created to simulate real-world scenarios by varying the size of the crowd and the motivation of individuals to pass through the bottleneck over several experimental runs. An initial representation of the data for one person is shown in Figure 2, where the left and right heel strikes of a subject are given in the movement space of the experimental setup. The steps of the right foot are always red, and those of the left foot are always blue. The black line connecting consecutive steps helps to visualise the timing. The step lengths were determined based on these steps. Where the distance between heel strikes is Euclidean. This step length was then plotted against the Voronoi density of the subject at the moment of the heel strike, which is the start of the step. In the following, further subject data will be evaluated in order to conduct a statistical evaluation. On the basis of this statistical evaluation, correlations between density and step length in movement direction, as well as other gait characteristics like the step width, will be determined. In addition, step types will be examined in relation to walking speed and density.

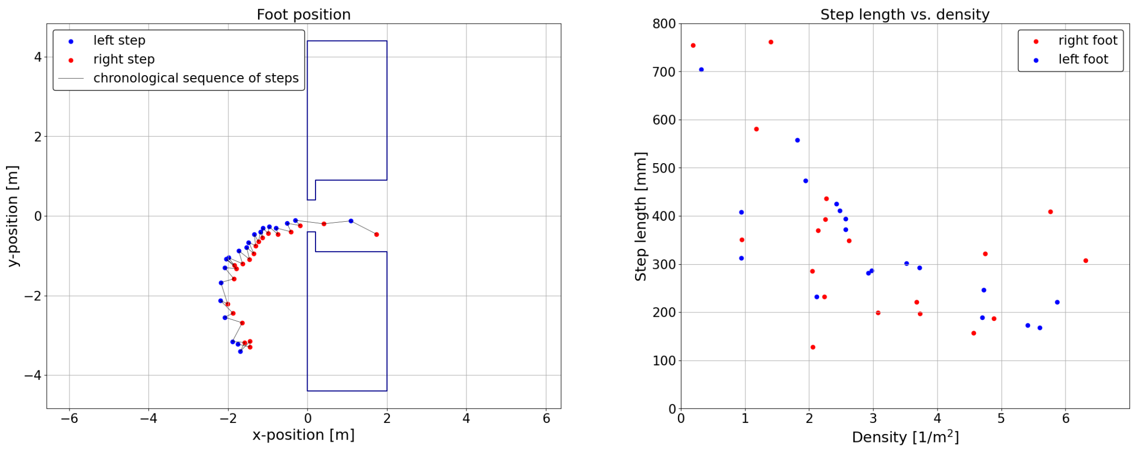

Figure 2: Data of one subject. (Left) Left and right steps of the subject in walking area of the test set-up, and (Right) the subject's step length in relation to the corresponding Voronoi density.

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