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# Microscopic Modeling Of Pedestrian Dynamics

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## Abstract

*Walking is the most primitive mode of transportation. In modern age this primary mode has not become obsolete as it furnishes access to those stretches of places which are not reachable by any vehicular mode of transport. Pedestrians are multiplying day by day in cities. Hence Pedestrian motion has immensely become a complex phenomenon. It is important to make out critical aspects of pedestrian motion to avoid collisions between pedestrians or any unexpected occurrence that has many precedents, like stampede. To understand this fuzzy motion, it is important to closely oversee this process of human movement and relate it to some mathematical form for easy understanding. In this study, a lot of data related to pedestrian motion are collected from various places in eastern India.*

*The study has mainly observed and recorded speed, flow and density of individual pedestrians. Statistical analysis is done here for comparing different types of data sets. Behaviours of pedestrians on different facilities and how these behaviours affect the flow parameters are studied here. The study analyzes Level of service of different pedestrian facilities. Oscillation phenomena occurring at bottlenecks are illustrated taking reference from already conducted experiments by other researchers. In this study a model is developed to mimic the pedestrian flow while moving along a corridor or evacuating from a closed space.*

*The model is a microscopic discrete model using cellular automata. The model imitates some simple rules practiced by the pedestrians for decision making while moving in a space. It can explain the lane changing phenomena in pedestrian streams. The model is very realistic in the direction choice approach of pedestrians. It is capable of modelling different crowd levels. The model is validated by the data collected from different facilities*

## Introduction

Cellular Automata (CA) is a mathematical tool that has been used for years to describe complex systems. It can be viewed as a simple model of spatially prolonged decentralized system comprised of a number of cells (individual components). The dissemination between these cells is restricted to local interaction. The overall formation can be perceived as a parallel processing device. This simple structure of cellular automata is dynamically stable i.e. addition of some new features would not lead to instability of the form and when these simple conformations are iterated several times it produces complex patterns which are similar in nature to those made by pedestrians. Cellular automata modelling involves in very less computational cost. There are various cellular automata models available in literature (*references*).

Blue Alder model which is one of the simplest models to understand pedestrian motion in pedestrian circulation areas but it is not logical in terms of direction choice of pedestrians when some obstacles (slow moving pedestrians or other obstacles) are found near vicinity.

There is a need to understand the correlation between different sizes of the sidewalks, different densities and how the pedestrian motion depends on them. Fuzzy inference based modelling is a tool that can be to fill up the gaps which were not addressed earlier. Fuzzy logic can help describe the fuzzy relationship between different parameters.

## Problem Statement

The problem statement has been described as two different ways. 'Empirical studies on pedestrian motion to understand the flow of pedestrians' and then 'development of a reasonable model to emulate the pedestrian motion in different circulating areas'. Structural data (Length, width, height, slope etc) and some traffic data of pedestrian movement (speed, flow, and density) are recorded from various pedestrian facilities. Level of service conditions of the existing facilities where the data are collected from, are calculated. Various statistical analyses are done to understand whether the movements of pedestrians differ from each other on different facilities. A simple cellular automata model that can efficiently and logically show the route choice behaviour of pedestrians is developed. Another fuzzy inference based model is also formulated to understand the correlation among sidewalk width, crowd density on the sidewalk and pedestrian speed on the sidewalks. It is aimed to validate the models with real data collected from field.

## Data Collection

For this study, pedestrian motion is recorded using high quality video camera from various pedestrian facilities across the eastern part of India. Railway platforms, Railway foot over bridges are cherry-picked as pedestrian movement is found at a constant rate on those facilities. Rourkela (Odisha) and Manoharpur (Jharkhand) station are selected for this purpose. There is another reason why Railway foot over bridges and platforms are chosen so deliberately. It is the recent gloomy episode of crowd crush at a railway station. Video of pedestrian movement on platforms is recorded in different densities. Pedestrians are categorized as male and female pedestrians and their speeds on the platform and on staircases of the foot over bridges are calculated and compared. Pedestrian data is also collected from foot over bridges on roadways from two different places. Pedestrian movement is recorded at different

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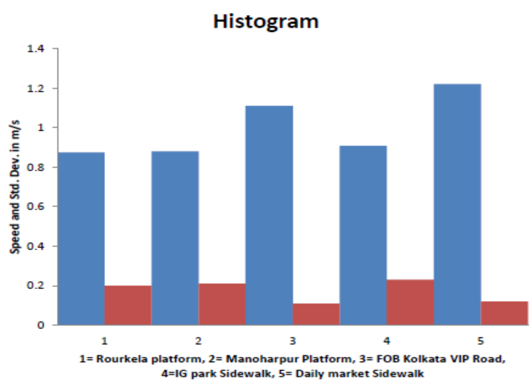
walkways. If one needs any convincing of how things quickly can change, of how rapidly order can turn into chaos, history offers us a number of painful reminders. Walkways or rather straight corridors are chosen after ruminating on the very recent events like Patna stampede. Stampede on 1st January 2015 at Shanghai brings melancholy as many people died and several injured. It was a straight corridor (shopping ally) where people gathered to revel. To get an idea of how bad things get and how quickly they escalate, one needs to study the behaviour of pedestrian's movement. In this study, in the following chapters an effort is made to understand and model the flow of people through corridors. However, extreme crowd events are not taken into consideration as such situations can't be created by experimental setup neither real data of speed flow can be collected for crowd on the spot.




## Proposed Model

The art of modelling is not to include everything that can be incorporated but rather to make the model as simple and tractable as possible to help answer the question that was posed. Consequently the judgement on the usefulness of a model is intricately linked to what problem it tries to address or the question for which it was devised to answer. In this study an attempt has been made to formulate a model which mimics the direction choice behaviour of pedestrians while they move along a long corridor. Here the proposed model is a very simple cellular automata model and only unidirectional motion is considered.

## Neighbourhood

Here in this proposed model, rectangular grid is chosen over other grid patterns because it is perfectly suited for the corridors with straight walls. A straight corridor is considered in this model. There is no geometrical variation or no bottleneck. No stationary obstacles remain inside the corridor. Co-pedestrians moving at a relatively slower rate are considered as obstacles for those pedestrians who are moving at a moderately higher speed. For the change of the cell states in cellular automata only information from the neighbouring cells are considered. Mostly there are two types of neighbourhoods which are basically used in cellular automata. These are:

- Von Neumann: Neighbouring cells sharing only one side with the basic cell are considered.
- Moore: All neighbouring cells sharing at least one corner with the basic cell are taken into account.

Here in this study, Moore neighbourhood is contemplated. Fig 4.1 shows different type of neighbourhood in cellular representation. While formulating and simulating the model, the forbidden moves of the Moore neighbourhood is kept in mind.

The Moore neighbourhood's forbidden moves should not be confused with the diagonal direction choice of pedestrians which is proposed in this study. A pedestrian can move diagonally when there is a vacant cell ahead of him/her or the pedestrian can change his direction of motion either diagonally right or diagonally left. This diagonal movement to the cell in the forward direction is made by the pedestrian if it is perceived by the pedestrian that there will be no conflict in stepping to that cell with other pedestrians who are moving forward and positioned parallel to him/her in side by lanes.

**Summary**

In this work, a huge amount of field data collection on pedestrian flow parameters is done. This video data collection is done for different pedestrian facilities. Some empirical studies are done using the collected field data. Some statistical tests are also conducted. Some existing phenomena in the pedestrian stream are explained. Some phenomena are explained through the microscopic model proposed here. Some are explained with some empirical parameters which are adapted from already conducted experiments (Chattaraj *et al.* 2010). Level of service is a measure of the existing condition and serviceability of a pedestrian facility. Level of service is evaluated for different pedestrian facilities in this current study. A microscopic model based on cellular automata is proposed for pedestrian dynamics. Another fuzzy inference based model which describes the correlation among sidewalk widths, sidewalk density and speed of the pedestrians has also been proposed. The models are validated with the real life collected data.

The main contributions of this work are:

i. Real life data collection of Indian pedestrians at different facilities

ii. Creation of a huge dataset of Indian pedestrians.

iii. Empirical observation of the flow parameters of pedestrian dynamics.

iv. Computation of level of service of different pedestrian facilities.

v. Development of microscopic models for pedestrian motion.

**Conclusions**

The major conclusions are as follows:

(a) Pedestrians move with different speeds on different facilities. This is one of the major behavioural findings in this thesis. This is established with the help of statistical tests. It is also found from the study that pedestrians walk with different psychology on different facilities.

(b) An oscillation phenomenon that occurs in bidirectional pedestrian movements in bottlenecks has been quantified with time series graphs.

(c) Pedestrians change their direction diagonally when they face some static or dynamic obstacles while moving along sidewalks. This direction choice behaviour is modelled proposing a cellular automata model.

(d) There is a strong relationship among sidewalk width, density of crowd on the sidewalk and the speed of the pedestrians moving along the sidewalk. This is modelled using fuzzy logic.

(e) Models can be validated with real-life data. In this study both the models are validated using real-life data collected on different pedestrian facilities.

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