Understanding the difference in social group behaviour of a spiritually motivated crowd and a general crowd

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Abstract. Over time, numerous studies have been conducted on pedestrian behaviour to improve the fidelity of pedestrian models considering pedestrians as individual entities. The participation of social groups is much higher than individuals in mass religious gatherings, which calls for studies focusing on understanding group behaviour in a crowd. Data was collected at two different settings (a) in Kumbh Mela 2016 representing mass religious gatherings and (b) Open day event held at Indian Institute of Science campus representing a regular urban setting. Trajectories of groups were extracted, and spatial formation of different group sizes were plotted. It was observed that group size 3 formed a linear or V-pattern and groups size 4 and 5 formed asymmetric irregular polygons. The area occupancy of groups and their average walking speeds were also calculated for both datasets, and it was observed that despite Kumbh Mela groups occupying lesser area, the average walking speed is higher than the groups in Open day. Looking at these group behaviour characteristics, this paper tries to uncover how group behaviour in mass religious gatherings is different from a low or moderate density setting and whether or not, there is a need for separate walking behaviour parameters.
Keywords: Crowd Dynamics, Group Behaviour, Mass Religious Gathering.

1 Introduction

Graphical simulation helps in proper assessment, planning and designing of mass gathering and other urban spaces, providing optimal architectural solutions for crowded facilities to ensure spatial effectiveness in terms of services and safety. But before these pedestrian simulations can support decision-making, it is important to calibrate and validate these computational models against empirical observations. Numerous studies have been conducted to understand pedestrian behaviour in crowd. All these studies aimed at understanding pedestrian behaviour in crowd to improve the fidelity of pedestrian simulation models. Majority of the work focuses on understanding pedestrian behaviour by considering pedestrians as individual entities. But speaking from crowd's characteristic standpoint, it is seen that social group visitors are the predominant population when compared to single visitors in any type of mass gatherings and as participation of social groups is much higher than individuals, it calls

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for studies focusing on understanding social group behaviour in a crowd and its impact on overall flow of crowd.

Considering the presence of groups within crowded pedestrian settings, extensive research has been dedicated to exploring group behavior. A comprehensive study conducted across 18 different locations revealed that approximately one-third of individuals arrived in groups of at least two members [1]. Likewise, an investigation conducted during a football event demonstrated that a significant majority, amounting to three-quarters of the participants, arrived in groups [2]. Notably, in the context of the Kumbh Mela, recognized as the largest mass gathering, a questionnaire survey indicated that a remarkable 95% of the surveyed individuals attended the event as part of a group [3]. The literature by [4, 5] suggests that the percentage of individuals arriving in groups within a crowd typically varies between 40% and 70%, with substantial dependence on the specific location and environmental factors.

Various researchers have examined the correlation between group size and walking speeds. The studies conducted by [6, 7] highlighted that an increase in group size adversely affects the overall speed of the group. Furthermore, [8] made an interesting observation that pedestrians tend to synchronize their steps when the crowd density surpasses a critical threshold. Moreover, it is widely acknowledged that pedestrian groups tend to exhibit distinctive patterns during their movement from one point to another. This notion is further emphasized by [9], who posited that pedestrian groups naturally develop unique patterns when they have the freedom to evolve over time.

This paper attempts to address the gaps in understanding social group behaviour of a spiritually motivated crowd in a mass religious gathering and an annual event that happened at an educational institution in Bangalore in a typical urban setup by focusing on the following:

1. Comparing the social group size proportion in both contexts.
2. Comparing the spatial formation of walking groups over time and space in both contexts.
3. Comparing the area occupancy of individuals with respect to varying group sizes in both contexts.
4. Comparing the average walking speed of groups with respect to varying group sizes in both contexts.

2 Study Area, Data Collection and Data Extraction

Data was collected in two different settings, i.e., Kumbh Mela event (representing spiritually motivated crowd) and Indian Institute of Science, Bangalore Campus (representing crowd in a typical urban setup). Data collection was done in Kumbh mela held in Ujjain, India, during 22nd April to 21st May 2016. Social groups were identified by authors and portable GPS devices were handed over to each member of the group. Highly accurate GPS devices were used to record location coordinates and speed of the social group members with time stamp. Data for 26 groups of size 3, 4 and 5 was collected GPS traces of a group of 4 is shown in Fig. 1. Another dataset representing controlled- setup was collected on open day event held at Indian Institute of Science in

Bangalore, India in 2018. Video data was collected to capture the social group movement inside the campus. Manual data extraction was done for 30 groups of size 3, 4 and 5. Fig.2. depicts the group identification and trajectory extraction of a group in Open day.

Fig. 1. GPS trace of a group of four persons

(a) (b)

Fig. 2. (a) Group identification; (b) Trajectory extraction

3 Data Analysis and Results

For comparison among the two datasets, proportion of the group size, group's spatial formation pattern, its average area occupancy and walking speed were looked at. These parameters were chosen as they were considered to be key indicators for any simulation model to closely replicate field conditions.

3.1 Group size proportion

The number of groups for each group size was manually counted for open day and Kumbh. A total of 1494 and 2098 groups ranging from group size one to seven and greater than seven were identified. Maximum number of people were found to be

moving in groups of two. About 77% and 67% of people along the study section in open day and Kumbh Mela respectively, came in groups. The plot between number of groups and group size peaks at group size 2 and declines gradually with increase in group size. Group size proportion for Kumbh Mela and open day is seen in Fig. 3.

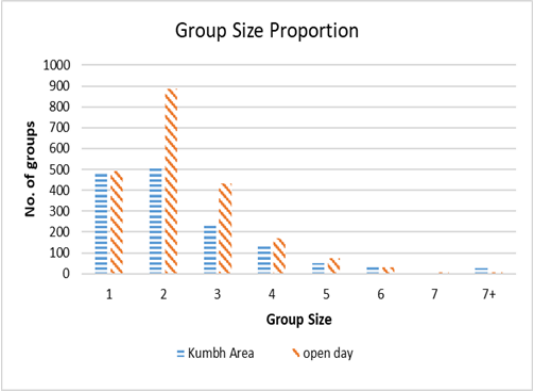

Fig.3. Group Size Proportion for Kumbh Mela and Open Day

In order to support communication and/ or close proximity with group members, the emerging spatial patterns that the groups take in order to walk in their comfortable positions was studied. The patterns that groups of size 3, 4 and 5 form along a straight corridor over a period, for both open day and Kumbh data, are plotted using their coordinates. Fig. 4, 5 and 6 show the patterns that were predominantly seen during the Open day event for group sizes 3, 4 and 5 respectively. Fig. 7, 8 and 9 show the patterns that are predominantly seen in Kumbh Mela for group sizes 3, 4 and 5 respectively. The spatial patterns are depicted inside the boxes and vertices of the polygons represent group members.

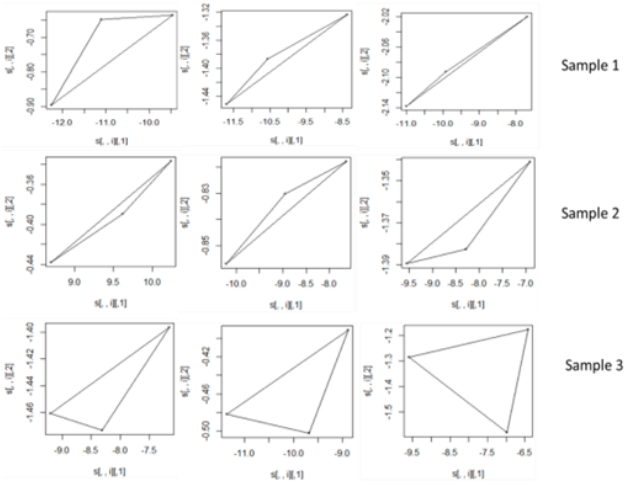

Fig. 4. Predominant pattern in Open Day for group size 3

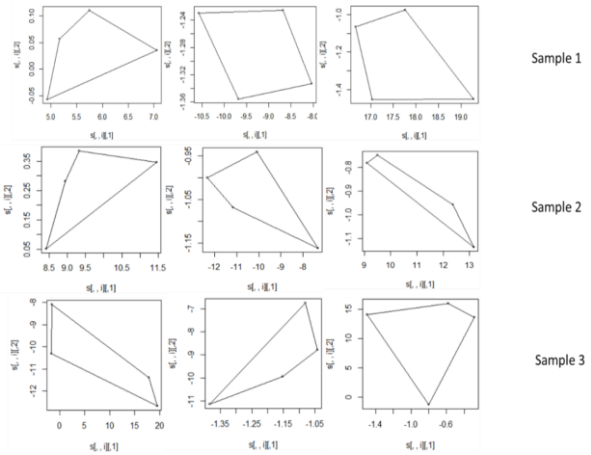

Fig. 5. Predominant pattern in Open Day for group size 4

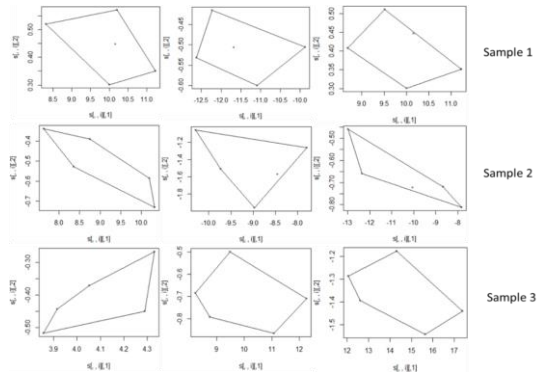

Fig. 6. Predominant pattern in Open Day for group size 5

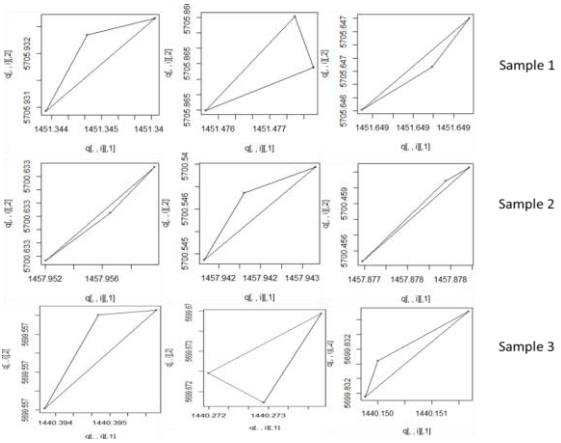

Fig. 7. Predominant pattern in Kumbh mela for group size 3

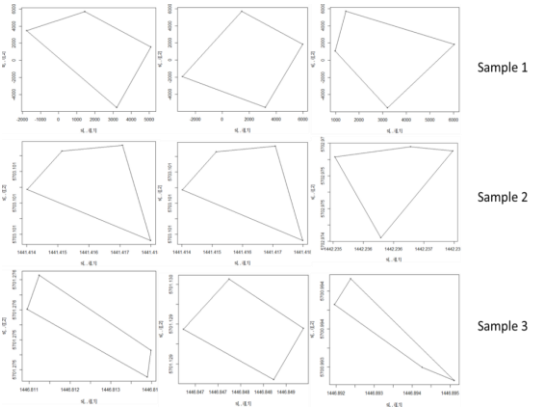

Fig. 8. Predominant pattern in Kumbh mela for group size 4

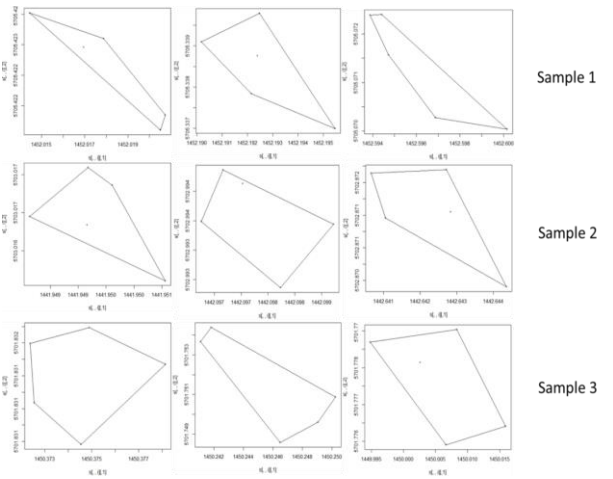

Fig. 9. Predominant pattern in Kumbh mela for group size 5

It is evident from the figures that group size 3, in both cases, majorly form linear or V-pattern whereas group size 4 and 5 form asymmetric irregular polygons.

3.2 Area occupancy

It was seen that as the group size increases, the area occupied by the groups also increases in both cases. This is supported by the spatial formation data as the group size 3 has a predominant linear or V-pattern which occupies lesser area when compared to group size 4 and 5 that predominantly forms irregular polygon, thus occupying more area. It was also observed that the area occupied by groups of sizes 3 and 4 was higher for open day when compared to groups in Kumbh Mela. This could be a result of higher number of participants, leading to prevailing high density conditions forcing groups to be more cohesive than the groups walking in low density setting. Table 1 summarizes the area occupancy of groups with respect to varying group size in open day and Kumbh.

Table. 1. Area Occupancy of different group sizes

Setting/ Event	Group size 3	Group size 4	Group size 5
Open day (in Sq. m)	0.66	1.9	3
Kumbh (in Sq. m)	0.8	1.8	2.05

3.3 Average Walking Speed

It was observed that the average walking speeds did not vary much for different group sizes but the walking speed was higher for Kumbh Mela. Table 2 summarizes the average walking speeds of groups with respect to varying group size in open day and Kumbh. The reason for similar average walking speeds for all group sizes in Kumbh

may be due to the motivation and the urge to achieve the common goal of reaching the destination as quickly as possible. The reason for similar average walking speeds for all group sizes in open day may be due to low density that is observed. Even at high densities, groups in Kumbh maintain high speeds which show that the average walking speed of groups in Kumbh is higher than groups in open day. This is owing to the spiritual gain that the people derive from the participating in the occasion and a sense of rare opportunity and urgency to achieve their goals. The average walking speeds are log normally distributed with $\alpha = 0.01$. Fig.10. shows the log normal distribution for Kumbh and open day.

Table 2. Average walking speed of different group sizes

Setting/ Event	Group size 3	Group size 4	Group size 5
Open day (in Sq. m)	0.45	0.44	0.47
Kumbh (in Sq. m)	0.96	0.99	1.03

4 Conclusion and Discussion

The central finding of the work is that behaviour of groups in mass religious gatherings is different from groups in regular urban settings. Owing to the number of participants and the geometric condition, density is high in Kumbh and so the area occupied by groups is less than area occupied by groups in open day. However, the average walking speeds of groups in Kumbh is higher than groups in open day and the groups maintain high speeds irrespective of group sizes. The reason is mainly due to the psychology of crowd towards the spiritual gain that the people derive from the occasion and urgency to achieve their goals. This induces motivation and urge to move forward to the destination which keeps people moving with constant high speeds. The study also attempts to analyze to what extent the spatial formation of different group sizes is changing in a narrow corridor over time for both settings and it is seen that group size 3 predominantly form linear or V-pattern whereas group size 4 and 5 form asymmetric irregular polygons. These results show that group behaviour has noticeable influence on the macroscopic parameters of crowd such as speed, flow and density.

As part of further work, the authors intend to study the impact of density on groups in two datasets. Understanding pedestrian group behaviour can help in decision-making by incorporating these empirical observations in pedestrian simulation model. The empirical results reported herein should be considered in the light of some limitations. In this study, the authors have compared GPS and video data. As different data sources are compared, measurement error cannot be eliminated, which is not considered. Also, this study is limited to groups of smaller sizes. Studying the behaviour of large groups can give more insights into their influence on crowd movements.

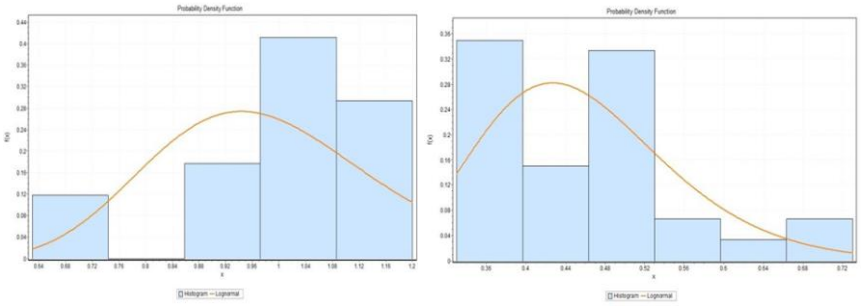

Fig.10. Average Walking Speed with Alpha = 0.01 for (a) Kumbh (b) Open day

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