Experimental Study of Step Behavior in Pedestrian Movement

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Background

• Large crowds or high density crowds disaster

Stampede accident of Shanghai the Bund, 2015, China

From: http://baike.baidu.com/
Background


Seyfried et al. — The fundamental diagram
— Lockstep behavior
Background

Asja Jelic et al

—Pedestrians walking in lockstep at high densities

Daichi Yanagisawa et al

\[ V(\rho) = S(\rho)P(\rho) \quad (h = \frac{1 - b\rho}{\rho}) \]
\[ S(\rho) = \begin{cases} s & (0 \leq \rho \leq \rho_c) \\ \rho_s h(\rho) & (\rho_c < \rho \leq \rho_j) \end{cases} \]
\[ P(\rho) = \begin{cases} p & (0 \leq \rho \leq \rho_c) \\ p - a[h_c - h(\rho)] & (\rho_c < \rho \leq \rho_j) \end{cases} \]

**Background**

- **Density** \( \rho \) (maximum \( \rho_j \))
- **Velocity** \( V(\rho) \)
- **Step size** \( S(\rho) \)
- **Pace of walking** \( P(\rho) \)
- **Headway (Distance)** \( h \)
- **Thickness of pedestrian** \( b = 0.35 \text{ m} \)
- **Free step size** \( s = 0.5 \text{ m} \)
- **Parameter** \( k, a \)

Daichi Yanagisawa 《Improvement of pedestrian flow by slow rhythm》 Physical Review E, 2012, 85, 016111

**Graph**

- X-axis: Density \( \rho \) [persons/m]
- Y-axis: Flow \( Q \) [persons/sec]
Issues need to be revealed

— Microcosmic Influence

— Synchronization & Antisynchronization
## Experiment

<table>
<thead>
<tr>
<th>Item</th>
<th>Detail</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Time</strong></td>
<td>October, 2009</td>
</tr>
<tr>
<td><strong>Place</strong></td>
<td>Baoji, China</td>
</tr>
<tr>
<td><strong>Organizer</strong></td>
<td>Weiguo Song et al</td>
</tr>
<tr>
<td><strong>Participant</strong></td>
<td>College school students</td>
</tr>
<tr>
<td><strong>Number</strong></td>
<td>5, 10, 15, 20, 25, 30, 40, 50, 60</td>
</tr>
</tbody>
</table>

- **Length**: 21.94m
- **Density**: 0.23~2.73 person/m
Data processing

1. Position extraction
   Extracting point from each frame

2. Pedestrian trajectory
   Tracking using Matlab

3. Trajectory rectification
   Direct Linear Transformation

4. Movement characteristics
   Statistical analysis

headway

2015/10/29
Experiment

Statistical Method

Duration

Length

2015/10/29 USTC Liu Chi et al
• Step Behavior: **Length & Duration**
Results

• **Step Behavior:** Stop & Go

![Graph showing pedestrian step behavior](image)

- **Headway < 0.344m**
  - Move -> Stop

- **Headway > 0.487m**
  - Stop -> Move on
Results

• **Step Behavior: Fitting**

- **Headway** $h$
- **Step Length** $S(h)$
- **Step Duration** $T(h)$

\[
S(h) = \begin{cases} 
0 & (\text{stop}) \quad h < 0.344 \\
0.61h - 0.08 & 0.344 \leq h < 1.1 \\
0.59 & 1.1 \leq h
\end{cases}
\]

\[
T(h) = \begin{cases} 
0.96 & (\text{stop}) \quad h < 0.344 \\
-0.38h + 0.96 & 0.344 \leq h < 1.1 \\
0.54 & 1.1 \leq h
\end{cases}
\]
Results

• Synchronization & Antisynchronization

N=25

N=40

Synchronization

Antisynchronization
Results

• Synchronization & Antisynchronization

![Graphs showing synchronization and antisynchronization](image-url)
Results

- **Synchronization & Antisynchronization**

\[ V(h) = \frac{S(h)}{T(h)} \]
Summary

A Single-file experiment was conducted

The relation between headway and movement characteristics is found

- Headway-Step length
- Headway-Step duration
- Headway-Stop & go
The characteristics of synchronization & antisynchronization movement are compared

- Headway-Step length
- Headway-Step duration
Thanks for attention

Any questions?
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