Prediction of Pedestrian Speed with Artificial Neural Networks

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Context and objective

• Pedestrian dynamics depends on the type of facilities
  → Difficult prediction of pedestrians movements in complex geometries (including corridor, bottleneck or intersection) with models based on a single fundamental diagram (FD)
  → Artificial neural networks could be suitable alternative for prediction of pedestrian dynamics in complex geometries

• Aim: Compare estimations of pedestrian speed with a FD-based model and a neural network for combinations of corridor and bottleneck training and testing sets

Models

Pedestrian speed models based on \( K = 10 \) closest neighbors

• Weidmann FD model
  \[
  v = \text{FD}(\bar{s}_K, v_0, T, \ell) = v_0 \left(1 - e^{-\frac{\ell}{\bar{s}_K v_0 T}}\right)
  \] (1)
  with \( \bar{s}_K = \frac{1}{K} \sum_i \sqrt{(x-x_i)^2+(y-y_i)^2} \) the mean spacing

• Artificial neural network with hidden layers \( H \)
  \[
  v = \text{NN}(H, \bar{s}_K, (x_i-x, y_i-y), 1 \leq i \leq K)
  \] (2)
  \( 2K + 1 \) inputs: Mean spacing + \( K \) relative positions

Data

Two datasets obtained in laboratory conditions

• R: Ring experiments
• B: Bottleneck experiments

\[
\begin{array}{c|c|c|c}
\text{Mean spacing, m} & \text{Speed, m/s} & \text{Ring} & \text{Bottleneck} \\
0.5 & 0.5 & 0.5 & 0.5 \\
1.0 & 1.0 & 1.0 & 1.0 \\
1.5 & 1.5 & 1.5 & 1.5 \\
2.0 & 2.0 & 2.0 & 2.0 \\
2.5 & 2.5 & 2.5 & 2.5 \\
3.0 & 3.0 & 3.0 & 3.0 \\
3.5 & 3.5 & 3.5 & 3.5 \\
\end{array}
\]

→ Different speed/spacing relations (fundamental diagram)

\[
\begin{array}{c|c|c}
\ell & 0.64 & 0.61 \\
T & 0.86 & 0.48 \\
v_0 & 1.60 & 1.58 \\
\end{array}
\]

Setting the neural network

50-bootstrap cross-validation with training and testing sets

• Assessment of the fit by mean square error (MSE)
• Different hidden are tested: \( H = (3) \) gives the best fit

Results

Evaluation on different combinations of training/test sets

→ Identification (partial) of the two geometries

\[
\begin{array}{c|c|c}
\text{R+B/R+B} & \text{R} & \text{B} \\
\ell & 0.63 & 0.66 \\
T & 0.68 & 0.59 \\
v_0 & 1.44 & 1.51 \\
\end{array}
\]

Conclusion

• NN: Improvement of pedestrian speed prediction up to 20%; Other FD, inputs, hidden and training sets to be tested
• Computation time \( \approx 10 \) h on a 2.7 Ghz processor \( (n = 4000) \): For large database the use of super computers is necessary
• Simulation of the NN model (recursive neural network)