Summer Reading 13: Social force model for pedestrian dynamics

Social Robot Navigation Project @ Bot Intelligence Group

Paper:
Social force model for pedestrian dynamics
1995
Dirk Helbing and Peter Molnar
II. Institute of Theoretical Physics, University of Stuttgart,
https://arxiv.org/abs/cond-mat/9805244

Summary:

Abstract

It is suggested that the motion of pedestrians can be described as if they would be subject to ‘social forces’.

Social force:

- These ‘forces’ are not directly exerted by the pedestrians’ personal environment.
    - However, these forces are a measure for the internal motivations of the individuals to perform certain actions (movements).

Force terms in the presented model of pedestrian behavior:

1. A term describing the acceleration towards the desired velocity of motion
2. A term reflecting that a pedestrian keeps a certain distance to other pedestrians and borders
3. A term modeling attractive effects

The resulting equations of motion are nonlinearly coupled Langevin equations.

Introduction

In the past decades, pedestrian behavior models drew interests because:

1. There are striking analogies with gases and fluids
    - In the 1970s, Henderson showed a fluid-dynamic approach. He compared measurements of pedestrian flows with Navier-Stokes equations.
    - Henderson’s approach was improved and mathematically founded by Helbing on the basis of a pedestrian specific gas-kinetic (Boltzmann-like) model in the 1990s.
    - Later, more attention was attracted by ‘microscopic’ approaches for vehicular traffic.
2. All model quantities (places, velocities, etc.) of pedestrians are measurable, therefore, comparable with empirical data.

The Social Force Concept

Human behavior can be stochastic, not chaotic, if we can find restrictions to the behavioral probabilities in a huge population/group of individuals.

It is possible to put the rules of pedestrian behavior into an equation of motion because:

- A pedestrian is used to the situations/environments where he/she is normally confronted with. Thus, his/her reaction is usually automatic and determined by his/her experience of which reaction will be the best.
- In the equation of motion, the systematic temporal changes dw/dt of the preferred velocity w(t) of a pedestrian are described by a vector quantity F(t).

The authors say that “A pedestrian acts as if he/she would be subject to external forces”.

Formulation of the Social Force Model

Main effects that determine the motion of a pedestrian:

1. A pedestrian wants to reach a certain destination as comfortably as possible.
    a. A pedestrian normally takes the shortest possible way (a way without detours).
    b. If a pedestrian’s motion is not disturbed, he/she will walk into the desired destination with a certain desired speed.
2. The motion of a pedestrian is influenced by other pedestrians.
    a. A pedestrian keeps a certain distance from other pedestrians.
        i. The distance depends on the pedestrian density and the pedestrian’s desired speed.
    b. A pedestrian keeps a certain distance from the borders of buildings, walls, streets, obstacles, etc.
3. Pedestrians are sometimes distracted/attracted by other persons or objects.
    a. The attractiveness normally decreases with time t since the interest is declining over time.
    b. Attractive effects are only influential for situations that are perceived in the desired direction of motion.
        i. Situations occurring behind a pedestrian will have a weaker influence.

Conclusion

It has been shown that pedestrian motion can be described by a simple social force model for individual pedestrian behavior.

The investigation of pedestrian behavior is an ideal starting point for the development of other or more general quantitative behavioral models since the variables of pedestrian motion are easily measurable so that corresponding models are comparable with empirical data.

Glossary: