A Survey on Agent-Based Modeling of Pedestrian Movement

Melanie Barker
University of Central Florida
Orlando, FL
United States of America

ABSTRACT

Agent-based modeling alters an important paradigm in computer simulation. Traditional discrete-event simulation looks down on a system from above, designing process flows and creating entities to travel through the system. Agent-based modeling changes the perspective of the simulation from the high-level processes to that of the entities, called agents. Instead of the processes evaluating and manipulating the agents, the agents themselves are able to gather information about their environment and react based on what they individually perceive. The power of agent-based modeling lies in its ability to allow the agents to have some level of intelligence and to control their own decisions, thus resulting in behavior and outcomes that are more authentic in systems dependent on individual actions. Because of this unique perspective, agent-based simulation techniques are well suited for modeling pedestrian flows through an environment. The techniques are able to address some of the difficulties from which pedestrian modeling has suffered when trying to obtain complexity on a microscopic level. This paper contains a survey on the history, current uses, and future possibilities of agent-based modeling of pedestrian movement.

KEY WORDS: agent-based, pedestrian movement

1. INTRODUCTION

Historical models of pedestrian movement have generally been limited to the macroscopic scale. Emphasis on transportation planning from the automobile perspective and lack of computing power are two factors that have influenced this focus [1]. As congestion becomes a serious factor in major cities, many transportation planners look to encourage inhabitants to return to walking [2]. However, little is understood about how to make walking desirable [3]. In tandem with this renewed emphasis on alternatives to using personal vehicles, complex microscopic models studying pedestrian movements are now more feasible given that the limitations of computing are rapidly evaporating.

Some of the more common historical modeling methods for pedestrian flow were simple statistical regression techniques and fluid-flow analysis. The first method used regression to determine the most important factors influencing walking volumes. Fluid-flow analysis treats pedestrian movement as a fluid moving around obstacles [1]. While both of these methods can show impact to pedestrian flow from a high-level perspective, they are weak at demonstrating behavior of individual pedestrians.

True microscopic simulation of pedestrian movement has been difficult to simulate for several reasons. Raw computing power was a critical limitation. Another programming issue was that the ability of software to reproduce accurate individual behavior had not been fully developed. With the rise of object-oriented programming, software has become more capable of emulating pedestrian behavior [1]. Object-oriented programming lends itself to pedestrian simulation well because it allows the pedestrians to be simulated as individual objects.

One final restriction on the rise of detailed models of pedestrian behavior was the complexity of the pedestrian behavior. In typical transportation simulations, vehicles are constrained to stay on roads, travel in a certain direction, and generally stay within a predictable rate of speed. Pedestrians face no such requirement. They can stop randomly, change direction, and choose from a nearly limitless set of paths. Depending on the setting for the simulation, group behavior may need to be taken into account to deal with family units traveling together. Some work has been done with crowd simulations, but most of that work has been limited to treating the crowd macroscopically. Many times this type of simulation has been for the benefit of the film industry rather than to understand accurate human movement.

2. BODY

With the constant introduction of improved computer speed, memory, and programmability, microscopic models of pedestrian movement have become more practical. Three types of microscopic models are common: cellular automata, behavioral force, and agent-based [4]. Cellular automata models divide the given space into discrete cells or points. Entities then occupy these points and move through the simulation, avoiding other occupied cells [5]. Behavioral force models are similar to the historical fluid-flow models, but operate on individual entities instead of modeling the group as a
collection. Finally, agent-based simulations model each individual pedestrian as an agent. The agents can have unique attributes and goals and respond to environments based on these attributes. They are autonomous and intelligent. Instead of moving through a simulation like typical entities, agents can recognize and respond to their environment. The simulation may contain a large number of these agents, all acting independently [6]. This makes agent-based modeling ideal for pedestrian flows.

Agent-based modeling traces its breakthrough back to Craig Reynolds’ boids model from 1987. Reynolds modeled the flocking behavior of birds by creating individual agents, or boids. The boids then adjusted their flight patterns based on the proximity and direction of their nearest neighbors. By controlling the behavior of the individual elements, the desired behavioral patterns of the group could be produced. The key difference with agent-based simulation is that of perspective—whether the control in the simulation belongs to the entities themselves, or to an overall process flow that dictates to the entities. Pedestrian modeling can take advantage of this to model the individual walkers and see the resulting patterns on the macroscopic scale.

In 1999, the Centre for Advanced Spatial Analysis (CASA) in London developed an agent-based pedestrian model called STREETS [7]. The model was considered to be a mesoscopic model—more detailed than a macroscopic level, but not quite to the microscopic model level [8]. The model was programmed in SWARM, a well-known agent-based simulation package developed by the Santa Fe institute. The model developers used socio-economic factors to give the agents individual goals, such as locations to visit. Behavioral characteristics set the ability of the agents to complete those goals, allowing some agents to be more able to be distracted than others. The model also used Geographic Information Systems (GIS) vector data of the buildings and raster data to define the desirability of walking on different surfaces in order to make the sidewalk highly preferred versus the street [7]. The STREETS model is widely considered to be an important early example of agent-based pedestrian modeling.

Current work in agent-based pedestrian modeling is focused on refining the individuality of the agents. The agents represent both the pedestrian themselves as well as the surrounding objects. PEDFLOW was a model developed in Java. In PEDFLOW, agents represent both the pedestrians and the objects that could potentially attract them, such as show windows and street performers [8]. Behavioral rules govern the movement of the agents. Set covering rules direct the movement of the agents. The model is limited to three lanes of travel in order to simplify obstacle avoidance.

CASA, the developers of the STREETS model, continue to refine their pedestrian modeling. Much of their work is focused on refining the pathfinding techniques. The newer movements involve fractal math to design the paths. They used some of the new techniques to model the Tate Britain Gallery in London. Density counts from the closed-circuit television cameras were used for calibration. SWARM was used for the modeling, as it was in the original STREETS model. They also tested another model incorporating both cellular automata and agents on the Notting Hill Carnival, which gave them a good chance to set up the model with a different group of behaviors versus their other modeling efforts [9].

XJ Technologies has developed a pedestrian library for their AnyLogic product. The pedestrian library was initially released in May 2005. The goal was to create a library with functions that could make pedestrian modeling more readily available and less complicated. In March 2006, they completed the development of the transport part of the library. The library now allows users to model roads, traffic signals, vehicles in the same area with pedestrians and their interactions [10].

Other groups are working on developing agent-based models. The University of Delaware’s Intelligent Transportation Systems Laboratory is working on developing a model [11]. The Matt MacDonald Group has a product called STEPS which is a microsimulation tool for predicting pedestrian movement [12].

Agent-based pedestrian flow is also having an impact on egress modeling. Because of the potential variations in behavior and the risk to life, there is a great deal of value to understanding egress on the microscopic level. The models are simpler in that the goal of the agents is singular: to escape and survive. Another interesting addition to the egress pedestrian models is the potential for agents to act irrationally when confronted with danger. The model allows different parameters to be set for when the agents become aware of the danger, how they attempt to escape from it, and their level of acceptable risk with respect to the danger [13]. In a macroscopic model, it may not be possible to truly understand the impact of individual behaviors. In most macroscopic models, the assumption is that small individual behaviors will not impact the larger picture, or will not have significant consequences if they do. In emergency scenarios, the behavior of one individual could affect others and the result could include serious injury or loss of life. Microscopic models can take into account individuals who are unable or less able to help themselves, such as the young, elderly, or severely disabled. The evacuation models can also test exiting various building types to see what effects different physical structures have on exit flows and length of time to exit [13].

Other interesting work being done in the agent-based pedestrian field involves validation of existing agent-based models. In Australia, a research group from the University of Melbourne used a recreation behavior
simulator called RBSim to predict movement within Twelve Apostles Port Campbell National Park. The group used Alge timing ankle bracelets to map where tourists actually visited. The ankle bracelets are the same type as used to track athletes in marathons. Tourists were intercepted and asked to wear the bracelets. The receivers were placed near the main path intersections and used to track individual tourist movement [14].

3. CONCLUSION

The value of using agent based modeling techniques for pedestrian movement is obvious. As computing power continues to become more available and cheaper, the difficulties of developing accurate, complex microscopic models lessen. Renewed interest in making cities more pedestrian-friendly will also help drive research in the area. Advanced simulation will be able to account for more and more of the complicating behavior patterns of the pedestrians. Natural path determination, especially non-logical path choices, is a major factor. Once the specific movement choices are improved, other factors can be taken into account.

Pedestrian modeling is beneficial to numerous industries. Transportation planners can develop better city designs, encouraging more people to walk and reducing pollution from vehicles. Many retail and entertainment companies can take advantage of pedestrian modeling to improve the design of their facilities before they are even built, improving customer satisfaction and profitability. Safety can be improved with egress models to avoid building obstacles that could cause loss of life. Certainly other unexpected benefits will appear as these models improve and usage of this type of modeling becomes more routine.

REFERENCES


