

Animating Autonomous Pedestrians

Wei Shao and Demetri Terzopoulos
New York University, Media Research Lab*



Figure 1: The Original (top) and Reconstructed (bottom) Pennsylvania Train Station in New York City with autonomous pedestrians.

1 Introduction

Our research addresses the challenge of animating pedestrians in urban environments through an artificial life approach, which integrates motor, perceptual, behavioral, and cognitive components. Our contribution goes well beyond so-called “crowd animation” to develop a comprehensive model of *individual* pedestrians that includes innovations in each of these components, and in their combination, yielding results of unprecedented fidelity and complexity for fully autonomous multi-human animation in large-scale virtual environments, such as a virtual train station (Fig. 1).

2 Exposition

To model a broad variety of realistic behaviors in individual virtual humans, we adopt a bottom-up strategy [Tu and Terzopoulos 1994] that uses primitive reactive behaviors as building blocks that in turn support more complex motivational behaviors, all controlled by an action selection mechanism. In the virtual train station environment, pedestrians are classified as commuters, tourists, law enforcement officers, performers, etc., each pedestrian having its own class-specific action selection mechanism. Behaviors are triggered according to the pedestrian’s mental state variables, which encodes his/her current physiological, psychological, or social needs, such as tiredness, thirst/hunger, curiosity, the propensity to get attracted by performers, the need to purchase a train ticket, etc.

At the reactive behavior level, we have developed six key behavior routines. Two routines support static obstacle avoidance. Another three are dedicated to avoiding collisions with mobile obstacles (other pedestrians). A fail-safe behavior routine handles imminent collisions with any obstacle. To enable pedestrians to go where they desire, we have developed navigational behavior routines—specialized for passageway selection, passageway navigation, perception-guided navigation, arrival-at-a-target navigation, etc.—to address issues such as the realism of paths taken, the speed and scale of path planning, and pedestrian flow control through and around portals and other bottlenecks. To make our pedestrians more interesting, we have augmented their behavior repertoires with a set of non-navigational behavior routines, enabling them to select an unoccupied seat and sit down, approach a performance and watch, queue at ticketing areas and purchase a ticket, etc.

At the highest level of autonomous control, a cognitive model [Funge et al. 1999] is responsible for creating reasonable global navigation plans for a pedestrian to travel deliberately between widely separated regions of the environment. To give pedestrians the freedom to decide whether or not, and to what extent, to follow their plans during navigation, we implement a coupling between the behavioral layer and cognitive layer in which a goal stack is maintained for every pedestrian. Intuitively, the goal stack remembers “what needs doing”, the mental state variables dictate “why it should be done”, the cognitive controller decides “how to do it” at the deliberative level, and the behavior controller attempts to “get it done” at the reactive level.

As a particular implementation of the low-level human appearance and motor levels, we employ a commercial virtual human animation package called *DI-Guy* [Koechling et al. 1998]. We have customized DI-Guy to incorporate a motor control interface to our higher-level behavioral controllers, making it easy to replace this API with any other suitable low-level human API.

We represent the virtual environment by a hierarchical collection of maps [Shao and Terzopoulos 2005]. A topological map represents the global topological structure of the virtual world. Linked within this map are uniform-grid perception maps, which provide relevant information to perceptual queries in constant time, as well as grid and quadtree path maps, which enable efficient online path planning for global and local navigation.

3 Results and Conclusion

Our pedestrian animation system enables us to run lengthy simulations of pedestrians in a large urban environment ($200m(l) \times 150m(w) \times 20m(h)$) without manual intervention. Real-time simulation, excluding rendering, can be achieved for as many as 1400 autonomous pedestrians on an Intel Xeon 2.8GHz system with 1GB memory. With each pedestrian guided by his/her own autonomous control and deliberative decision-making abilities, the autonomous characters imbue the virtual world with realistic liveliness, social (dis)order, and complex multi-human dynamics, as shown in the lower half of Fig. 1. We are currently applying our pedestrian simulator in the domains of computer vision, as a testbed for visual sensor networks, and virtual archaeology, to visualize urban social life in reconstructed archaeological sites.

References

- FUNGE, J., TU, X., AND TERZOPOULOS, D. 1999. Cognitive modeling: Knowledge, reasoning and planning for intelligent characters. In *Proc. SIGGRAPH 99*, 29–38.
- KOECHLING, J., CRANE, A., AND RAIBERT, M. 1998. Applications of realistic human entities using DI-Guy. In *Proc. of Spring Simulation Interoperability Workshop*, Orlando, FL.
- SHAO, W., AND TERZOPOULOS, D. 2005. Environmental modeling for autonomous virtual pedestrians. *SAE Symp. on Digital Human Modeling for Design and Engineering*, in press.
- TU, X., AND TERZOPOULOS, D. 1994. Artificial fishes: Physics, locomotion, perception, behavior. In *Proc. SIGGRAPH 94*, 43–50.

*www.mrl.nyu.edu/~{weishao,dt}