SE-Star: A Large-Scale Human Behavior Simulation for Planning, Decision-Making and Training

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ABSTRACT

The purpose of this extended abstract is to present SE-Star, a Thales proprietary large-scale multi-agent simulator, together with the content of two scenarios, designed with the Paris Police Department, demonstrating its capabilities at offering powerful features for planning, decision-making and training in real-life scenarios.

Categories and Subject Descriptors

I.2.11 [Distributed Artificial Intelligence] Intelligent agents – Multiagent systems.

General Terms

Algorithms – Design – Experimentation – Human Factors – Performance – Security.

Keywords

Agent-based simulations – Human behavior simulations – Large-scale simulations – Tools and environments.

1. INTRODUCTION

The use of multi-agent systems for simulating human behaviors within large-scale environments is more and more increasing over the years in many industrial fields, such as Defense and Security, Smart Cities and Grids, Transportation, Training, Entertainment and Social Sciences. Their ability to reproduce the complex behaviors of thousands of virtual humans within large 3-dimensional environments allows them playing a large panel of real or fictive scenarios that require credible human activity. Thus, it makes them particularly well designed for tackling many use-cases, including:

- Assisting the decision-makers by exploring several hypotheses from a given situation, and making prediction about it.
- Designing physical or virtual critical infrastructures, such as stadiums, airports or energy grids, as well as testing and evaluating their procedures.
- Training operators acting in, or supervising, those infrastructures, by replaying scenarios that already occurred in real life, or by confronting them to newly created situations.

To fulfill those goals, those simulations must model several basic aspects of the human behavior, such as perception, navigation and visual appearance, together with more complex abilities, like memorization, cognition, emotions, planning and communication. On the other hand, they must allow simulating a large number of virtual actors, in order to breathe life into otherwise static environments.

There already exist several approaches trying to tackle the problem of large-scale human behavior simulation. Some of them focus on the behavioral complexity at the cost of the number of simulated entities, like Autonomous Pedestrians [6]. On the contrary, approaches such as YaQ [3], simulate environment populated with hundreds of thousands virtual entities exhibiting simple – mostly navigational – behaviors. Finally, some simulators try to take the best of both worlds by using scheduling [7], distributed [1] and level of detail [2] methods. SE-Star belongs to this last group, by implementing all three.

2. OVERVIEW OF SE-STAR

SE-Star is a microscopic multi-agent simulation, which is able to reproduce a large panel of human behaviors via the use of several completely independent processes, like Autonomous Pedestrians. However, unlike the latter approach, it also aims to animate dozens to hundreds of thousands agents in real-time.

Assuming that the experts responsible for the design of the agents' behavior are not those modeling the infrastructure in which the latter evolve, SE-Star makes a clear distinction between the intelligence of the agents and the one contained in the environment. Hence, on the one hand, an agent in SE-Star is fully autonomous and possesses unique physical and psychological traits characterizing its physiology and personality, thus defining its needs. On the other hand, the environment is populated with services, provided by objects as well as other virtual actors, which are used by the agent to fulfill its needs. Both aspects are fully customizable, allowing SE-Star to be extremely adaptable to any kind of scenario. The simulator even includes a repository of agents and objects behaviors, which can be easily used to build new simulations. This dual approach is reflected in the architecture of SE-Star, which is divided into a set of independent modules, each managing a feature of the simulator. They are as follow:

- SE-Base is the core of SE-Star, scheduling the simulation and managing parallel computations.
- SE-Detect computes the detections of each agent, via an artificial retina, mimicking the human visual system.
- SE-Brain is a motivational engine based on the Free-Flow Hierarchy approach that computes the physiological and psychological state of each agent.
- SE-Object manages the behavior of the objects populating the environment, modeled as hierarchical finite state machines.

Appears in: *Proceedings of the 14th International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2015)*, Bordini, Elkind, Weiss, Yolum (eds.), May, 4–8, 2015, Istanbul, Turkey.

- SE-Satisfy allows each agent to plan actions on the environment by using services provided by objects and other virtual actors.
- SE-Move drives each agent across the environment, relying on either steering, vision-based navigation or Reciprocal Velocity Obstacles approaches.
- SE-Com allows agents to exchange asynchronous messages, thus influencing each other.

This architecture makes SE-Star a powerful and modular microscopic multi-agent simulation, which can reproduce rather complex human behaviors. Experiments performed on a 3.30 GHz Intel Xeon E3-1245 PC with 8 GB memory showed that SE-Star is able to animate 7.000 agents in a large urban environment at 60 frames per second. This places it among the most advanced systems, according to the complexity of the reproduced behaviors.

In addition to these results, SE-Star implements three approaches allowing it to increase the number of simulated agents without relieving the real-time constraint. The first is to increase the time interval computed by each simulation step, relying on interpolation techniques to reduce the number of updates per second. It allows animating 20.000 agents in the large urban environment at 10 frames per second without any noticeable change. The second approach uses artificial intelligence level of detail techniques, described in [4] and [5], which increase the number of simulated agents up to 100.000 in the large urban environment at 60 frames per second. Finally, the last approach relies on peer-to-peer techniques to split the environment across several computers, each of them animating a subset of the virtual actors. Migration of agents between tiles, time synchronization and cross-tile detection are handled. A separation between simulation and rendering engines has been made, allowing displaying the whole simulation in any 3D textured renderer, thus hiding the peer-to-peer approach to the user. Recent experimentations showed that this approach allows simulating 30.000 uniformly distributed agents on five computers.

3. PROPOSED USE-CASES

The features described previously are demonstrated within two scenarios. Each of them has been designed with the Paris Police Department, in order to answer real use-cases. Specific features have been added to SE-Star, to model the procedures used by police forces on the operational field, such as the navigation of police formations, the hierarchical transmission of orders with possible information loss and interpretation, the tactical display of units on a geographic information system and the interaction between citizens, demonstrators and police forces. Those use-cases aim to provide an adaptive and user-friendly tool for training officer cadets on real and fictive scenarios, by supervising the operation field and moving their troops. The simulation also helps decision makers to optimize the placement of police checkpoints, thus facilitating the access of dozens of thousands agents to the supervised critical infrastructure.

The first scenario, illustrated in Figure 1, takes place in the Paris exhibition center at the Porte de Versailles. It stages a VIP visiting a medium-scale event. Several police forces have been deployed in order to ensure the security of the VIP. They can be moved at will, to prevent demonstrators from perturbing the visit. On the other hand, the attributes of each citizen and demonstrator can be modified in real-time, in order to provoke specific events such as riots, congestions and evacuations. The state of the simulation can be observed via a free camera, or via fixed cameras reproducing the real behavior of security cameras.

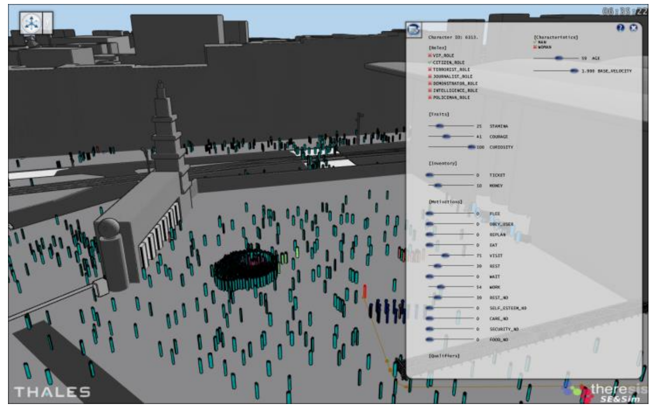

Figure 1. Screenshot of the "Parc des Expositions" scenario, with the VIP surrounded by a crowd of onlookers.

The second simulation takes place near the "Parc des Princes" stadium in Paris, where important events occur. It starts before a football match gathering together up to 50.000 supporters. Here, the police tactical command has placed several checkpoints, thus constraining the people flow to avoid congestion and fights. Those can be activated and deactivated in real-time to observe their influence on the agents' behavior. Moreover, fights can be triggered. This scenario can be executed in distributed mode, allowing the simulation to animate a large number of agents.

Those fully interactive scenarios browse nearly all the features described in this paper. Both have been validated by Paris Police Department experts as accurate enough to reproduce real-life scenarios, thus allowing them to explore hypothesis, planning and training officer cadets on securing large-scale events.

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