Improving Crowd Behaviour for Games and Virtual Worlds

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Fig. 1: Interactive crowd in the game *Assassin's Creed 2* [1]

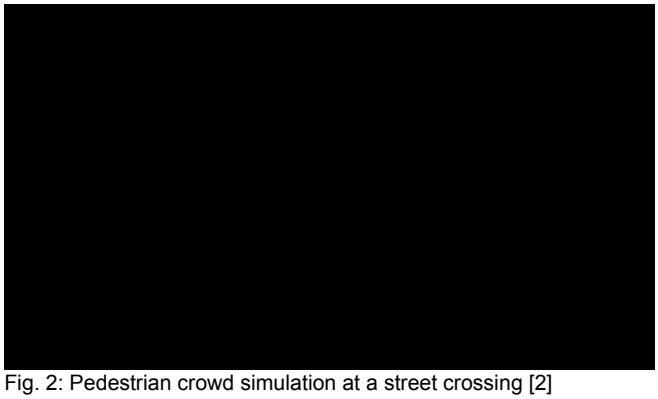

Fig. 2: Pedestrian crowd simulation at a street crossing [2]

Keywords

Crowds. Real-time. Path planning. Behaviour.

Introduction

When wandering around in the real world, a person is often surrounded by other people which inhabit the same area. In a virtual world, the absence of others thus creates an unrealistic effect and can destroy the feeling of immersion. Filling the world with crowds is an important step towards more realism, in computer games and other virtual environments.

Populating virtual environments with realistic behaving crowds is a challenging and diverse subject, where the need to compute large crowds in real time has to be balanced against the wish to simulate complex human behaviour.

In the computer game community, games that utilize crowds are just starting to emerge, making this field a very interesting area to work in. At the forefront of this development is Ubisoft's *Assassin's Creed 2* [1], shown on Figure 1. The game uses crowds of up to 120 characters at a time to serve as obstacles to the player, but also allows a limited interaction with the crowd: the player can follow groups of people to “blend in” on a crowded street and avoid being seen. But this is “only the beginning”, as the game's creative director puts it: “we are learning how to do a crowd, how to play with crowds, it is something you don't do in other games, or you don't do that much” [3].

In the scientific community, much research on crowd simulation has been published in recent years. Crowds are in particular used for simulating emergencies, but the population of virtual environments to enhance credibility is also a topic. One of the biggest problems in real-time simulations remains the believable behaviour of individuals within a crowd. Many crowds are only realistic if one does not watch them too long or too closely, as techniques which save computation costs also limit the diversity in look and behaviour of virtual characters.

Common problems with crowd behaviour – in games as well as in research - are characters that follow unrealistic paths, abruptly change their direction, oscillate back and forth, walk in circles because they have no memory, walk into obstacles, do not react to changes in the environment, or all walk by themselves instead of forming groups. There is also a notable uniformity in the looks, movement and mannerisms of individuals, instead of the variety of behaviours that can be observed in real crowds.

My work focuses on improving the real-time behaviour of individuals in a crowd in such a way that watching an individual for an extended period of time will not destroy the illusion of “natural” behaviour, and that a wide range of different behaviours can be observed within a crowd. I plan to achieve this by developing new algorithms for path planning and following, combined with a high-level description of the world which influences behaviour.

Related work

Real-time crowd simulation

The dynamics of crowds have been studied extensively in the past, and a variety of crowd simulation approaches exist. They range from early social forces models and fluid simulations [4] to cellular automata [5], rule-based systems [6] and agent systems. A recent example is shown on Figure 2.

Path following
Many path planning methods exist and are used in games, like grid based A* methods, navigation meshes, and flocking. I base my work on the Indicative Route Method (IRM). It can be used to steer characters though a complex virtual environment in real-time [7]. It creates a path based on a Voronoi diagram of a static environment, and an additional corridor which defines the area that a character can walk in while reacting to local conditions. Characters move towards a goal following an attraction point that moves along the path in the center of the corridor. The IRM only supports goal-oriented behaviour, and draws characters towards the center of a road, while people tend to walk on the sides. It does also not deal with turning corners in a realistic manner, nor take into account the different movements of people that are familiar or unfamiliar with an environment, people wandering around as tourists, people stopping or people striding purposefully, e.g. on the way to a meeting or home. Similar approaches with the same limitations have been proposed by [8].

Crowd diversity
Visual cues are the most common focus when trying to achieve diversity in a crowd while minimizing the number of 3D character models used: [9] have found that by changing the colour of characters' clothes, especially on the torso, the time it takes onlookers to detect clones in a crowd is extended. [10] have studied the effect of desynchronization and speed variation of motions of characters on clone perception, while [11] added a variety of props such as hats and bags to make a crowd look more diverse. Those approaches vary the look of characters, but not their behaviour.
To create complex behaviours, agent systems are often employed. In those systems, individual agents contain behavioural models, where different behaviours are triggered by the agent's internal states. The internal state can be the result of an emotion model or a set of rules [12]. Agent models of sufficient complexity are too computationally demanding to achieve real-time speed for large crowds and are therefore not feasible for computer games. One approach to solve the complexity problem was proposed by [13], who move the “intelligence” from the agents into objects in the scene, which tell approaching agents how to interact with them, but this does not scale to inter-agent interaction.

Research goals

My goal with this research is to fully automatically create and simulate crowds of people in real-time based on high-level descriptions. In particular, I want to achieve the following sub goals:

- To create new algorithms for crowd simulation based on path planning by expanding and enhancing existing methods like the IRM. I will focus on more realistic behaviour when turning corners, crossing open spaces and keeping distances from mobile and immobile obstacles, with the explicit constraint of real-time frame rates.
- To give the people in the crowd a range of varied behaviours, from the commonly found goal-oriented behaviour to distinctly different behaviours like shopping, wandering aimlessly or exploring.
- To handle dynamic changes in the world. This includes moving obstacles which completely block a path, as well as more indistinct influences on path choice such as crowd density and visibility in an area.
- To extend the variety of inter-character collision avoidance behaviours related to personality, gender, age and other properties of the characters.

To achieve those goals, I will begin by studying real-world crowds and their behaviour using observations, tracking people in videos, and controlled experiments in our motion capture lab. I will then derive computable models from the observations, design and implement algorithms simulating these models, and evaluated them in terms of quality and efficiency.

Relevance of research

The simulation of large crowds of people is increasingly gaining importance in video games, with crowds starting to become an integral part of game-play, instead of serving as the little observed backdrop where errors do not matter much. As soon as a player can interact with a crowd, or individuals therein, it is imperative that the crowd members behave in believable ways. Erratic behaviour will destroy the immersion in a virtual world and game creators cannot depend on suspension of disbelief regarding behaviour in an environment that offers ever more realistic graphics. They have to keep up with the development in other areas to create a balance that is essential for a high-quality overall game experience.
Another area where crowds are gaining importance are avatar-based online 3D social networks, e.g. Second Life [14]. A common complaint of business owners, tourist destination- and cultural heritage representatives trying to establish a virtual presence in those worlds is the emptiness of the environment. To give an example, one can imagine a tourist center rebuilding the ancient ruins of a culturally interesting area to give potential tourists an impression of the environment and draw new visitors. Without the addition of simulated crowds, the virtual area will not give a faithful representation of its real-world counterpart – leading to possible complaints from misled tourists and the general depreciation of the concept of virtual tourism.
A third application of crowd simulation lies in the area of serious games. Training people in a 3D environment for real-world tasks asks for a faithful representation of the situation which is trained. One can think of emergency situations involving large numbers of people, such as fire or natural catastrophes, which are impossible to create in the real world for training purposes due to the dangers involved. A realistic crowd simulation can give the trainees a much better impression of the tasks required.

I am convinced that all those areas will benefit immensely from crowds that express more varied and more realistic behaviours than are available at the moment.

Research plan

I am currently studying real crowds to classify the different behaviours that are most prevalent. I observe crowds in different locations – such as in a shopping area, in a touristic area and in a business district - which yield very different behaviours. From this, I will extract behavioural patterns and determine rules on how to implement them in an efficient way in a crowd simulation. Moreover, I study the variations on collision avoidance behaviour of individuals.

As a second step, I plan to create a framework which simulates crowds in a virtual world. The world will be described in terms of different layers. The lowest layer consists of the geometry of the scene. Additional layers will describe other parameters, for example obstacles, flow direction, areas of behaviour, areas of attraction or areas which a specific group of characters frequent. Each layer will influence the crowd in a different way, triggering local or global behaviours. By using a layer approach, it will be possible to incorporate the geometric as well as the high level properties of an environment in an all-encompassing format.

The global movement of the crowd will be determined by a network of routes, based on a further development of the Indicative Route Method. I am planning to expand this approach by enhancing it with non-goal-oriented behaviour and different ways of moving inside the predetermined corridors, as I believe that drawing all characters towards the center of the corridor is not the best possible solution. Instead, corridors should give information about preferred directions of motion, that can then be exploited in the local behaviour simulation.

My research offers ample opportunity for collaboration with academic as well as industry groups. It is supported by the ITEA2 Metaverse1 Project, a collaborative effort of industry, universities and research institutes to create a standardized global framework enabling the interoperability between real and virtual worlds [15]. Moreover, my work is embedded in the research of our group at Utrecht University, where several researchers are working on related subjects as part of the Dutch GATE project [16].

I am hoping to reach my research goals within the next three years, and contribute to the advancement of crowds as an integral part of games design and virtual worlds.

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