Extending ProactiveCrowd crowd behaviour model with additional agent behaviours

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In crowd behaviour research one of the key problems is realistic agent modeling. Typical models define the actions of an agent on two levels, a global one for reaching the end goal and a local one for obstacle and agent avoidance. In our work we re-implement the ProactiveCrowd model, which extends these approaches with proactive steering behaviours, which aim to minimize the time for reaching the end goal and mimics the real-life behaviours of individuals in a crowd. Such behaviours are gap-seeking and following, which often occur in real life crowd experiments. We then intend to extend the baseline ProactiveCrowd model with additional behaviours, namely stop-and-go and overtaking, which could lead to more realistic modeling of more complex crowds.

Crowd behaviour, agent-based modeling, proactive steering behaviours

Introduction

Crowd behaviour is the behaviour of a group of individuals who gather at the same place, often with a similar purpose. In psychology, there exists crowd psychology, a field that researches why people do the things they do in groups and how it differs from the acts of individuals. Since crowds appear everywhere in our society, modeling them is essential for studying architecture planning, safety designs of buildings, and optimization of crowded places. Agent-based crowd simulation has become one of the most powerful and realistic approaches to modeling groups of people, allowing us to model every individual with its own characteristics. Therefore the crowd dynamics appear as a result of behaviour of individual agents and interactions between them.

Agent-based modeling is often applied on two levels. The first one is global navigation, which steers the agent towards its goal location, and local navigation, which reactively changes the path of the agent, avoiding obstacles and other agents. In real-life experiments, we also observe proactive steering behaviours, which people perform to minimize the time spent on their path. We implement the existing model Proactive-Crowd, which utilizes two proactive steering approaches - gap-seeking and following. The existing approach will then be extended with additional behaviours - stop-and-go and overtaking. The latter could enable a more realistic simulation of more complex scenarios (e.g. multiple flows of crowds).

Project goal

Our work focuses on re-implementing the ProactiveCrowd model as seen in [2]. The reference model includes two implemented behaviors - gap-seeking and following. Since gap-seeking and following are somewhat separate behaviors, this provides us with the opportunity to add additional behaviors to this modular system. We start by implementing the general decision-making pipeline, to ensure default agent behavior - walking towards its goal. We follow by implementing the gap-seeking behavior and after that the following behavior, as it is dependent on the gap-seeking behavior. The original work compares itself to the DenseSense[3] and role-dependent steering[4] models, proving to be in most cases best and in a few cases match their performance based on several evaluation criteria, both agent-wise and crowd-wise. The basis for evaluation consists of two real-world examples that were recorded and documented in controlled environments to which all models are compared. Our goal is that our re-implemented model will achieve comparable performance as the reference model. Finally, our goal is to extend the model with two new behaviors - stop-and-go and overtaking to make our crowd simulation even more realistic.

Methods

Since our project is strongly based on the ProactiveCrowd model, we must first get familiar with the implemented crowd agents and behaviors. After that, we present additional behaviors with some new agent parameters that enable more realistic simulation.

Crowd modeling

Crowd modeling is used in various situations, from construction planning, to virtual simulations and military training. To approximate the real-world as closely as possible a good behavioural engine is required for the agents in the crowd. Agent-based modeling has appeared as the most realistic approach, since it enables modeling a heterogeneous crowd, where we can specify different actions for each individual. Proactive behaviours employed by the individuals in a crowd tend to realistically model the real life crowds. Such behaviours are gap-seeking, following, stop-and-go and overtaking. We implement the existing ProactiveCrowd model and extend it with two additional proactive behaviours.

Crowd behaviour, agent-based modeling, proactive steering behaviours

ProactiveCrowd model. ProactiveCrowd is a framework that seeks to model an agent's behavior in a crowd. The framework consists of three modules, namely the path planner, the proactive steering module, and the reactive collision avoidance module. At the start of the simulation, the path planner determines the start and the goal point of each agent. Along the charted path the proactive steering module is used to monitor the environment, and select and execute appropriate proactive behaviors. Proactive behaviors seek to proactively minimize future conflicts, instead of reacting to the conflicts as they occur. The proactive behavior module determines a desired velocity, which it then passes to the reactive collision avoidance module, where actual velocity is determined, to prevent collision with nearby agents and obstacles. Agent's behavior is defined by three main stages that are described in the following sections.

Default behaviour. At the start of the simulation, a start point and an endpoint are determined for each agent. The agent then attempts to go directly towards their goal, provided no other behaviour changes their path.

Gap-seeking. An agent only enters the gap-seeking state when they are not so close to their goal as to make gap-seeking detrimental to reaching their goal. If they are too close to their goal they only enter the gap-seeking behavior with a certain probability, which gets lower the closer they get to their goal.

Once the agent enters the gap-seeking state, they proceed to perform gap detection. The entire experiment state is divided into a grid, with the tiles being marked as occupied or unoccupied based on the presence of other agents or obstacles. The agent's vicinity is checked for unoccupied spaces and subsequently seeded randomly and then expanded, similarly to a crystal seed. The expansion spreads to nearby unoccupied and uncrystallized cells until it encounters a cell occupied by another agent or obstacle. Through this separate gaps are detected.

After all gaps in the detection area are detected the agent proceeds to decide which gap to pick. In case no gap was detected, the agent does not proceed to gap selection and instead follows another behaviour. To select a gap from the available gaps the gap must be within the agent's vision range, big enough for the agent to enter, must not deviate too much from the agent's moving direction, and should not already be a target of another agent's behaviour. If a suitable gap is found, the agent then proceeds to calculate the direction and speed required to reach the gap. It does so by computing the speed of the gap by averaging the speeds of the gap's bounding agents and computing the approximate time required to reach the gap. It then directs itself towards the gap's future position with the appropriate speed.

The agent continues to follow this behaviour until the center of the gap is reached, or until the seeking time expires.

Following. The following behaviour is dependant on gap-seeking, as followers follow either gap-seekers or other followers. The behaviour consists of choosing an appropriate followee, determining the length of the following behaviour and determining the follower's motion.

To trigger the following behaviour, an agent must first detect a gap-seeker or another follower within the same crowd flow. Once this condition is met, the viability of the followee is determined. For a followee to be a valid choice, their path must not deviate too much from the follower's path, and they must not already be followed by another agent. If a suitable agent is not found, the following behaviour is not performed. Among the valid choices, the closer followee candidates have a higher chance of being followed by the agent. After a followee is selected, the duration of the behaviour is selected. The further in the follower chain a follower is, the shorter their behaviour duration.

While following, a follower needs to adjust their desired velocity to keep following their followee. Direction should take precedence over speed, as it may affect the entire crowd dynamic.

Additional behaviours. For additional behavior to work we have to add some additional properties to our agents:

- **Urgency factor**: This parameter defines the urgency of the agent's path which will determine the speed of the agent's walk and will affect the agent's behavior selection. The higher this parameter is the more likely it is that the agent will perform gap detection or overtaking.

- **Start acceleration factor**: This parameter defines the agent's acceleration from the agent's starting speed to its final speed which is determined by the urgency factor. This will enable us to simulate the congestions that can happen because of the stop-and-go behavior.

Both behaviors are chosen from the behaviour pool on a random basis if all of the prerequisites for the chosen behaviour are met.

Stop-and-go. [5] Stop-and-go behaviour is usually observed in bigger crowds and when the subjects are queueing. Stop-and-go behaviour is the result of the agent's sudden stop and of the uncoordinated acceleration of the agents behind the stopping agent. This behaviour can lead to congestions since after an agent starts moving from a stopped position it takes some time for it to achieve its final speed again. This effect is propagated to all of the agents that were stopped behind the newly starting agent. The stopping agent can stop at any time and must be stopped for some randomly selected period of time from the given interval.

Overtaking. [6] The prerequisite for the overtaking is that the urgency of the overtaking agents is significantly higher than the urgency of the overtaken agent. The action of overtaking consists of detecting lower urgency agents in front. The next step is the detection of the overtake paths. An overtake path is defined as a gap to the side of the overtaken agent and clear space for an overtaking agent in front. The side gaps must be wide enough for the overtaking agent to squeeze through. The overtake has to happen within a limited time frame and if it fails the agent continues its path normally.

Evaluation. We will evaluate our model on the individual level and on the crowd level. We will try to replicate the same environment as in [2], which will enable us to compare our model with real world data. Since both datasets [7] are stored on a FTP server, which requires login credentials, we have contacted the authors and hope to acquire them.

Individual level evaluation. Evaluation on the individual level is important, since it enables us to see how accurately can our model replicate real world proactive steering behaviours. First, we will visually inspect the behaviours of individuals by analyzing the simulations. Agents that will engage in any of the proactive behaviours will be colored by a predefined color, which will enable us to observe their performance. We will visually compare both simulated and real-life crowds and draw conclusions.

Agent trajectory similarity will be used for quantitative analysis of the similarity between the agent and human data. We will use the longest common subsequence (LCSS) metric, which gives more weight to similar portions of the sequence. This will be used to compare the agents engaging in proactive behaviour, although we might have problems evaluating new behaviours, for which we don't have real world data.

In order to evaluate new behaviours, we will compare the average time it takes the agents to reach their destination if they're engaging in stop-and-go and overtaking or not. We assume that these behaviours should decrease the average time, since in real life people engage in them to reach their destinations faster.

Crowd level evaluation. Overall crowd dynamics will be evaluated by comparing the speed-density relationship of agents in a simulation and people in a crowd. Speed of agents tends to increase when the density decreases and vice versa. In the middle of the simulation we will define a region and whenever an agent passes through that region, his speed and the region density (depending on the number of other agents in the region) is recorded. For each agent we will acquire his speed-density pair. We will do the same on real-life data and compare the measurements.

Discussion

In this project report, we presented our plan of the re-implementation and the evaluation of the existing ProactiveCrowd model and outlined the plan for its extension with two additional behaviors. These additional behaviors will enable more realistic crowd simulations.

CONTRIBUTIONS. Hafner wrote the abstract, introduction and evaluation, Mur wrote the project goal and discussion, Bernard wrote the ProactiveCrowd model section, and Mur and Bernard wrote additional behaviours in collaboration.

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