Simulation of group behaviour during a protest

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The purpose of our project is to model the behaviour of a crowd during a protest as accurately as possible and attempt to observe the emerging behavioural patterns. At the start of a simulation we populate the scene with agents belonging to different subgroups: leader, protester, bystander. Eventually they can fluidly change between groups based on various parameters, such as proneness to defection and recruitment. These parameters depend upon the distribution (in the sense of groups) of agents in an individual's field of view. The movement of the leader is determined by arbitrary goals within the topological map, while the other agents follow the leader when it appears in their field of vision. To give the simulation a practical use, we additionally allow the user to manually place police agents into the scene and observe how they impact the behaviour of the crowd.

Protest simulation | group behaviour | leader dynamic

Protests are a widespread phenomenon involving typically large groups of people, oftentimes with different, or even conflicting goals between their respective subgroups. As such they are a fascinating subject for studies in various fields, from human psychology to group behaviour simulations, which was be our primary focus during the course of this project.

The central idea for the project was inspired specifically by the 2020 protests in Ljubljana, that had a distinguishing feature of a prominent individual leader emerging and influencing the movement of the crowd, but we have attempted to make our model applicable more generally (for instance, with minor parameter adjustments, we should be able to easily model sports riots or other similar events with various subgroups).

Related work

Although there are many existing attempts to model protest behaviour, in terms of general structure, our project will primarily build on concepts proposed by Lemos, et. al. [1]. The basic idea is to split the agents into subgroups depending on their level of involvement with the protest. The proposed subgroups are:

- active protesters, further divided by their level of aggression,

- passive protesters - hereafter we refer to them as bystanders,

- police/crowd control agents: their primary goal is dispersing a crowd or redirecting it in a specific direction.

Clements and Fadai [2] have developed a model that attempts to simulate emotional contagion in the context of a sports riot. Although our problem is slightly different in nature, we do apply the same principles of defection and recruitment in order to create approximately realistic transitions from active protesters to bystanders and vice versa, depending on what group the majority of agents in the current field of view of an individual belong to.

To make simulations appear as realistic as possible, it is necessary to give all agents movement parameters that aim to mimic human behaviour in crowded environments. The forces that impact each agent are described, for instance by Itatani and Pelechano [3] and are divided into: collision avoidance force, wall repulsion force, end-position seeking force, group dynamics force and anticipatory collision avoidance force.

Methods

In this section we discuss our implementation of the crucial subproblems required to make the simulation appear as realistic as possible.

By conducting simulations of protests using various models for different subgroups of people, we hope to gain some insight into group behaviour during such events, that might make them logistically easier to organize/control in the future.

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Subgroups. In addition to Lemos' subgroups [1], we also implemented the concept of a leader and for this purpose we divided the simulation into two modes:

- user manually controls the movement of a single leader: this can be used for instance to recreate very specific movement from real-life situations.

- a leader emerges from the group and causes nearby protesters to form a chain of followers.

Vision. To give our agents awareness of their surroundings, we also need to model vision (example of a visualization is shown in figure 1). This consists of two parts:

- field of view to model a human's eyesight. Default angle value is 120° (adapted from Itatani), with a distance of 20 Unity units.

- peripersonal space to model a human's ability to feel a presence outside of their field of view, if the distance is small enough. Default angle value is 360°, with a distance of 1.7 Unity units.
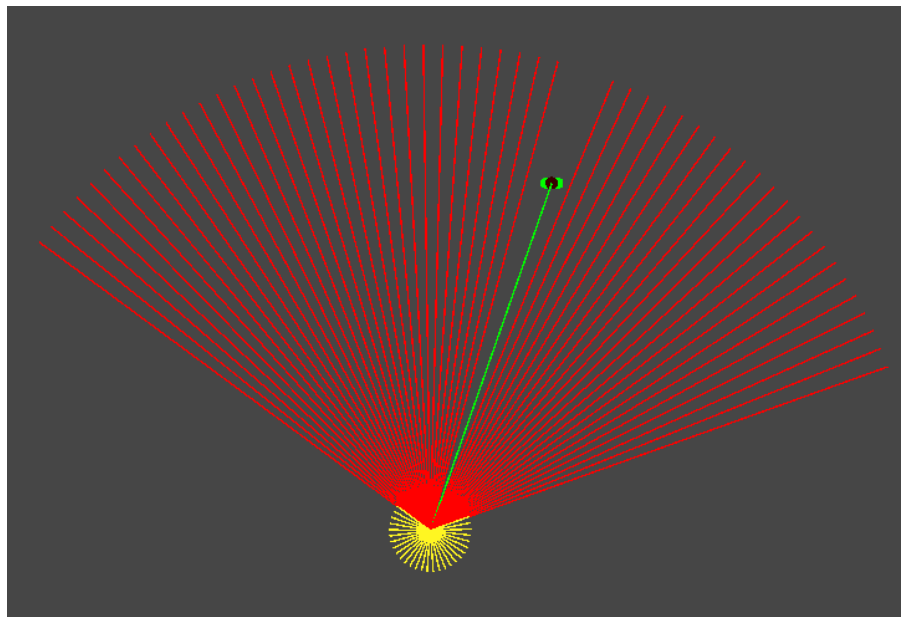
Figure 1. Visualization of the implemented vision: red rays represent field of vision, yellow rays represent peripersonal space, green ray represents a detected agent.

Additionally, we created a function for agents to look around without changing their position (an equivalent of a human turning their head around to observe their surroundings), with a default value of 300° and a distance of 20 Unity units. This function is used in various scenarios, for instance when deciding on a suitable move position, or for a leader to determine how many active protesters surround it at a given moment.

Movement. Agents switch between four states during the course of the simulation: stationary, in-motion, herd and disperse. The latter two come into effect when follow leader behaviour starts and stops. For this purpose we have come up with a restlessness parameter that gradually increases in agents that are standing still and once it reaches a certain threshold, the agent begins to move. To ensure that not all agents start and stop moving at the same time, it is paramount that the restlessness parameter is increased randomly and that different groups also have a different threshold in different scenarios. Generally protesters should have a lower restlessness threshold, however bystanders surrounded by protesters can become even more restless (to model anxiety to leave a heated area).

We deviate from Itatani [3] when it comes to End-Position-Seeking-Force, because the nature of our problem is considerably different. Our agents do not have an end position per se, therefore we have to set this value either to the position of the leader (in case a particular agent is currently following the leader), or an arbitrary nearby point in space (if an agent is not attached to the leader). The point in space is calculated differently for bystanders and protesters, since their movements typically have inherently different purposes: bystanders tend to move away from the heated crowd, while

the active protesters usually attempt to join in. Therefore the point for protesters should be placed within a circle with a radius equal to the distance of the farthest protester in the field of view, while the point for bystanders is positioned within an annulus spanned by distance of the furthest protester and an arbitrary constant.

Leader Following Behaviour and hierarchy. The leader is selected randomly from among the protesters. When a leader is chosen, nearby agents observe this and adjust their internal state to start following the leader. Their internal state is also visible to other nearby agents and when these agents see that the majority have changed their state to follow the leader, they also adjust their state accordingly, essentially forming a hierarchy of followers. When a leader disappears (either unidentifies itself or exits the field of view of closest followers), the rest of the herd will eventually stop following as well, with respect to a cooldown timer.

Emotional contagion. For the purpose of transitioning between protesters and bystanders (both ways) we modify Clements' formulas to fit our perception model: instead of their predefined grid, we use agents' vision to determine neighborhoods for each individual. We also add a constant $c = 0.53$ to compensate for the speed of our simulation (i.e. to make the changes observable in real time) into the recruitment condition 1 and defection condition 2:

$$\frac{m}{m + n_p} * c < 0.5 \qquad [1]$$

$$\frac{m}{m + n_b} * c < 0.5 \qquad [2]$$

Value m represents motility rate, which per Clements' mild unrest definition should be set to 100, while values n_p and n_b are defined by the number of nearby protesters and bystanders respectively.

Results

The simulation is designed to start with a fixed number of agents (default value is 200), one being the leader, the rest being randomly distributed between protesters and bystanders, as well as randomly positioned on the map. Additionally, the user can manually place a certain amount of police agents into the scene (upper bound is set to 50 by default) in straight lines to simulate barricades.

One of the principal observations is that the end-position-seeking-behaviour correctly and realistically forms a group of protesters in the center of the crowd, while the bystanders seek to move away from the formed group (example shown in figure 2). Emotional contagion ensures that if an individual bystander is surrounded by a group of protesters for a long enough period of time, it will eventually turn into a protester as well, with a gradually increasing probability.
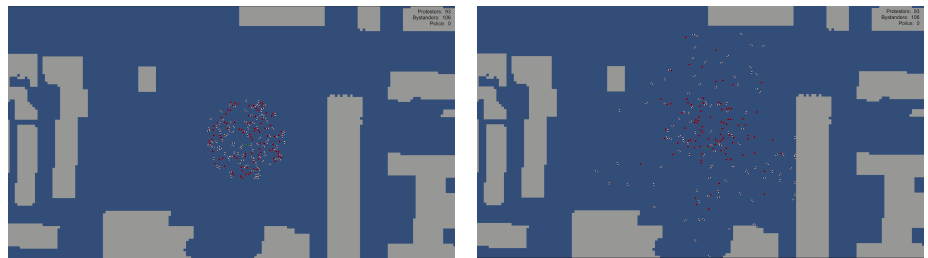

(a) State at the start of the simulation

(b) State after end-position-seeking-behaviour

Figure 2. Example of the effects of end-position-seeking-behaviour.

Leader Identification Time Interval is set to 1.5 by default to ensure that the simulation starts without a leader, so that we can observe how it emerges. Once the leader identifies, the nearby agents gradually begin to follow and form a hierarchy as shown in figure 3. The formed group moves seamlessly around the map and successfully avoids arbitrarily placed police barricades.
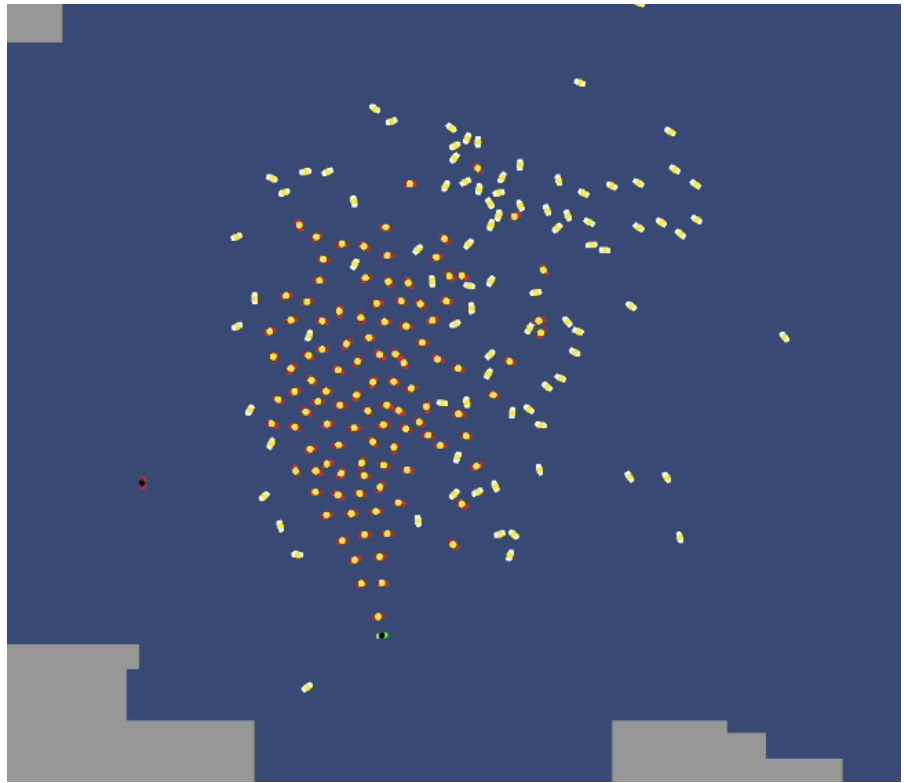
Figure 3. Example of leader following behaviour: leader (green), following protesters (orange), bystanders (white) and a regular protester who is looking away and therefore not joining yet (red).

We also observed various situations in which the leader unidentifies itself when the number of its followers is small enough for a long enough period of time. This causes a chain reaction that eventually leads to a complete dispersal of all actively following agents. However, some still remain protesters and a new leader can eventually emerge again.

Discussion

Most of the goals of the project were accomplished successfully, however we propose some potential improvements that are yet to be implemented:

- current implementation of the map assumes buildings are the only structure that acts as a repulsive force on the agents. To increase realism, it would be necessary to also include other objects, such as trees, statues, etc.

- solving the problem of displaying the agents' dimensions relative to building's dimensions (i.e. how to simultaneously show a big portion of the map while maintaining a clear vision of the agents).

- developing an approach for police agents to find more optimal formations other than static barricade-like structures (e.g. by using genetic algorithms).

- introducing some uncertainty into vision might further improve the realism of the simulation - an agent should occasionally incorrectly recognize a protester as a bystander or vice versa, with a low, but non-zero probability.

The entire source code and other materials related to the project are publicly available at https://github.com/bajicluka01/CollectiveBehaviour-GroupA.

Bibliography

1. Lemos C, Coelho H, Lopes RJ (2014) Agent-based modeling of protests and violent confrontation: a micro-situational, multi-player, contextual rule-based approach.

2. Clements AJ, Fadai NT (2022) Agent-based modelling of sports riots. *Physica A: Statistical Mechanics and its Applications* 597:127279.

3. Itatani R, Pelechano N (2024) Social crowd simulation: Improving realism with social rules and gaze behavior in *Proceedings of the 17th ACM SIGGRAPH Conference on Motion, Interaction, and Games*, MIG '24. (Association for Computing Machinery, New York, NY, USA).

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