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Psychology-based Crowd Simulation

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Digital Arts and Entertainment

Howest.be

CONTENTS

ABSTRACT

This paper proposes a model for simulating human behavior in crowds, heavily based on psychology so to hit a high level of realism. This model accounts for individual agents with their own, independently perceived environment and responses to said perceptions. At its core, this model is an AI capable of dynamic collision avoidance on a basis of proxemics, other perceived entities and static obstacles. The model will also be capable of navigating unknown environments by making use of target flow.
This psychology-based approach will fit the agents with a realistic psychological model to different stressors, expressed as time pressure, positional stressors, area stressors and inter-personal stressors. This approach will not only respond to the right stressors but also respond in the right way, emulating all applicable real-life psychological developments. This approach is also equipped with techniques on personality and identity modeling to capture a variety of behavioral changes.

Keywords: crowd simulation, psychological model, personality modeling, proxemics, social force models, flocking, target flow.

INTRODUCTION

We've been trying to simulate the movement and dynamic behavior of a great number of entities for as long as we have the necessary computing power.
There have been many different techniques or algorithms and the number of purposes has grown excessively from science to architecture, urban planning and even virtual media like films and games. All of these different purposes result in completely different approaches and eventual results.

In the pursuit of high realism of crowds comes the psychological aspect of the individual and crowd as a whole, in this paper, a study is presented of these topics and analysis of every facet that comes with it.

RESEARCH

In this part of the paper all research topics for this project will be described. Each will be thoroughly examined and documented and they will ideally be implemented in the case study.

All psychological and sociological occurrences will initially be described and as final topic of the research chapter any AI structures will be described that can be used to implement aforementioned topics.

2. PSYCHOLOGY

2.1. STRESS

Stress is the sum of the body's responses to disturbances to homeostasis.
The source of the stress is named the stressor. A stressor is an event or occurrence, real or imagined, that disrupts homeostasis and forces the body to either resist or adapt.

TIME PRESSURE

Pressure related to a time limit, where an objective or goal needs to be achieved within a certain time interval.

$$I_t = max(t_e - t_a, 0)$$

In the antecedent formula, I_t is the intensity of the time pressure, t_e is the estimated time to reach the goal and t_a is a time constraint.

AREA PRESSURE

Area pressure refers to any stressors coming from an environmental condition, such as heat or noise in an area.

$$I_a = \begin{cases} c & if\ p_a \in A \\ 0 & if\ p_a \notin A \end{cases}$$

In the antecedent formula, I_a is the intensity of the area pressure, p_a is the position of the agent in an area A and c is a constant.

POSITIONAL STRESSORS

Positional stressors refer a local source of stress that increases in intensity as the agent approaches the source.

$$I_p = \|p_a - p_s\|$$

In the antecedent formula, I_p is the intensity of the positional stressor, p_a is the position of the agent and p_s is the position of the stressor.

INTERPERSONAL STRESSORS

Pressure that's defined by an overflow of other agents in the original agent's vicinity.

$$I_i = max(n_c - n_p, 0)$$

In the antecedent formula, I_i is the intensity of the interpersonal stressor, n_c is the current number of nearby agents within a unit space and n_p is the preferred number of agents within a unit space for that particular agent.

GENERAL ADAPTION SYNDROME

A three-stage process, first proposed by Dr. Hans Selye in 1936, that describes the physiological changes all biological organisms goes through when they respond and adapt to stress.

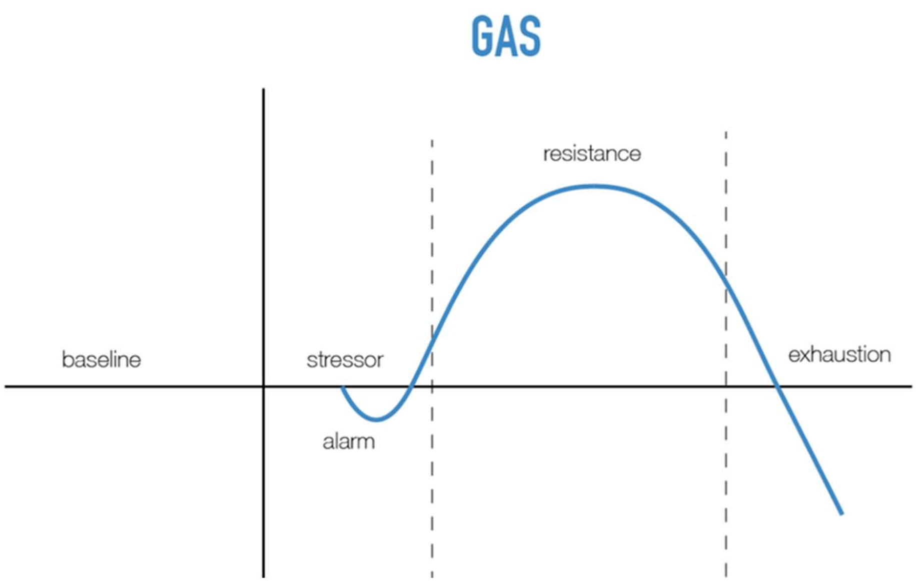

Figure 1: General Adaption Syndrome (The Science of Lifting by Greg Nuckols)

STAGE 0: HOMEOSTASIS

The state of total conformity where the body is being normally regulated and its state is constant.
Doesn't actually count as a state, but I've added it here to indicate the starting position.

STAGE 1: ALARM (ACUTE STRESS RESPONSE)

This is the first reaction of agent to the presence of the stressor and it immediately triggers a shock phase.
The body's initial resistance is low due to no preparation to it and thus cannot adapt to the new situation.
The counter-shock stage starts as soon as the body begins to cope with the stressor and the body beings to mobilize its resources so it can induce an adequate response.
This response is commonly referred to as a the fight or flight response, the organism prepares to either defend or flee.

STAGE 2: RESISTANCE

The organism has responded to the stressor and keeps up this high-intensity performance to try and deal with the stressor. Since this requires great resources, the body can only keep this up for a finite time as its resources are gradually depleted.

STAGE 3: RECOVERY / EXHAUSTION

During this phase, the stressor has been active for a long period of time and the body starts to lose its ability to combat and reduce their harmful impact because the adaptive energy is depleted.
If the stressor has been overcome the organism can now restore homeostasis and start the recovery process.
If the stressor hasn't been overcome, the biological resources will completely deplete and the body will enter a state of bare exposure to the stressor where it tries to use its limited remaining energy for recovery.

2.2. PROXEMICS

The study of spatial requirements of humans and the effect population density has on behavior, communication and social interaction.

Every single living being in the universe tries to occupy, cultivate, preserve and utilize space. The degree in which this is done, or even how is heavily influenced by culture or nature but the eventual objective is a standard of familiarity and comfort.

INTERPERSONAL SPACE

There are 4 kinds of spatial relations man applies, described by Edward T. Hall.

- Public space (3.5m – 7.5m):
  Zone for public interaction, like public speaking. It requires a louder voice, a reduced speech rate and a more formal style of attitude.
- Social space (1m – 3.5m):
  The standard for any kind of social gathering or meeting.
- Personal space (0.5m – 1m):
  Popularly referred to as the 'personal bubble', this zone is meant for people who are well known.
- Intimate space (0m – 0.5m):
  Zone for mainly non-verbal communication and intimate interactions.

CULTURE TYPES

Different culture types maintain different standard of personal space and communicational rituals.
The Lewis Model is the latest model on culture types, developed in the 1990s, Richard Lewis concluded that the variations in personal and interactive qualities can be divided into 3 clear categories, based primarily on behavior, omitting nationality or religion.

- Linear-active cultures (Germany, Norway, USA):
  Cool and decisive
- Reactive cultures (Vietnam, China, Japan):
  Accommodating and non-confrontational
- Multi-active cultures (Argentina, Brazil, Mexico, Italy):
  Warm and impulsive

SPATIAL REPRESENATIONS

Hall distinguishes in his representations of space in proxemics 3 categories.

- Fixed feature space:
  The space formed by fixed obstacles like walls.
- Semi fixed space:
  Space formed by fixed obstacles that has a direct impact on the communication of participants within.
  This category of space can be divided into 2 subcategories:
  - Sociofugal space: keeps participants separated and hinders communication
  - Sociopetal space: brings participants together and stimulates communication
- Informal space:
  Private space people maintain when they interact, its distinct bounds heavily influenced by culture.

2.3. HUMAN CHARACTERISTICS AND BEHAVIOR

"Each person is an idiom unto himself, an apparent violation of the syntax of the species."
Gordon Allport (1897 - 1967)

Differences in human characteristics and behavior are governed by multiple factors, including gender, differences in stimuli, genetic endowment, psychological state, cognitive state, social environment, cultural environment, personal characteristics and personality.
The combination of these has an astounding impact on an individual's behavior and will result in uniqueness.

PERSONALITY

According to formal personality psychology, personality can be defined as a collection of several personality traits. This trait theory will seek habitual patterns of behavior, thought and emotion. Given this theory, traits are relatively stable over time, differ across individuals and, as said, have an impact on an individual's behavior.

There have been a number of different theorists who came up with different models to categorize or at least classify the huge variety of personality traits that exist into a more manageable assortment.

GORDON ALLPORT'S TRAIT THEORY

Gordon Allport could be considered one of the pioneers of formal personality psychology and of trait theory.
In 1936, Allport went through a dictionary and picked out more than 4000 words that describe the human personality.
Gordon Allport then divided these traits into a three-level hierarchy.

- Cardinal traits:
  The dominant traits that make up an individual's life. They shape an individual's behavior in such a way that a person is known specifically for these traits.
- Central traits:
  These traits make up, as opposed to cardinal traits that make up an individual's behavior, an individual's personality. They are easily detected characteristics of a person.
  According to Allport, every individual has from 5 to 10 central traits and they are present in varying degrees.
- Secondary traits:
  All traits that are significantly less generalized and less relevant are considered secondary traits. These could be traits that are sometimes related to attitudes or preferences.

RAYMOND CATTELL'S SIXTEEN PERSONALITY FACTORS

In the 1940s, Raymond Cattell reduced the number of observable traits from Allport's initial list of 4,000 to 171, by combining similar characteristics and eliminating uncommon traits.
Cattell proceeded to rate a large sample of individuals for these 171 traits and, using a statistical technique known as factor analysis, he identified closely related terms and reduced his list to just 16 key personality traits.
According to Cattell, we all have these main traits and they make up the source of all human personality.

Warmth, reasoning, emotional stability, dominance, liveliness, rule-consciousness, social boldness, sensitivity, vigilance, abstractness, privateness, apprehension, openness to change, self-reliance, perfectionism, tension.

EYSENCK'S THREE DIMENSIONS OF PERSONALITY

In the book 'Dimensions of Personality', published in 1967, Hans Eysenck describes a model of personality based on just three universal traits.

- Introversion / extraversion:
  The personality trait that defines where the attention is directed, whether it be inwards to inner experiences or outwards to other people and the environment.
- Neuroticism / emotional stability:
  This dimension is related to moodiness as opposed to even-temperateness. It refers to an individual's tendency to become upset or emotional.
- Psychoticism:
  Individuals who score high on this trait tend to have difficulty dealing with reality.
  They may be antisocial, hostile, non-empathic and manipulative.

THE BIG FIVE MODEL OF PERSONALITY

Theorists researched both Cattell's and Eysenck's model thoroughly and this led them to believe that Cattell focused on too many traits, while Eysenck's model has too few. As a result, a new trait theory was developed that represents five core traits.

Extraversion, agreeableness, conscientiousness, neuroticism, openness.

EMPLOYED ARTIFICIAL IDENTITY (EAI)

This project will need a model of identity that can be applied to artificial intelligence which will represent an individual's personality and unique features adequately enough to make it emulate humane and realistic behavior. As it's applied to artificial intelligence, complexity needs to be avoided as much as possible.

This model is composed based on researched personality models, necessity and positive impact in this project.

PERSONALITY

Dominance:
How much space an agent will want to occupy.
Agreeableness:
The degree of invasion of space the agent is comfortable with, how much the agent will comply with other agents' intentions and how much the agent will accommodate other agents.
Anxiety:
The degree of influence stress has on an agents' motivations.

RESPONSIVENESS

Mobility:
Movement speed of an agent.
Energy:
The total amount of energy an agent can spend while applying high-intensity performance to deal with a stressor.

INFLUENCE

Authority:
The degree of influence an agent acts out on other agents.

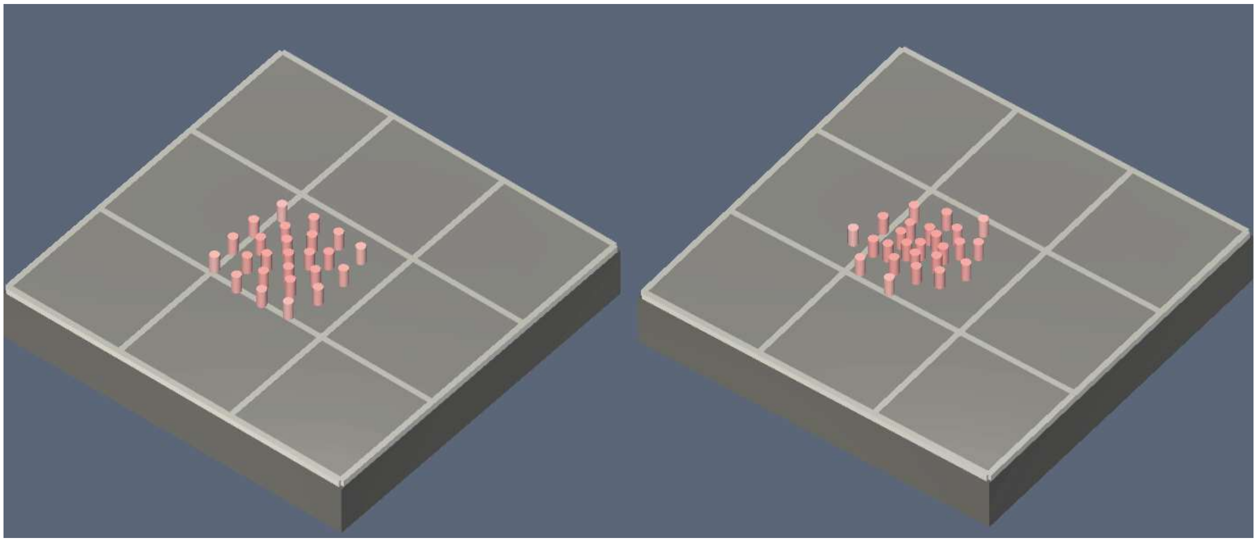

Figure 2: Employed Artificial Identity in action.

Consider figure 2, a crowd visualized as a group of cylinders moves from the leftmost tile to the rightmost tile.
The left scenario has EAI disabled, while right has it enabled. Note how on the right, every agent behaves in a unique way which results in a much more realistic flow of behavior.

3. SOCIOLOGY

Sociology refers to the systematic study of the development, structure, interaction and collective behavior of organized groups of human beings.

3.1. SOCIAL CONSTRUCT

AUTHORITY

Authority can refer to the right to exercise power. It is the capacity and right, inherited or acquired, for exercising ascendency over a group.
Figures of authority are universally listened to in high-stress situations and they have a greater influence on the behavior of the rest of the group since their behavior is often an example to the rest of the group.

SOCIAL NORMS

Social norms are an informal, sociological development that dictate the behavior of individuals towards others.
Such norms are composed on several individual factors such as age, gender and class.
These norms can play a fundamental role in high-stress scenarios, with the prime example of how women and children are being evacuated first in situations that require it.

3.2. SOCIAL RELATIONS

Social relations are defined by the quality of interactions among individuals within a community.
The Department of Economic and Social Affairs of the UN Secretariat described a framework to help assess levels of social integration by examining the state of social relations.
It identifies six stages of social integration, which are formulated as stages of social relations.

- Fragmentation:
  Social relations disintegrate, usually in situations of abuse, conflict and social breakdown.
- Exclusion:
  Participants are in situations of neglect and oppression.
- Polarization:
  Social relations are hostile and combative.
- Coexistence:
  The participants tolerate each other's existence and differences.
- Collaboration:
  Great sense of socio-economic justice.
- Cohesion:
  Participants support discovery or creation of shared meaning and value while respecting each other's existence and differences.

3.3. DEINDIVIDUATION

Deindividuation is a development in crowd psychology when an individual loses its self-awareness to strife towards group cohesiveness.
Theorists of deindividuation propose that it's a psychological state of decreased self-evaluation and loss of personal responsibility where an individual assumes the identity of the group.

3.4. SOCIAL FORCE MODELS

In 1995, Dirk Helbing and Péter Molnár published a paper called 'Social force model for pedestrian dynamics' in which they describe how the motion of individuals can be interpreted as if they would be subject to 'social forces'.
These forces are defined by the internal motivations of the individuals to perform certain movements.
This Helbing model would later become the standard of all social force models, suggesting a way to identify and predict movement of individuals within a larger collective.

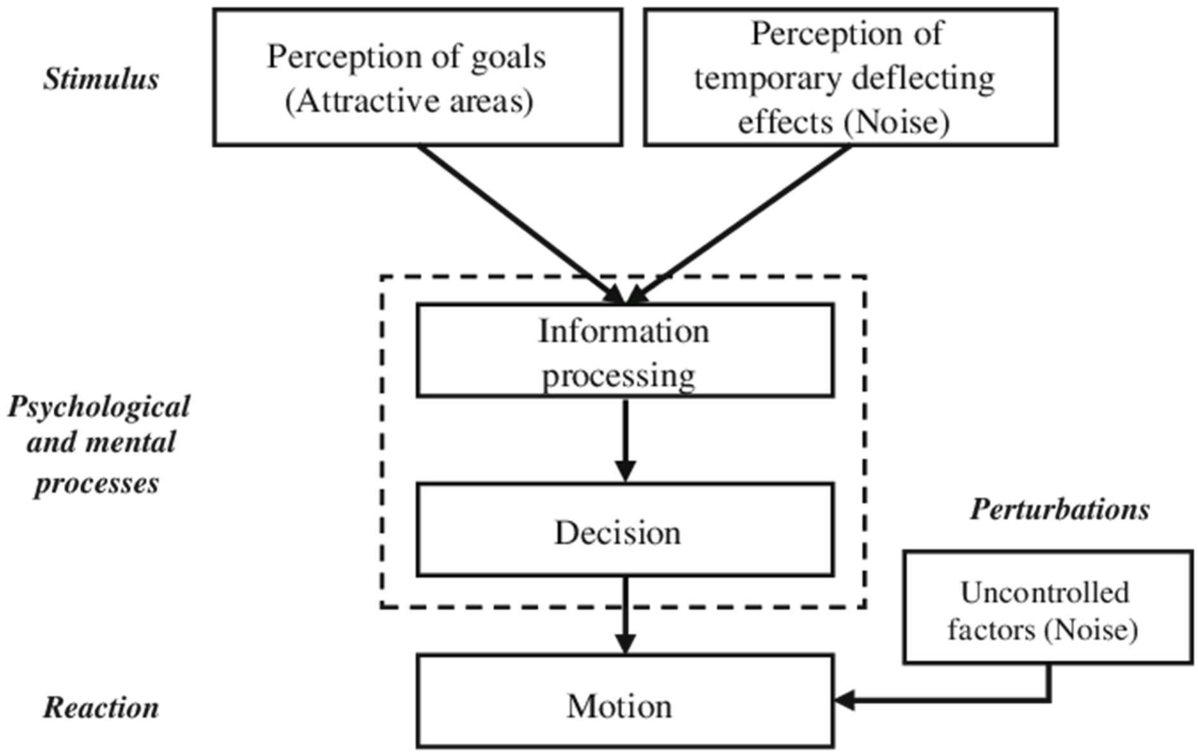

Figure 3: Schematic representation of processes that induce behavioral changes (Static force field representation of environments based on agents' nonlinear motion by Damian Campo, Alejandro Betancourt, Lucio Marcenaro, Carlo Regazzoni)

HELBING SOCIAL FORCE MODEL OF PEDESTRIAN FLOW

The Helbing social force model is a model based on Newton dynamics with unit mass, describing the different motivations and influences of an individual within some collective as various forces.

Helbing describes a set of guidelines naturally occurring in pedestrian movement:

- An individual will always choose the fastest route by default
- An individual will ideally move at the speed they are most comfortable with
- A certain distance is kept between individuals

There are several forces acting on the individual, but three fundamental forces can be identified and make up the core of Helbing's social force model.

DRIVING FORCE

The most obvious force, reflects the motivation of an individual to move to a desired location with a desired velocity.

INTERACTION BETWEEN AGENTS

The interactions between individuals are described in this model as socio-psychological forces and physical interactions. Most importantly, individuals try to keep a certain distance from one another, this is implemented as a repulsive force.
This repulsion factor is defined by the distance between the interacting individuals, it has the highest value at the lowest distance and declines to zero with increasing distance.

INTERACTION BETWEEN STATIC OBSTACLES

Any individual will always try to keep a certain distance between itself and obstacles but there are multiple models available to decide which obstacles are ignored and which are considered.

- Superposition: All boundaries and obstacles influence the individual and thus all forces are summed up
- Shortest distance: Only the obstacle closest to the individual is considered
- Biggest impact: Only the obstacle with the highest influence is considered.

ADDITIONAL FORCES

The model also describes additional forces such as social attraction and fluctuation. These will not be described or documented because they are being handled as separate topics elsewhere in this paper.
Social attraction, as Helbing describes it, can be interpreted as herd behavior. (Represented in section 3.1)
Furthermore, fluctuation and distinction in behavior are thoroughly studied in the personality topic of this paper. (As mentioned in section 1.2)

4. CROWD SIMULATION

Since human behavior is a complex phenomenon which is difficult to capture into computers as mathematical equations, there are several techniques to modeling crowds. Existing models can be categorized in either one of the following groups:

- Flow-based
  Flow-based models use the density of nodes in continuous flows. Also known as macroscopic models, this model is often compared with fluid and particle motions.
- Cellular Automata
  As the simplest method but by far the least realistic, this model divides space up as a two-dimensional array. The simulation technique then proceeds to use a time-frame pre-defined in which the occupants can move from one cell to another based on obstacles and if the target cell is occupied or not.
- Agent-based
  The agent-based approach is probably the most realistic solution since it allows modeling of individual agents with their own unique characteristics and reactions to perceived environments.
  This model was eventually chosen for this project because it fits the motivation of building realistic agents that emulate correct human behavior in order to build realistic crowds.

4.1. ARTIFICIAL INTELLIGENCE

Artificial intelligence plays a fundamental role in correct crowd simulation. In order to build a highly realistic crowd, highly realistic agents should be the goal. If constructed correctly, these will make up correct crowd behavior. It is in these specific agents that AI will dictate and define behavior.

DECISION MAKING TECHNIQUES

Decision-making is a vital part of any AI system in which the actions and responses are constructed based on applicable conditions and demands.

DECISION TREES

A decision tree is a flowchart-like, hierarchical structure in which each node represents a condition and each branch represents the outcome.

Decision trees have the huge advantage that they’re simple and easy to implement.
They also execute quite quickly but this can change depending on size.
Decision trees, however, are heavy on performance when it has to go through the entire tree to find an applicable condition.

(FINITE) STATE MACHINES

A state machine is a logical construct consisting of different states and conditions to transition between states.

State machines have the advantage of being much more performance friendly, but are harder to debug and in general much more complex.

FLOCKING / HERD BEHAVIOR

The sociological behavior of flocking will be analyzed in-depth further in this paper, but the implementation for artificial intelligence will be described here.

ALIGNMENT

The alignment aspect is a behavior that makes a particular agent line up with all agents in its proximity.
This can be calculated by iterating through all agents within a certain radius and averaging all velocity vectors.

COHESION

This behavior will allow for specific agents to move closer to others, or the center of the flock.
This will be calculated by first averaging the positions of all agents and then normalizing the vector towards said position.

SEPERATION

The separation behavior allows for agents to move further away from others to avoid collision.
This is calculated by negating the vector towards the point an agent wants to separate from.

TARGET FLOW

Target flow is custom concept that will be used to describe the target of a crowd.
Since crowds have no specific target they will follow a sort of flow, defined by the collective of agents within.
Every agent has a general direction, heavily influenced by any potential stressors, other agents and the environment.

The target flow will thus provide the crowd with a universal, short-term direction which is applied by the individual agents but influenced by their respective obstacles.

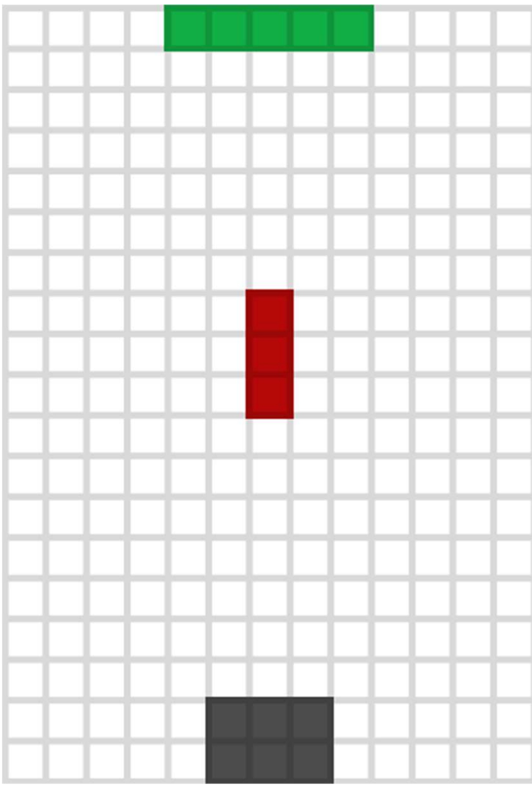

Figure 4: Target flow example scenario, grey is a crowd, red is a stressor and green is the target area.

Consider the above scenario (figure 4), the crowd will want to move forward until it reaches the target area.
Depending on the magnitude of the stressor, the crowd will move around it, or just flee and try to get as far away as possible, never crossing the room and thus never reaching its target area.
This is what target flow is all about, the general sense of destination and direction, without a specific path or guideline.

The concept of target flow is applied in this project for two reasons.
Primarily, it is believed that in order to build a realistic crowd, one should not build a realistic crowd but rather a collective of realistic agents. These agents have no universal knowledge about other agents or the environment and can only behave based on what they perceive.
Second, this project will feature customizable environments and thus pathfinding or any other form of global planning are impossible to implement because there is no prior data to construct an environmental graph.

LOOK-AHEAD ALGORITHM

The lookahead algorithm, as described in a paper called 'Hybrid Long-Range Collision Avoidance for Crowd Simulation' by Abhinav Golas, Rahul Narain and Ming Lin, models a crowd as a set of individual agents, each of which has a specified position that it attempts to reach while avoiding collisions with other agents and the environment. Please note this is a summarized version of the algorithm, since it will be heavily adapted to fit the project.

The algorithm works as a central coordination system that has access to every present agent and defines each agents' velocity with a loop.

1. Global planning to construct a path that avoids collision with static obstacles
2. Step-based local collision avoidance (LCA) to alter every agents' velocity to avoid other agents.

The first step will represent the connectivity of free space in the environment as a graph and proceed to perform a search to determine a collision-free path.
This step will not be implemented in this project, as it will be completely replaced by the concept of target flow.

The second step is what the look-ahead algorithm is all about. The goal is to find a velocity for each agent that fits their originally preferred velocity and that avoids both congestion and collisions with neighboring agents.

For an agent to plan its own motion, it needs to estimate the motion of other agents over a time interval, while the future motion of other agents is unknown, they can be estimated using the agents' current velocities.
To reflect the uncertainty of this estimation, the predicted location will be treated as an area as opposed to a point. The scale of this area properly representing the probability of finding the agent at that given position.

In other words, the velocity of every agent in the simulation will be used to predict its future position. This prediction will behave as an area that needs to be clear for the agent to move in that direction and the area size decreases as the prediction advances.

As said, this algorithm has a central coordination system, which makes it incompatible with the type of agent-based algorithm that is being described in this paper, in which each agent independently and simultaneously decides behavior and movement.
This algorithm still provides a solid way of collision avoidance and will thus be adapted to fit the needs of this project.

LOCAL COLLISION AVOIDANCE

There are two kinds of local collision avoidance, each defining how crowds will be represented and considered towards agents that are not a part of it.

1. Continuum collision avoidance:
   The agents of the crowd will be considered as one collective. This collective is a continuum distribution of density and velocity over space and will thus have a density field and velocity field to interact with.
2. Discrete collision avoidance:
   The agents of the crowd will all be considered as individual obstacles, this is very research expensive in dense crowds.

CLUSTERING

To improve efficiency and to facilitate combining the two LCA techniques, clustering of agents is introduced.
Within a certain radius, all agents will be considered with discrete collision avoidance. With distance, however, near agents can be clustered and continuum collision avoidance will be used on these clusters.
The values already studied in the proxemics topic will be applied to decide the different distance subdivisions.

CASE STUDY

1. INTRODUCTION

In this part of this paper, the development of both the agent and the interactive tool are described.
Each will be subdivided into their main components and in each of these the workflow and approach are documented.

2. AGENT DEVELOPMENT

As previously mentioned, the approach for this project is to build crowd simulation by building realistic and authentic agents that correctly emulate human behavior.

2.1. AGENT ANATOMY

The agent is represented by a rigidbody and visualized by a cylinder.
The rigidbody is necessary for the implementation of forces as motivations (further elaborated in section 2.2).
The agent has a sphere collider with a radius of 3, acting as a trigger. This trigger will act as perceivable social space around the agent and will detect any nearby agents or static obstacles.

2.2. AGENT CONSTANTS

The agent is equipped with several constant values to be subsequently used in behavioral compositions.
These constants reference the studied proxemics values, multipliers and blending values for the social forces and agent-specific values such as radius and preferred number of surrounding agents.

2.3. SOCIAL FORCE MODEL

The social force model implementation plays a fundamental role in this project, as it lays the foundation for all behaviors of the agent.
The social force model described by Helbing, as documented in this paper, distinguishes several different forces acting on the model:

- Driving force
- Interaction force between agents
- Interaction force between obstacles
- Social attraction
- Fluctuation

As this model is heavily adapted both in method of functioning as in implementation, these are the forces acting in this model:

- Driving force
- Social forces
- Repulsive stress force

The aforementioned forces are blended with blending constants that reflect the weight of each force and can subsequently act out on the agent.

DRIVING FORCE

As the first force to be calculated, and the most important one, the driving force is composed with the position of the target of the agent.
It is influenced by the mobility of the agent, since mobility defines the speed of the agent and by the herd behavior.

$$F_d = \frac{p_t - p_c}{|p_t - p_c|} \times m_d$$

The driving force is constructed by normalizing the difference in vectors between the target position and the current position, and multiplying that resulting vector by the driving force multiplier.
The speed of movement is decided by multiplying the final vector by the mobility constant.

SOCIAL FORCES

REPULSION AND ATTRACTION TOWARDS OTHER AGENTS

Repulsion towards static obstacles is calculated by normalizing the difference in vectors between the closest point of the agent and the position of the agent. This result is inversed to generate a force that directs away from the agent.
The multiplication factor to reflect severity is calculated by subtracting the difference between the closest point and the agent of the social space constant. This is clamped to -1 to use negative values as attraction forces when agents separate too much.
The previously achieved vector is multiplied with the intensity factor to achieve the end-result.

REPULSION TOWARDS STATIC OBSTACLES

Repulsion towards static obstacles is calculated by normalizing the difference in vectors between the closest point of the obstacle and the position of the agent. This result is inversed to generate a force that directs away from the obstacle.
The multiplication factor to reflect severity is calculated by subtracting the difference between the closest point and the agent of the public space constant. This is clamped to ignore negative values.
The previously achieved vector is multiplied with the intensity factor to achieve the end-result.

REPULSIVE STRESS FORCE

The repulsive stress force is only calculated if the positional stress is existent.
The force is calculated by subtracting the position of the stressor from the agents' position.
This vector is normalized and multiplied by the positional stress multiplier.

2.4. STRESS

The present stress should not only make agents more nervous and increase mobility, it should also be another force to be considered and potentially avoided.
Every stressor has three components: the position, the magnitude and the radius.
This implementation was designed to maximize the potential, since now area stressors such as noise or heat (small magnitude, large radius) can be simulated as well as hazardous, positional stressors (large magnitude, small radius).
Every agent seeks out all stressors and calculates positional stress on the basis of magnitude and radius.
The eventual stress-factor that is used throughout other behavioral constructs is calculated by averaging the positional stress and the interpersonal stress.
In the interactive tool, agent color is defined by their stress-factor.

POSITIONAL STRESS

Positional stress can be calculated as a float value to define influence, or as a force, earlier described as the repulsive stress force.

The float value can be calculated by subtracting the vector magnitude of the agent position minus the stressor position from the stressor radius and dividing the result by the radius. This is then multiplied by the magnitude of the stressor and clipped to zero to ignore negative values.

INTERPERSONAL STRESS

The preferred number of surrounding agents subtracted from current number of surrounding agents, clipped to 0 to ignore negative values.
This is subsequently divided by the number of surrounding agents to get a float value indicating interpersonal stress levels.

GENERAL ADAPTION SYNDROME

The general adaption syndrome is implemented with a basic energy system for every agent. When an agent encounters very sudden stress levels they could enter shock, which leaves them vulnerable for a short time.
Whenever the agent suffers from severe pressure, the body enters a resistance phase of high-performance.
This can only be maintained for so long, and is implemented as depleting energy.
Once energy is depleted and the stressor is still present, the agent will lose its ability to move.

2.5. HERD BEHAVIOR

ALIGNMENT

The alignment is the only part of herd behavior calculated as a separate vector.
It is calculated by averaging all velocities from surrounding agents.
If there is no driving force, the alignment force will take its place, leaving agents without a particular target prone to deindividuation.
If there is a driving force, it will be averaged with the alignment force.

COHESION AND SEPERATION

This is implemented as a social force for agents.

2.6. EMPLOYED ARTIFICIAL IDENTITY

Each EAI factor is implemented as a multiplier for the force it has to influence.
Every agent gets these factors assigned to them randomly within reasonable limits. The random value will decide if the factor is more or less prominent than the default value for every agent individually.

3. INTERACTIVE TOOL

The interactive tool is a way to create a solid environment to test and experiment with the agent in a crowd application.
The tool allows for customizable environments, tweakable crowds and customizable stressors.
Due to the employed artificial identity, every same simulation will always play out differently.

3.1. BASIC FRAMEWORK

The tool, at its core, consists of a tiling system to keep input easy and clear while still allowing for various potential scenarios.
Tiles are used as a backbone for the whole tool, as they provide spawns, targets, stressors and even input.

3.2. USER INTERACTION

The user can select objects, which will cast a ray in world space and identify the selection target.

ENVIRONMENT

The walls count as environment and clicking in between tiles will construct a wall to separate said tiles. Walls can easily be removed again by clicking them.

TILE

When a tile is identified as the selection target it gets highlighted as the selected tile. A number of agents can be set to spawn there and a goal can be appointed to all agents of the aforementioned tile.
Furthermore, for each tile the user can create a stressor which is customizable in magnitude and radius.

AGENT

When the user clicks on an agent, that agent's identity is visible and accessible for customization.

Figure 5: User interface of the interactive tool.

CONCLUSION

This work shows the research and implementation for a different type of crowd simulation, one that is heavily based on psychology and implements social and psychological elements.
The model is also equipped with a custom-designed identity model to guarantee uniqueness and individual responses.
The model is implemented in a tool to experiment and put it to the test. The crowd simulation model shows many similarities with known phenomena and developments described by Helbing.
Downsides of this model is the approximate implementation of the social force model and the eventually discarded look-ahead algorithm.

Future work could include a solid long-term collision avoidance algorithm like an improved look-ahead, as well as better target flow to properly guide the crowd through corridors.

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