# CROWD SIMULATION IN AN EXHIBITION ENVIRONMENT

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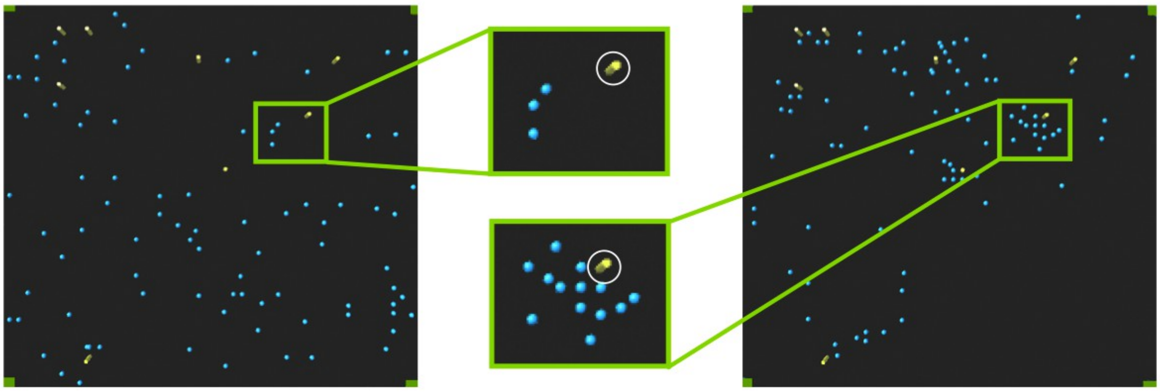

Figure 1: Various stages of the simulation. (left) initial step, (right) step during movement. Blue spheres are participants that are interested in objects (yellow cylinders) and are groupped around these interesting objects.

**ABSTRACT**

We introduce a novel grid based method of presenting participants in a crowd. We propose a psychological approach in the special case scenario in the exhibition environment. For this environment we use three dimensional approach for emotions, that is widely used in psychology. We map context-specific axes to achieve better emotional control for our specific environment. Moreover, we discuss also possibilities of low level behavioral control, collision detection. We extend the pedestrians movement methods with our novel behavior model for the setup.

**KEYWORDS**

Crowd Simulation, Exhibition Hall, Psychology

## 1. INTRODUCTION

The main research question is how to simulate crowds with behavior specific to exhibition environment. However, we have to limit the answer by assuming grid and browsing behavior. Crowd animation [PAB08] can serve either to bring more diversity to the environment or to manage emergency situations, like fire drills, panic, evacuations, where these simulations could point out e.g. bottlenecks of evacuation routes. Human behavior understanding is very complex problem, therefore it is important to choose specific environment with the specific problem and try to simulate behavior there. Our research brings contribution to the first group, diversification of the exhibition hall or virtual museum with the crowd. This type of the environment causes specific behavioral patterns. We analyze them from the psychological point of view and we propose and implement the solution. Our work can be extended for more complex behaviors.

The rest of the paper is structured as follows. Section 2 surveys related research results. In Section 3, we describe our solution. Section 4 discusses future work and Section 5 offers conclusions.

## 2. RELATED WORK

Recent crowd simulation research focuses on general problem of walking pedestrians [KZ11], emergency situations [TCP06], [TM07], or very specific problems, e.g. virtual wolves [TB01], individual psychology [SMK05]. Many of them combin global approach (macroscopic) for collision detection and local control (microscopic approach) for behavioral and emotion models [SHT10]. In global methods crowd is set of objects, where these objects have common attributes. These attributes include, but are not limited to: sharing same environment, do not bump to each other. On the other hand, in microscopic approaches individual objects have attributes and personal desires, such as personal goals, emotions, personality and crowd is created as set consisting of these objects. These microscopic methods usually model autonomous behavior and use rule-based systems [DDW06]. We combine these two different methods, we use cellular automata as global approach for collision detection and detour decision, which was also successfully used in other approaches [BA00], [Sti00], [SHT10]. This method lacks realism of movement, because one individuals occupies one cell usually in 0.5m x 0.5m grid, but there are also method to enhance this problem [SHT10]. We also propose a modification of the grid. We also use rule-based method for behavior control over the crowd, which is also used in other approaches [DDW06], [Rey87].

From the point of behavioral control, there various level of behavior that could be simulated [Par07]. Even low level behaviors, such as immediate responses to the input values from the environment could be interesting when set properly. Our goal is not to model complete human behavior with complete human mind. We will choose only important phenomena, that are specific for exhibition environment. Which phenomena to choose is based on the psychological theories. These theories include description of emotions [AA02] as well as how to simulate emotions and which structures to use. Well known model is three dimensional, where each axis represents phenomena and point in this system is described by the local vector and represents current emotion and mood [TB01]. Which phenomena to map on these axis is depending on the situation that is simulated. We use phenomena based on the psychology theory describing behavior of museum visitor [RSS+28].

## 3. OUR SOLUTION

There are several assumptions in our solution. Our environment is very specific, it is exhibition hall, with entrances, interesting objects, without narrow corridors and crowd is not dense. Also model of the floor of the hall is a finite part of Euclidean plane, divided into the regular grid. Because of these assumptions, we benefit from grid-based approaches, with no need to deal with a dense crowd. This allows us to simplify work with collisions and also with behavior, because neighborhood is well defined and easily found.

### 3.1 Space Relations

**FLAGS**

| | | |
|---|---|---|
| 1,1 | 1,2 | 1,3 |
| 2,1 | 2,2 | 2,3 |
| 3,1 | 3,2 | 3,3 |

Figure 2: Flags used for the coordinates of an individual.

As is stated in previous section 3, our crowd moves on the two dimensional plane and this plane is divided into regular cells of rectangular shape. We have chosen rectangular cells for their simplicity, but there are other polygonal regular grid, that might be more suitable for our problem. We postpone this discussion in the future work considerations, section 4.

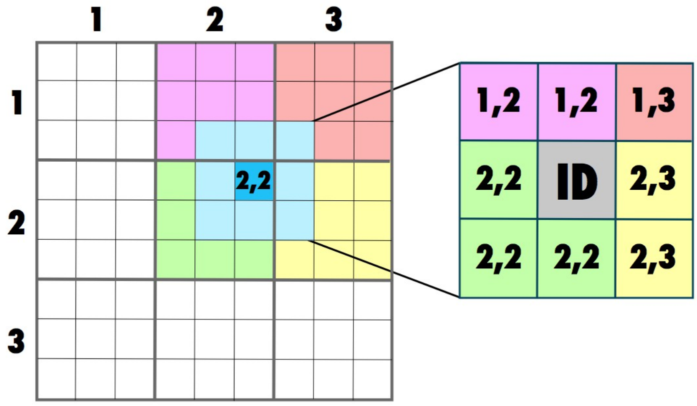


Figure 3: Coordinates of the participants related to the lay- out grid with flags and neighborhood grid.

A real person occupies approximately 0.5m x 0.5m. However, our layout cells cover 1.5m x 1.5m, because we experiment with a special two-level mapping of coordinates. The model of every person has coordinates in a grid that we call layout grid. Cells in this regular grid have 1.5m x 1.5m and we call them layout cells and whole layout space is covered with this larger grid, without any holes. Every person has also 2 flags - horizontal and vertical (according to 3x3 grid, into which the cell is divided, see fig. 2). These flags mean position in the layout cell, depending to which part of the cell the person belongs. For the layout we need to store only width/1.5m x height/1.5m cells, where in traditional approach it is width/0.5m x height/0.5m. For the person we need to store 8 pointer values for the flags. As our crowd is sparse, therefore there are less cells we store as they are in the grid with 0.5m x 0.5m. Moreover, this reduces memory requirements.
Every participant store it's ID from the array of crowd members. Moreover, participants also update 3x3 grid, with cell size 0.5m x 0.5m. We call this grid neighborhood grid, see fig. 3. This grid is aligned in the way that participant coordinates and flags are always in the middle. So in the middle of the neighborhood grid is participant ID (position of this cell is not important as it is always aligned with the participant). Other cells of the neighborhood grid contain coordinates in the layout grid of a cells they lay on. This mapping allows us to have easy access to the neighborhood cells, as this access is needed for collision detection and behavior control. Difference between our mapping and standard layout mapping is that our cells are bigger, therefore less memory is consumed because we have sparse crowd. Difference between our mapping and adaptive grid is that surrounding (neighborhood grid) of the participant is handled from the perspective of the participant, which brings easier access to this property. Access to the neighborhood cells is better in our approach, because we use simplicity of access in grid approaches and we store specific pointers to the cells that are aligned to participant's position. This way we have adaptive access to the cells of a layout grid that are really in the surrounding of the participant.

## 3.2 Collision Avoidance

Collision avoidance we solve in our approach in three steps. In the first step new desired coordinates with flags are calculated. We call these desired coordinates with flags desired positions. Desired positions are only those combinations of desired coordinates with flags, that are desired destination for some crowd members. It could happen that two or more persons have same desired position, we call these colliding positions and colliding people. In the second step colliding participants (with same desired positions) are resolved. In the third step participants actually move.

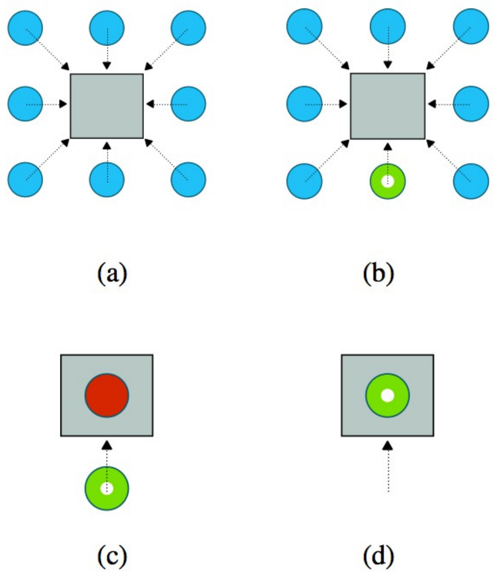


Figure 4: Decision process used for finding the next person for a cell.

The second step is also divided into the parts. Firstly, we need to find only one person, that will move to the position. Secondly, we need to check if desired position is available (if it is not occupied). We opted for this order, because the occupied position could be available during the decision process, as we cannot move them all at time. If a position is occupied, we set person, who want to move there to a waiting status. This status will expire in another round. This way we could achieve following behavior. Therefore, crowd members could move locally on line segments, which is natural.

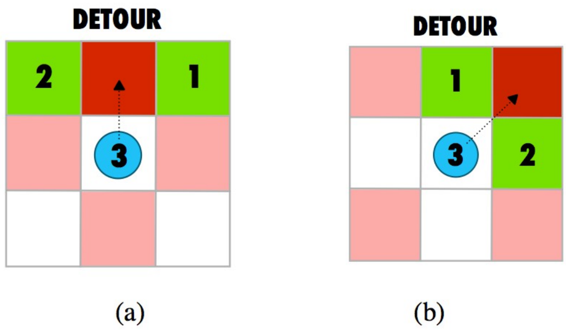


Figure 5: Number 1, 2 are detour possibilities, which one is first, depends on the behavior control, it is not hard coded. Number 3 is previous location and possible new location

Our decision process, see fig. 4:

- Desired positions that are not colliding could be directly set as new positions for the participants, no decision process is needed.
- Colliding people are resolved separately, each colliding position at time. From colliding people in this position is chosen one, based on priority. Person with waiting status has highest priority.
- Other colliding people, that are not set to waiting in this step, or did not find new position yet are set to detour behavior. Currently, detour behavior is simple detour to the right, or left from the desired position. Because we have rectangular grid, detour to the left and right have two different possibilities, see fig. 5. Which of this two is selected depends on the behavior control, see sec. 3.3.
- If none of the above movements is possible (all desired positions are full, no movement in the desired direction is possible) participant will stay at old position, or change goal, depending on the behavior.

### 3.3 Behavior

Standard behavioral patterns using when simulating crowd of pedestrians is line forming and side stepping. This behavior is proper when discussing walking in the narrow pathways. On the contrary, in our environment we have large open space without narrow pathways, therefore line forming is not that important. Our behavior is goal-oriented, our agents have goals - prioritized list, each agent has one, what they want to see from an array of exhibits, we call this List of Goals LoG. There are different priority values for the goals, also different types of visitors could come to the exhibition. Depending on which kind it is, this LoG could be generated. Moreover side stepping is implemented as collision avoidance behavior, see sec. 3.2.

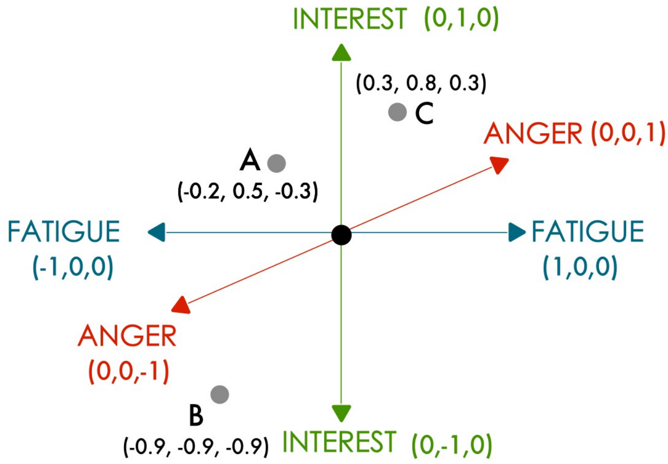


Figure 6: Three dimensional behavior model.

For more complex behavior, we use three dimensional model, which is used in behavioral studies in psychology. This model defines three dimensional space with three axes. Each point on these axes represents a possible mood, or phenomena and actual behavior is 3-vector from this space, we call it behavioral vector. The phenomena assignment depends on the situation. For our special situation we propose these three axes: I fatigue (x-axis), anger (y-axis), interest (z-axis) as is in fig. 6. We propose this emotional assignment, fatigue is a confirmed phenomenon in the museum [RSS∗28]. We chose anger, (angry and calm) emotions as a result of detours and crowded places, because they according to the Law of minimal change and Least Effort are usually omitted by the pedestrians. In the museum walking people from exhibit to exhibit are also pedestrians. Moreover, our specific environment is filled with exhibits, and people stay for a while to enjoy the exhibit. It is similar approach to the artistic pictures that are discussed in [RSS∗28]. According to this study, people spend time looking at the exhibits and generally this time varies, in our case it varies according to the variable interest. In the future this variable should be set more precisely depending on the type of exhibit and the environment, as they affect the looking time [RSS∗28]. Currently it is set only in a way that interest decreases with the time spent on the exhibit.

In initialization, every agent, when is created, has ran- domly set three pairs of values (each pair for limiting value decrease and increase on the axis), we call them personality. These values mean how fast is behavior changing on these axes. Every agent also has critical values. When one of these values is violated, agent goal immediately changes to an exit.

Depending on current behavioral vector, goals of the agents could change. Mainly we focus on these behaviors:

- when goal is reached, agents keeps examining the exhibit, until his/her value on z-axis keeps positive, in each step this value is decreased, depending on the personality value for the axis then goal is changed to next from the LoG
- when goal is not reached, but agent waits because of overcrowded space around the exhibit, value on the y-axis is decreased, when zero is reached, goal is changed to the next

- when there are lot of people around, value on the y-axis decreases, when zero is reached agent tends to move in less crowded space
- when any of the coordinates reaches critical value, agent's goal is changed to the nearest exit
- as fatigue increases, interest decreases in the new objects, if critical value of fatigue is reached, goal is changed to the exit.

When moving to another goal, coordinates are changing each step, depending on the number of people around, how long they are walking, how much they are excited about the goal exhibit. There are also other behaviors possible, we leave these for the future work, see sec. 4.

## 4. FUTURE WORK

We would like to incorporate better perception model with agent virtual vision, that will constrain view depending on Field of View and also will broaden the view in some directions, depending on the real Human Visual System. This will help us with collision detection, which will be more realistic. Also goal changing behavior could be based not only on behavioral model proposed here but also on Visual System, where some goals could be skipped in the LoG to the beginning, when they are in the Field of View. Selected exhibits could be in virtual pamphlet that will lead the visitors to these goals. There are also other psychological patterns that are proved to be in the museum environment. We would like to incorporate these patterns. It would be also interesting to allow pairs or smaller groups to move together, forming hierarchical model.

We would like to use hexagonal grids instead of rectangular and prove hypothesis, that the movement will have less problems.

## 5. CONCLUSION

The main contribution of our approach is combination of well known theory from psychology, which is dimensional description of emotions with behavior control that is defined for a very special scenario - exhibition hall and museum. This combination is then applied on crowd to create crowd simulation. We also enhance cellular automata approach, with our special small grid that is moved with participants. This grid allow us to have neighborhood defined in a wide range and not so much regular than in traditional methods. This approach is one of the methods that is normally used for crowd simulation.

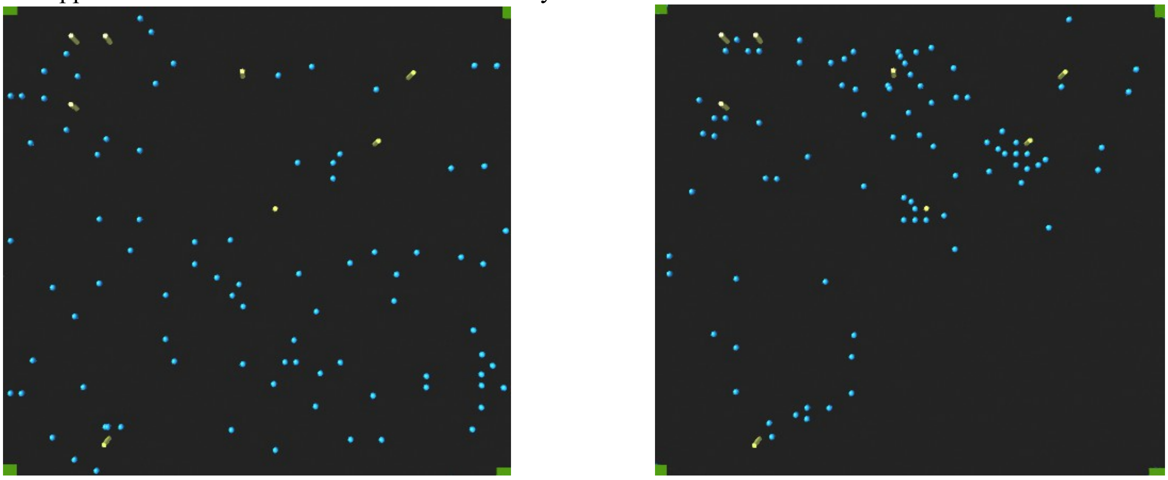

Figure 7: Initial step of simulation on the left and step during the process on right. Interesting objects are only above the right-top left-bottom diagonal

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