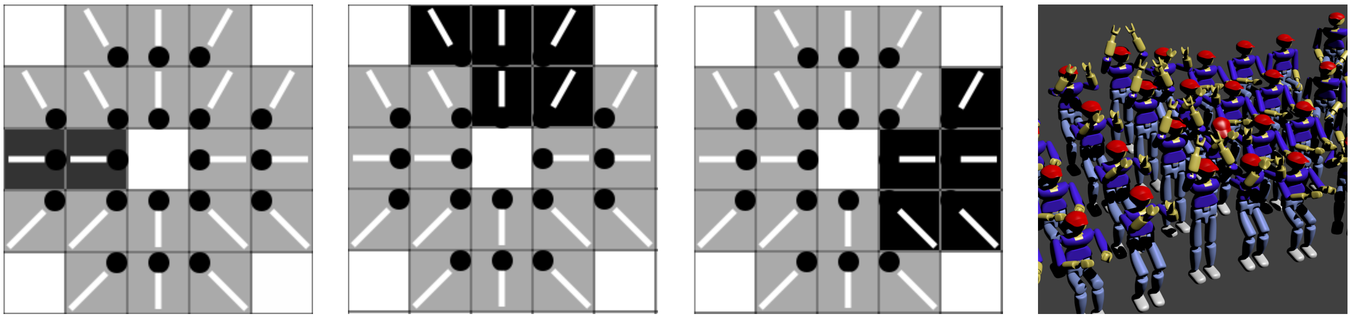
Cellular Automata based Crowd Simulation of Mexican Wave

Jana Dadová *
Comenius University, Slovakia

Andrej Ferko †
Comenius University, Slovakia



(a) (b) (c) (d)

Figure 1: Cellular automaton mexican wave initialization and propagation (dark cells) (a),(b),(c) and final rendering (d)

Abstract

Animated crowds offer modern methods to show both social relationships and emotions to enhance plain virtual scenes. When animation is created by an artist, it is a hard and time consuming process, but allows to create impressive results. On the other hand, when results do not need to be artistically accurate, more automated techniques are in place. Our solution contributes to the second group and helps to create perceptually rich animations more automatically. Simulation used is based on cellular automata, that control motion of the crowd itself. Special definition of rules and behavior are needed and we discuss option with a simple visual system incorporated. We compare both methods in a sequence of crowd simulation performing mexican wave at a sport or a cultural event.

CR Categories: I.3.7 [Three-Dimensional Graphics and Realism]: Animation—Virtual reality; I.3.8 [Computer Graphics]: Applications

Keywords: crowd simulation, cellular automata, mexican wave, visual system

1 Introduction

Crowd simulation and crowd animation are both based on working with a group of individuals. Difference is in the visual information they give. In crowd animation, rendering is important result. On the other hand, in crowd simulation rendering and visual information is less important than overall structure, flow a relationships between individuals. In our solution we try to fulfill both of these requirements for a popular mexican wave, see fig. 1. We use simulation to gather information about neighborhood and relationship of individuals. They cope together as a group and our method can be combined with modern rendering techniques. However, our contribution in field of animation and rendering itself is very minimal and it is not scope of this paper. Nevertheless, we show that our approach can be successfully combined with various rendering techniques.

Traditional techniques of computer animation include a lot of artistic work with every movement for every individual described and defined by a skilled artist. More automatic solution based on physics or other algorithm fail to create directed motion. On the other hand, there are still lot of problems that can be solved with the support of more automated solutions. Such problems include large crowds when camera is further away and motion of individuals does not need to be perfect, because tolerable errors cannot be seen. We contribute to solution of similar problems in second group.

2 Related Work in Crowd Simulation

Approaches of behavioral animation can be divided into two groups: microscopic models and macroscopic models. Microscopic models simulate crowd by setting the properties of the individuals. These methods include rule-based models [Dudek-Dyduch and Was 2006] and agent-based models, sometimes these two groups are considered as one. On the other hand, macroscopic methods simulate crowd by setting the properties of the crowd as a whole. These methods include cellular automata [Blue and Adler 2000] and social forces [Helbing and Molnar 1995].

Our method, as many others is combination of a microscopic and macroscopic approach. Propagation of the mexican wave sets global property of cellular automata, which is macroscopic, but field of view, head rotation and individual motion are rule based and microscopic. Combination of microscopic and macroscopic are often used in simulation [Thalmann and Musse 2013] because

*e-mail: dadova.jana@gmail.com
†e-mail:ferko@fmph.uniba.sk

they can be combined to define emerging behavior of a crowd and individual behavior of a person.

Crowd simulations that use CA are mostly simulating pedestrians [Blue and Adler 2000],[Dudek-Dyduch and Was 2006],[Sarmady et al. 2009],[Thalmann and Musse 2013] . In these simulation, pedestrians are moving from cell to cell and solution of collision avoidance is needed. On the other hand, we use cellular automata for other purpose. We use states for each time frame as a input for the motion definition of an individual. With proper definition of an automata, rich motion could be created.

Mexican wave is interesting topic also for crowd simulation and some solutions were already found [Farkas et al. 2003], [Chaudhuri et al. 2004], [Yilmaz et al. 2011], but none of them used cellular automaton. If we would like to describe this wave in terms of simulation, propagation of a wave is phenomenon very similar to well-established approaches to excitable media such as forest fires or wave propagation in heart tissue [Farkas et al. 2003].

3 Problem Analysis

Crowd simulation should manage different distributions of both visible and invisible signals from one individual to another one. A Mexican wave is a popular event in sport audience, but we expect, that it just visualizes a more general signal distribution, e.g. emotions, rumors or smell ones. Recognizing circular and parallel waves, we focus on the later case.

A parallel (Mexican) wave in a rectangular evenly distributed crowd (we refer to rows and columns) consists from even number of columns, where in the central column people stand and their left and right neighbors decrease their height to imitate the sinus wave. This state is repeatedly changed by moving the top of the wave to the right causing appropriate changes of heights in the whole number of columns.

The observable global parameters to control a Mexican wave are all integers. There are total rectangle sizes RX, RY, size (extent) of the wave in number of columns NW, the distance of two adjacent waves DW, wave movement direction WMD, and the speed of wave SW. The local parameters can be modeled using a state (and a limited vision of a) cellular automaton individual (cell). Modifying these parameters we intend to simulate more general signal distributions.

Spatial relationship between cells is in cellular automata well defined. Moreover in our situation, members of a crowd do not change cells they belong to, because they stay in their seats during the wave. Therefore propagation to the neighborhood and cooperation between members using cellular automata should be possible. From the definition of cellular automata, cells have states which are changed during the time, same are inner states for individuals. These inner states define if individual is seated or performs a wave. Also pattern that is created by the wave should be possible to simulate by the cellular automaton. This pattern is usually approximation of a straight line. Very rough approximation actually creates this type of pattern, but more fine look at the crowd creates a curve. This curve shows that either front rows, or upper rows are little bit faster than others, which means that pattern is curved either at the bottom or at the top in C shape when wave is propagating in clockwise direction and mirrored C shape in counterclockwise direction. Definition of an automaton that will allow us create these patterns is needed. In following section we will describe our solution to the problem.

4 Visual System

In our solution we incorporate approximation of human visual system. Field of View is usually taken within 60 degrees horizontally either side of the direction [Rymill and Dodgson 2005]. Others claim, that horizontal perception field is divided into three main parts. The first part is defined by a vision angle of 30 degree. In this field a human can see object in detail, in vision angle of 100 degrees can see only object forms, in 200 degrees only movements of objects are seen [Beltaief et al. 2011]. Moreover, within the human eye there is a small region known as the fovea, which extends over a visual angle of 2°. This is the main region used to make detailed observations of the world: the rest of the eye provides peripheral vision, with only 15-50% of the acuity of the fovea [Rymill and Dodgson 2005]. We can use this information to have four different rendering techniques for four different levels of detail, depending in which region they are.

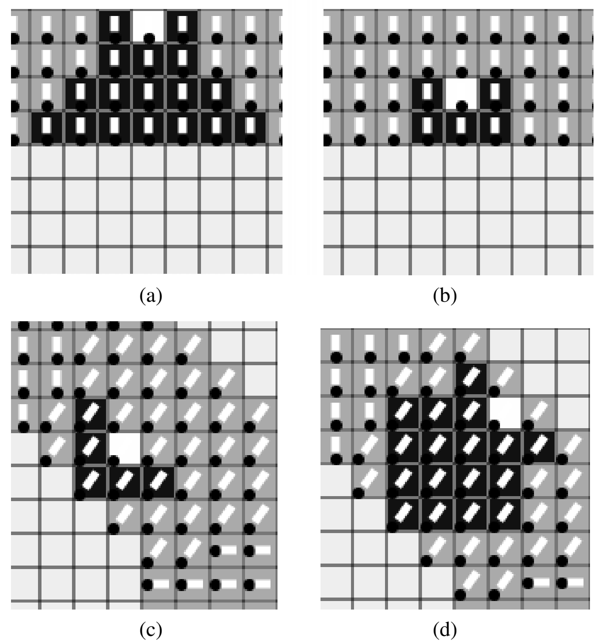


Figure 2: Definition of a neighborhood with visual system incorporated. (a) neighborhood for a person in 4th row and axis-aligned direction (b) neighborhood for a person in 2nd row and axis-aligned direction (c) neighborhood for a person in 2nd row and diagonally-aligned direction (d) neighborhood for person in 4th row and diagonally-aligned direction

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Nevertheless we decided to choose only 45 degrees for our visual system, because of the inattentional blindness problem, which describes that people may not even perceive object without attention [Simons and Chabris 1999]. As we have situation of a crowd in a stadium and spectators are fixed on the sports performed and also their attention is more to the looking direction. Moreover, also wave itself is moving and visual system is more attracted to the movement, therefore only part of the Field of view to the front direction and cell behind are taken into account. These restriction simulates slight rotation of a head. The other problem is, that we need to approximate visual system to the cellular grid. Therefore in this solution we use also diagonal directions, which divides seated space in eight parts.

Moreover, neighborhood is defined by each row of seats separately, because it is wider and larger for the back seats. People in back seats have front seats included in their field of view. To achieve this perceptual realism, determination of a row number is needed. We use coloring algorithm based on the flood fill which starts at the center of a stadium (space without seats) with value 0 and recursively expands in more cells in 8-neighborhood direction. When recursion encounters seated area, value is changed to 1 and saved in the cell (first row) and increases in each immersion. When cells already have a value, only new lower values are set as new values in the cell. If the new value is larger, recursion stops. This way we get row number for each cell with the seats.

States of the cells are calculated from the sum of cells in the neighborhood, that depends on the field of view. If enough cells in neighborhood are active, this cells becomes active, if join mood value (percentage) allows it. The random value is generated, that is affected by the sum of active cells in the neighborhood, if it is lower than the join mood value, this cells becomes active in the next step. More realistic results are shown in below. In this results each person have not only join mood defined but also other personal properties, such as willingness to attend (the higher this value is, the more willing person is to join the wave) .

Results of this solution are regular and do not change rapidly after wave enters corners. This solution is still too regular with every seat occupied and every cells becomes active in the very deterministic order. Our world is not so much deterministic, therefore some enhancements are shown in the section 6.

5 Movement Association

Firstly, we define the mapping between motions clips and CA. For our purposes motions of one figure are pre-defined and stored in the database. However this approach would work also for MoCap data. Database is created so the motions are suitable for the scene needed. Which motion use for the database is defined by the properties of motion - depending on what the topology of characters is, what kind of motion and what diversity of a group is needed. Afterwards, motion graph is created so more motion sequences can be used in the simulation. Currently only few motions are used, because of the motion we had in our disposal.

We map one motion from the database according to the state value in member of a crowd for each time step. There could be one motion mapped to more people. Example are occupants of active cells, where all of them performs same action. Because there is no restriction for the grid dimensions in CA, we could use as many models as is needed.

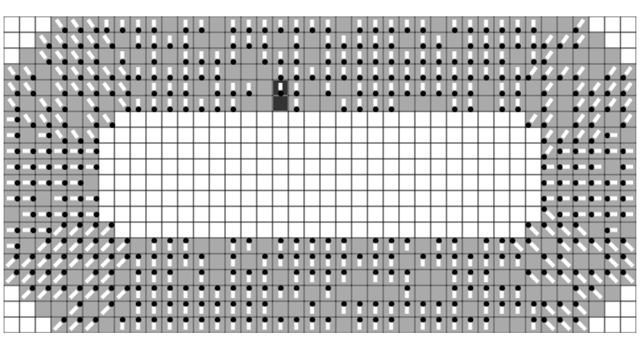

Figure 3: Sparse crowd with 80% occupancy value. Dark cells are starting cells

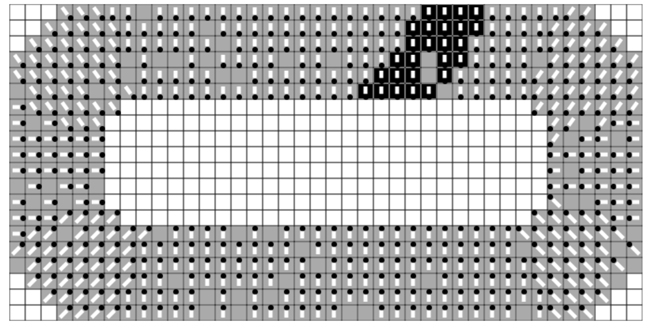

Figure 4: Result of the wave propagation after 9 iteration steps with 90% occupancy and 70% join mood and with one behind cell included in the neighborhood.

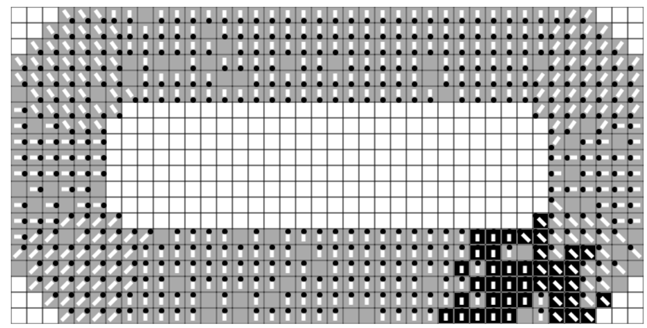

Figure 5: Result of the wave propagation after 32 iteration steps with 90% occupancy and 70% join mood and with one behind cell included in the neighborhood.

6 Results

In this section various results are shown. However we use only few variables that can affect realism of the simulation but this approach is not limit to use many more parameters. Currently there is possibility to define how much dense is the crowd (in occupancy percentage, where 100% means fully occupied, if it is sparse not every seat is occupied (see fig. 3). This means, that probably sport that takes place at the stadium is not so much interesting. This happens also in the real situation scenario and director has ability to set parameters according to the needs.

Moreover, not only occupancy can be set but also simple personality of the members in a crowd. Their personality is based on the mood parameter. This mood determines how much is person willing to join the wave performance, in percentage, where 100% means that person is willing to join fully. There is also global parameter, which describes global mood of the crowd and in the figures is described as *join mood*, see fig. 4, 5, 6. With this parameter we can also set how many members would join the crowd lately (with setting the global mood in lower terms), see fig. 6. This behavior is seen also in the real crowds.

7 Conclusion

To verify our results we watched various captured videos from the sport events, where mexican wave was performed. We observed, that most of the patterns that were created by the wave propagation

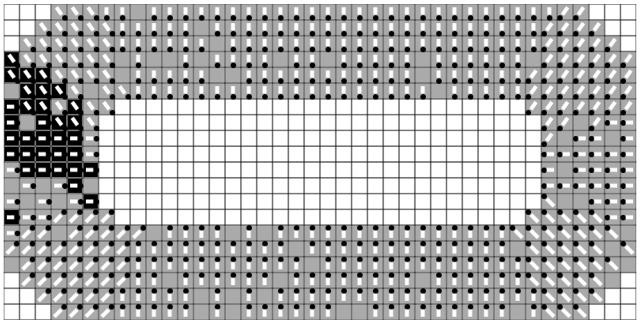

Figure 6: Result of the wave propagation after 64 steps with 90% occupancy and 70% join mood and with one behind cell included in the neighborhood. Single late members are shown.

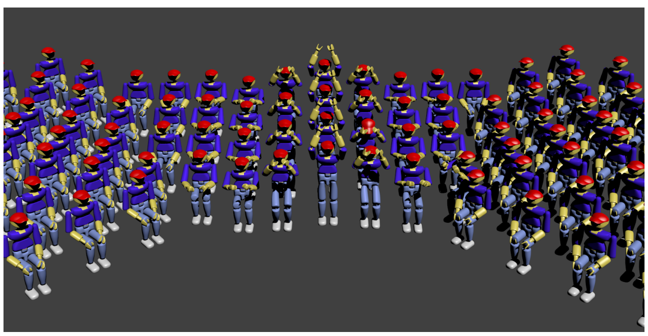

Figure 7: Rendered image, that shows result during the simulation.

were not rectangular, or straight lines, as was our preliminary assumption. However with the visual system our assumption changed and our results show that with personality added and occupancy value our pattern is in very rough approximation of rectangle, but more realistic with noise in the shape. Moreover also this pattern does not change when wave comes to the corners. Also in real situation, audiences tries to preserve same patterns as they expect the mexican wave should look like. On the other hand, not in all videos rows with higher number join the crowd earlier as is case in our solution.

We described cellular automata with special rules and neighborhood definition to create simulation of the mexican wave in the stadium. Other solutions didn't used cellular automata and we also directly applied states of cells in the simulation to the index in the database of motions and automatically gather motion of a crowd which was then rendered, see fig. 7. This way we used cellular automata not only for successful simulation of a crowd, but also for motion definition itself, where states in each simulation step are directly applied to the motion.

In the future work we would like to present more parameters that would describe personality and distraction, that could be described by the head motion. Also movement of a participants to the next cells is not possible in the current solution, but is present in the real situation, therefore this is left for the future work. We consider using bindings among the individuals based on distance and estimated visibility.

8 Acknowledgement

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