Force-based group formation control

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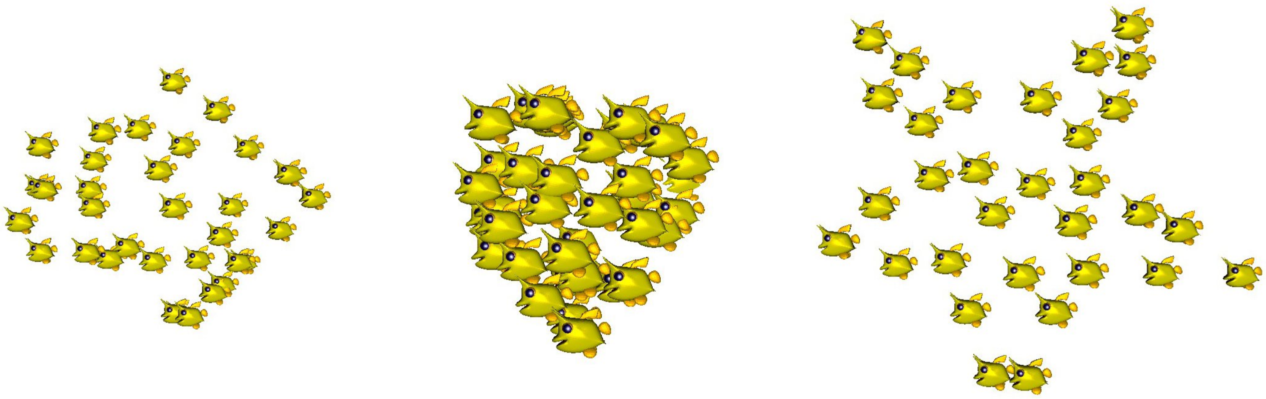

Figure 1: Formations created with flock of fish.

Abstract

Nowadays, simulations of groups are important to bring more natural look to the virtual world. Moreover, large crowds can be used not only to fill space, but to create visually interesting shapes with perceptive or cognitive meaning. Positioning of people to create shapes is well known from live performances, or shows, where dancers are positioned to create formations. This principle is transferred from people to the animals in various motion pictures as another channel of metaphor.

Our stochastic approach in distribution of individuals is different from regular ones, where participants are equally distributed. We use particle systems for representation of individuals and apply repulsive forces for distribution. This bring semi-regular approach, where participants are more naturally, less equally distributed with shape-preserving. Moreover we bring more automation and simplicity to the process, where chief animators, or designers define only shapes. Afterward we distribute individuals and create movement between formations.

Shape-preserving is a feature which depends on human perception. Therefore we verified our results with the group of children that are target group of most motion picture movies and also with the group of adults. We tested meaning of the formations for humans in various ages and backgrounds.

Keywords: animation, formation, repulsive force, particles, flocks

1 Introduction

In our approach we would like to consider either flocks or herds of various kinds of animals in more complex and general way. We define crowd, where participants can be animals as well as human beings. Therefore a variety of objects can be used, but method of processing them is the same. Therefore we observe crowd as whole, from the outside, where individuals are equal and we are not dealing with the animation or behavior of individuals. Particle systems seems good solution for processing the crowd with such manner. Our goal is to create visually attractive shapes with right distribution of particles as is shown in figure 1. As inputs we consider model with materials, textures and rotations of a participant in a crowd, polygonal shapes and number of participants, then we process these information. Afterward positions in keyframes and middle frames for participants are calculated. These positions can be directly rendered or exported.

Firstly, in the next section 2 we discuss related work to the crowd simulation and animations as well as distribution within the group. Secondly, in section 3 we discuss detailed description of the force-based method used to create visually attractive formations. In the last section 4 results of sample applications and render are discussed, where we used questionnaire to obtain personal impression and meaning of the shapes. At the end in the conclusion, section5, we summarize our success.

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2 Related Work

Animation of large groups are interesting topics of computer graphics, because they are visually attractive and are widely used in motion pictures [Kermel 2005], [Remington 2003]. Therefore, researchers are dealing with this problem over twenty years. Firstly, classical paper of flocks and herds [Reynolds 1987] considered group of animals as agents with defined behavior, however we define crowd as particle system without behavior. Important steps in crowd animation are also movement of individuals, appearance and performance. Many authors are discussing heterogeneous groups of human individuals [Ulicny et al. 2004], [Thalmann and Musse 2007], [Thalmann and Musse 1997] to look natural. On the other hand, we are dealing with crowd as whole, therefore these results are not relevant for us. When considering performance of a crowd, Levels Of Detail are created as discussed in [O'Sullivan et al. 2002a], [O'Sullivan et al. 2002b]. This research can be extended using more levels, but we leave this the future work.

More relevant for our approach are papers, where motion of one group is constrained [Lien et al. 2005], [Anderson et al. 2003]. We study the case, when motion of a group is constrained by the pre-defined shape. Moreover, physical forces are also not new in the crowd movement [Heigeas et al. 2003]. Here forces are used to the flow of crowd in the virtual city and we use forces to distribute participants in a shape to create formation. Most recent paper about crowd formation control is [Takahashi et al. 2009] where individuals are positioned to create shapes and bring very smooth movement, but does not use forces. We create formations but use forces not only for distribution, but also for the movement as well. Methodologically, we combine advantages by [Lien et al. 2005] and [Takahashi et al. 2009].

3 Force-Based Method

Firstly, in pre-processing step shapes are created, by a chief animator. These shapes are simple polygons, either convex, or concave without intersecting edges. Our method can be easily extended to the simple 2D manifold 3D objects, but polygonal shapes are enough for groups, where participants lay on the plain, or when camera is set right to observe shape. After shapes are defined the

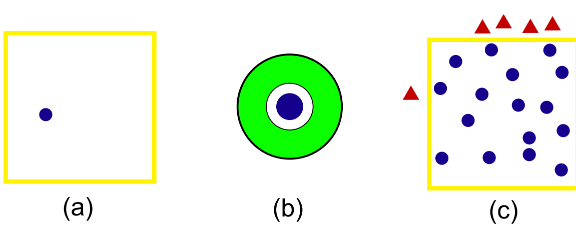

Figure 2: Finding initial position. (a) Polygon with first position found. (b) Surrounding of point, where next position will be found. (c) Particles outside the polygon as red triangle and inside the polygon as blue disc.

crowd has to be created. Because our approach is based on stochastic finding position there will not be same distribution of crowd for same shape after two creations. The first step is we call **Seeding**. In this step initial positions for participant are found, where position of participant is meant by center of the bounding sphere. There are two approaches of finding initial positions. First, where edges are not preserved, with is suitable for more curved shapes, and second, that preserve corners better. In the first one, we have to find position of the first particle in the center of polygon. We do this by simple calculating barycentric coordinates of a polygon. Positions of other particles are calculated with finding random angle and length in some range as is shown in figure 2(b). Polar coordinates of new particle are then angle and length in a system, where the center of polygon is zero point as is shown below:

$$x = F_x + cos(\alpha) * l, \quad (1)$$

$$y = F_y + sin(\alpha) * l, \quad (2)$$

where (x, y) are coordinates of a new point, $F = (F_x, F_y)$ are coordinates of a center, α is angle and l is length as discussed before. Inner point property is used to check if this coordinates are inside the polygon, if not, process of finding angle and length is repeated as is shown in figure 2(c). In another method instead of center we take vertices of polygon and change coordinate system in a way, that zero point in the system is one vertex of polygon.

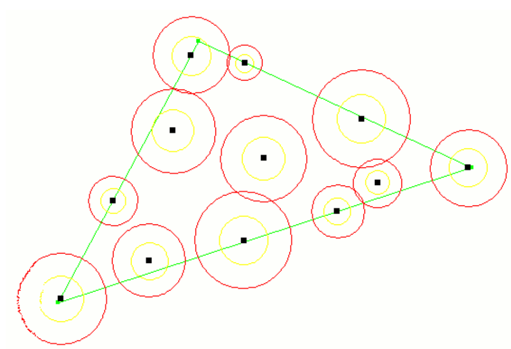

Figure 3: Participants represented by the black dots, and are where forces still apply is represented by the red circle. The defined shape is a green triangle.

Afterward repulsive forces are applied and are evaluated in the steps. In each step forces applied to one particle are calculated. One repulsive force between two particles is defined as:

$$\vec{f} = \frac{(B - A) * C}{d}, \quad (3)$$

where $\vec{f}$ is final force, B is point, on which are applied forces and we calculate them, A is a point that affects B, d is distance between A, B and C is constant. Constant C depends on an area of polygon, number of particles and it means in which distance particles affects each other. It is calculated as follows:

$$C = \sqrt{\frac{a}{p * \Pi}}, \quad (4)$$

where C is constant, a is area of polygon and c is a number of particles. When particles should move behind the border, then particle is moved according to the force, but only until intersection with edge is found.

Forces are applied in recursive order, where recursion stops, when all particles do not move, or when number of movements is exceeded. When recursion stops this is a **stable stage** as is shown in figure 3. Afterwards, this stage can be collapsed by moving of vertices in a polygon and recursion starts again. When the particle is outside of the shape before applying forces, it is moved to intersection of a polygon in direction to the center of polygon. When using this approach for 3D space, random positions in some range in z-direction are applied.

Animation of a group is created by morphing of vertices in a polygon to another polygon with linear interpolation or other technique, that will not cause intersecting of edges. To gather meaning of a shapes, animation itself should stop in a stable stage of final polygons for certain time.

4 Results

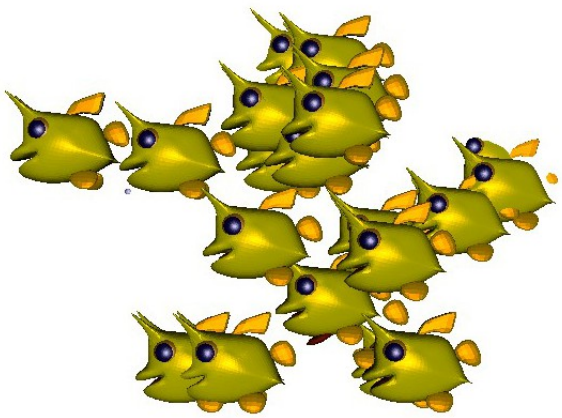

Figure 4: Results of the method in 3D.

We took flock of fish as our referencing crowd, where result of our approach is shown in the figure 4, where fish create a shape *star*. We tested our approach for 2D shapes in 2D space and also for 3D applications, where rendered them in Blender v2.49. We showed these shapes in online questionnaire. Answers were from 45 users in age 20 - 32 years. Accurancy was between 50%-90% for *exact match*, where we considered same meaning as has designer of shape. On the other hand, some shape do not have single meaning and we call this *reasonable match*, which was between 60% - 90%. 8% of the users misunderstood meaning of a question and described participants, so the answer was *fish*, mostly in the beginning.

Moreover we showed our results also to 30 children of dancing class in an age 8 - 12 years and explained what should be observed. These children understand meanings of formations, because it is commonly used in dancing. 40% - 100% of the children understood correct meaning behind the formations. It is higher than online questionnaire probably because it was presented personally. However some of them have stunning imagination and slight spaces in a triangle can cause, that child see there a face.

These results are from our point of view accurate, because images were shown without any prior knowledge. When formations will be shown in a row it could bring even better results. These shapes were simple, therefore without previous knowledge some iconic representations can have more meanings. We succesfully confirmed, that people found some kind of meaning in the formations, it were not only group of participants distributed in a plane and this was our goal.

5 Conclusion

In conclusion we would like to point out that we successfully used repulsive forces for control over the group, positioning and movement. These formations did not act by behavior rules, but created reasonable shapes. Our approach brings more automation to the control over the group where positions are important. We tested distribution of a group to the shapes by questionairre, where our assumptions were confirmed. Our approach needs more evaluation, because it is not common to use such a method.

6 Acknowledgement

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