Boidz: An ALife Augmented Reality Ambient Visualization

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Abstract

Boidz is an ambient visualization populated by autonomous a-life flocking agents situated in a 3D augmented reality environment. This work allows users to visualize population fluctuation as multi-agent flocking behavior using a spatial metaphor. Because this work is presented while simultaneously situated in the hub of a busy university social space, the project intent is to study how emergent agent behavior can become expressive and aesthetic aids in understanding the visualization. The author has developed a prototype visualization to test these claims. Preliminary user responses and future directions are included.

Keywords: artificial life, autonomous agents, ambient visualization, virtual environment, augmented reality

1. Introduction

This paper proposes an ambient visualization system motivated by our desire to combine the following domains:

- **Multi Agent Systems** have the capacity for expressive emergent behavior [1].
- **Immersive virtual environments** has received attention in manufacturing [2], computer aided architectural design (CAD) [3], and commercial computer game [4] communities.
- Automated **image based modeling** technologies virtualize the physical world [5] while conversely enabling the virtual to appear more real.

This work presents an ambient visualization of site specific data in a photorealistic virtual environment. The motivations are twofold, the first is to give an aesthetically pleasing visual experience, and the second is to check whether users would understand the visualization when it is applied to a spatial metaphor using emergent agent behavior. The implications of this pursuit have allowed for further innovation in augmented reality systems.

An augmented reality (AR) system is defined as having the following properties: combines real and virtual objects in a real environment, runs interactively, and in real time, and registers (that is, aligns) real and virtual objects with each other [6]. Boidz supplements the real world with virtual (computer-generated) objects that appear to coexist in the same space as the real world.

Large format display systems have become more prevalent and cost effective yet existing AR frameworks [7] have predominantly focused on mobile devices and small displays. Another motivation was thus to develop an AR for large displays.

We address these motivations with a prototype visualization system called Boidz. The system consists of two parts (see Figure 1): a data driven multiagent system and a photorealistic virtual environment as described in the next sections.

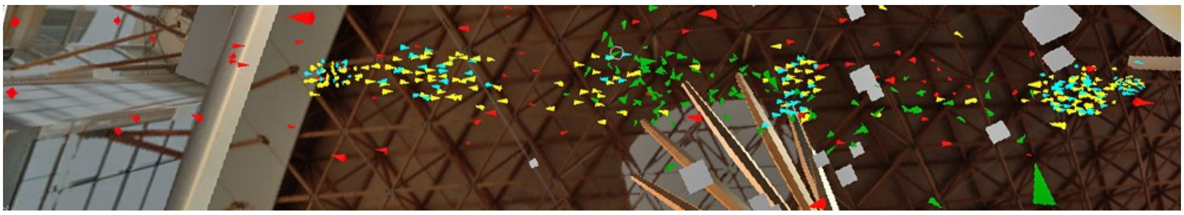

Figure 1: Multiple flocks of agents (triangles differentiated by color) virtually inhabit the main social space in this augmented reality ambient visualization showing population fluctuation over time.

2. Steering Agents

In a multiagent system (MAS), complex and intelligent collective behavior *emerges* from individual agent's behaviors and their relationships with the environment.
In our case we used Reynolds model of autonomous agent steering behaviors that is defined as the agent ability to navigate around their world in a life-like and improvisational manner [8]. Reynolds differentiates agent steering behaviors between locomotion (the articulation of motion) and action selection (strategy and goals). Steering behaviors must also anticipate the future and take into account eventual consequences of current actions. Reynolds "boids" flocking agents were selected for this project because of their capacity for expressive and emergent flying behavior based on simple behavioral characteristics.
For Reynolds, all agent behaviors can be represented as asymmetrical steering forces (thrust, braking, and steering) comprised of the following vector and scalar values: position, velocity, force, speed, and orientation. Per agent and for each time increment, these values are updated into a new direction where the agent local space is reconstructed. This allows for variable steering forces: magnitude, acceleration, velocity and position. On top of this, additional flocking characteristics include:

- **Cohesion:** The ability to cohere with (approach and form a group with) other nearby agents.
- **Separation:** The ability to maintain a certain separation distance from others nearby.
- **Alignment:** The ability to align itself with (head in the same direction and/or speed as) other nearby agents.
- **Collision avoidance:** keep agents which are moving in arbitrary directions from running into each other.
- **Flock Neighborhood:** Steer the agent towards a specified moving position in global space. Flee is the inverse.

The Boid agents are data driven and depicted in a cartoon non-photorealistic rendered (NPR) manner.

3. Virtual Environment

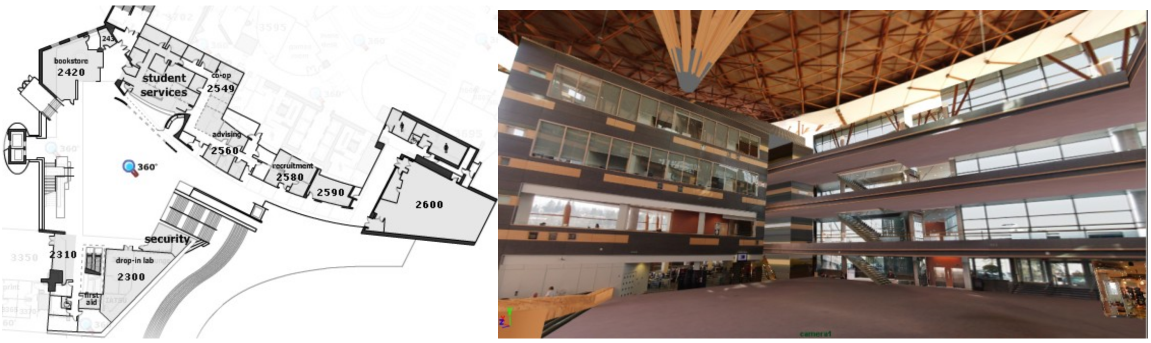

Figure 2: Plan (left image) of the large atrium space which is the large social area used as reference for the photo-real 3D model (right image).

The project took place inside a large atrium space which is the central entrance for Simon Frasier University, Surrey Canada (see Figure 2). Because this space is very open it is well suited the boid's flocking behavior potential. All pedestrians must pass through this space when entering the campus ensuring high traffic and thus fluctuating population data. For Boidz, mirroring this environment as well as the people populating it was a priority.
An image based modeling approach was chosen for the environment presentation because the way in which a user perceives a virtual environment is closely linked to how compelling the environment may seem [9]. Although the amount of presence users feel in virtual environments is difficult and subjective to measure [10-12] for the purposes of this study the virtual environment was photo-realistically constructed to maintain a high degree of presence.
The goal for this project is for participants to examine emergent behavior within an embodied and familiar (social) setting and not a remote laboratory (otherwise a virtual or CAVE environment would have been sufficient such as in the Swarm Art Project [13]). In Boidz the large display is located within the atrium space which is why it can be considered as AR.

4. Data Visualization

Boidz is a data driven ambient visualization system that mirrors the campus population present in the atrium. Figure 3 shows the data used for Boidz. For the purposes of this prototype, four flocks were created to represent diverse and fluctuating population groups on campus daily (undergraduates, graduates, faculty & staff, and visitors). Thus agents are representative of the campus population. Population types are differentiated by flock color and changing flock behaviors which is accomplished through the manipulation of the boid’s attributes. Some of these behaviors are exemplified in Figures 5a and b.

<table>
<tr><td colspan="4">Approximate Campus Population & Flock Color</td></tr>
<tr><td>count</td><td>color</td><td colspan="2">Population Type</td></tr>
<tr><td>1,600</td><td>Red</td><td colspan="2">Undergraduate Students</td></tr>
<tr><td>255</td><td>Yellow</td><td colspan="2">Faculty & SFU Staff</td></tr>
<tr><td>100</td><td>Green</td><td colspan="2">Graduate Students</td></tr>
<tr><td>30</td><td>Cyan</td><td colspan="2">Visitors per day</td></tr>
<tr><td>1900</td><td></td><td colspan="2">Approximate Total</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td colspan="4">Approximate Time of Global Behavior</td></tr>
<tr><td colspan="3">Morning (6am-9am)</td><td>Calm</td></tr>
<tr><td colspan="3">Mid Morning (9am-11am)</td><td>Escalation</td></tr>
<tr><td colspan="3">Lunch Hour (11am-2pm)</td><td>Hectic</td></tr>
<tr><td colspan="3">Afternoon (2pm-5pm)</td><td>Decay</td></tr>
<tr><td colspan="3">Evening (6pm-10pm)</td><td>Calm</td></tr>
</table>

Figure 3: Data tables showing campus populations separated by group and traffic patterns within the mezzanine space collected from informal observation and conversation with staff.

4. Prototype

5.1 Game Development Process

The prototype implementation incorporated a game development pipeline integrated with a steering behavior library running on Microsoft C# code XNA Game Studio 2.0.

The content creation pipeline is comprised of the following four steps: image acquisition and processing, modeling and image mapping, optimizing for real-time game environments, and final programmatic modifications within the game engine. First digital photographs of the environment from multiple views were shot. These shots were bracketed with multiple exposures to allow for high dynamic range post processing. Using high dynamic range techniques enhances the quality of the final image and is a common practice in professional photography. Second Autodesk Maya, a computer modeling software package is used to import and apply these images to 3D geometry from architectural drawings (see Figure 2). This process was done by hand although there are techniques to do this with more accuracy and automatically [5]. Third, the model “mesh” is optimized by reducing the amount of triangulated faces (to about 1000 in total) and compressing the image sizes (14 separate images used). This content is then exported into a scene graph suitable to run in the game engine using FBX (an open-standard platform-independent 3D file). Microsoft C# XNA v2.0 includes the scene graph, corresponding images, and the required content libraries. Lastly final modifications were made such that the model is correctly associated with the updating camera view projection matrices.

Steering Behavior Library

SharpSteer [14] is a C# port of OpenSteer [15], Craig Reynolds open source C++ implementation to construct steering behaviors for autonomous agents in games and animation. This library is identical to Reynolds for the following parameters specifically pertaining to boids:

- Default Flock Size (count)
- Flock World Size (radius)
- Steering Force Magnitude

- Obstacle Avoidance
- Boid Velocity, Speed, & Orientation
- Boid Separation, Cohesion, & Alignment
- Multiple camera views of flock behavior

The library was modified for the purposes of this prototype to include the following attributes: multiple flocks differentiated by color, dynamic flock population change, and new cameras.

The four flocks are enabled each with their own steering behavior properties that can be selectively manipulated to suit the appropriate global behavior. For the purposes of this prototype, a per-flock population increment or decrement from a variable time step is created. These are presently hard coded from actual traffic data collected (Figure 2) but eventually it is hoped this data will be based on real time data.

Lastly, additional camera views were created that are not attached to the moving boids to facilitate different viewing orientations This further emphasizes different navigation and viewing metaphors [16]:

- 1st person human and a static position perspective in the space/agent behavior. Human observer.
- 3rd person (sees the local behavior)
- Boid view

For the present prototype, the camera position alternates by a determined time step and requires no user feedback. Figure 4 shows some samples of the variety of views used in the prototype.

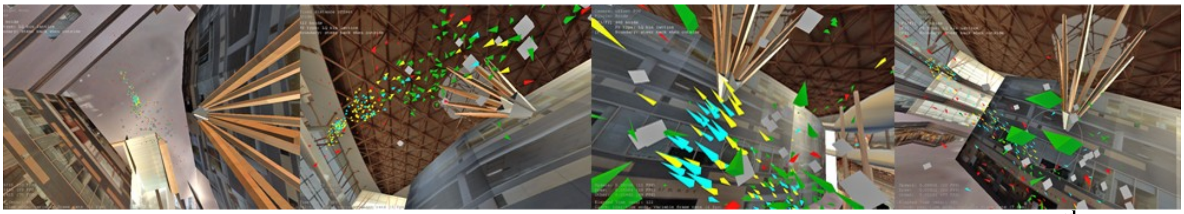

Figure 4: Boidz seen from alternating camera points of view such as top down, bottom up, 3rd person, and 1st person. By changing camera views, the visualization is referring to human and boid relative positions.

5.1 Informal Response to Prototype

The notion of purposeful agent behavior increasingly depended on the juxtaposition of an environment situating both human and agent. Thus agent behavior resulting from environmental attributes are not only important from a programmatic view but also how these behaviors end up *cohesively* presented to a human assessor in understanding the visualization.

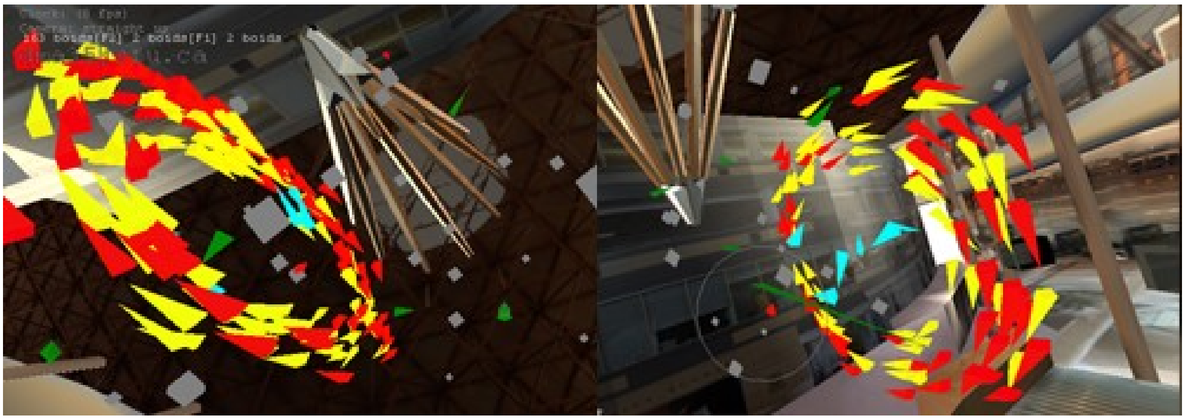

Figure 5a: Views showing the participant from the boid point of view (a graduate student) however the emerging flock behavior is seen in the red and yellow flocks (representing undergraduate students and faculty). In this case they both are in a synchronous behavior.

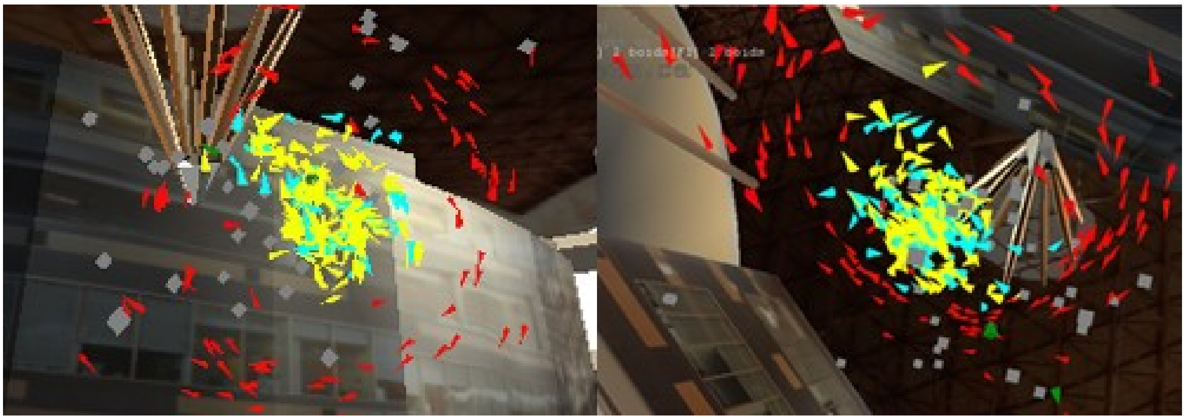

Figure 5b: This view shows emerging flock behavior representing the red flock (undergraduate students) encircling all the other flocks (including graduate students, faculty, and visitors).

This work has been showcased in the intended university space as an alpha test with no user instructions. The ambient visualization ran continuously for a whole day while the behaviors changed over time. The setup tested alternated camera views of the space and the flock population mirrored estimates of the actual population fluctuations according to the time of day (in Figure 3). A number of undergraduate students were curiously drawn to the visualization because of the behaviors however in conversation they were unclear on the information mapping and why there was no interactivity since it looked like it could be a game. In this situation there was not enough richness in the agent behavior since the observer now wanted to be more involved. A consequence of the development process is that Boidz actually looks like a video game demo. Indeed the tools used are similar to video game development which reflects on the aesthetic. The project was explicitly playing with this ambiguity.

The audience interest is a good indication of the success as an ambient visualization but leaves more to be desired in the spatial communication potential of the system. Further and more thorough evaluation testing is required. More variety and complexity in agent behavior itself is also desired. Because the flocking behavior worked well within an open atrium space, the existing parameters were well suited. However the visualization vs. narrative potential is closely limited by agent capabilities which are currently abstract. Reynolds has noted that steering behavior attributes should be customized to suit new combinations and this seems like another logical step for this project. Some behaviors that would work particularly well for this implementation are: seeking and fleeing, arrival and departure, path following, and containment.

6. Related Work

Amongst agent based visualization systems, Klima's Ecosystm [17] favored a data driven method specifying the action selection and steering in an imaginary NPR virtual world. Ecosystm is a 3D virtual world and real-time representation of global currency volatility fluctuations, consisting of flocks. Klima also extended these ideas in Ecosystm2 where user generated stock portfolios determined new behavioral states such as breeding and feeding.

Another approach using Reynolds boid's is in Shiffman's Swarm installation [18] that instead emphasizes agent emergence in shape and movement for a painterly brush effect. In this case the rendition (environment) is a real-time 2D video abstraction of the user. Although parameters controlling flock movement are fixed, the changing visual shape is easily interpreted to the user.

Amongst ambient visualization works include the Garden of Chances [19], a 2D computer generated installation. Hutzler seeks new representational strategies that may be used in order to make dynamic organizational processes become apparent to the beholder's eyes. There question of user coherency is also addressed in his work where through a sociological or biological metaphor the multi-agent systems becomes more clear for the user.

Lastly a 2D Data driven visualization approach using flocks and user biofeedback has also been explored [20] however this mapping to agent behavior is currently difficult to intuit.

To our knowledge no related work combine multiagent system, immersive virtual environments, ands image based modeling.

7. Summary

This paper has documented a design exploration encompassing an ambient visualization prototype that merges emergent agent behavior within a photorealistic augmented reality setting. This project prototype has been showcased with initial success on visual appeal however the user's ability to understand the visualization when applied to a spatial metaphor remains to be tested. There is still much more work ahead in terms of customizing agent behaviors to better suit the space, extending the agent expressive behavioral features, and to consider interaction.

8. References

References

[1] P. Cariani, "Emergence and Artificial Life," in *Artificial Life II*, Langton, Taylor, Farmer, Rasmussen, Ed. Redwood City, CA: Addison-Wesley, 1997, pp. 775-797.

[2] M. Mantere, "Visualization of Flow Data in Photo-realistic Virtual Environment," in *Department of Electrical and Communications Engineering - Interactive Digital Media*, vol. MSc: Helsinki University of Technology, 2001.

[3] K. Oosterhuis, *Hyper Bodies*. Boston: Birkhauser, 2003.

[4] Kot, B.; Wuensche, B.; Grundy, J.; Hosking, J., "Information Visualisation Utilising 3D Computer Game Engines Case Study: A source code comprehension tool," Proceedings of the 6th ACM SIGCHI New Zealand chapter's international conference on Computer-human interaction: making CHI natural, Auckland, New Zealand, 2005.

[5] Oh, B. M.,Chen, M., Dorsey, J., Durand, F., "Image-Based Modeling and Photo Editing," *SIGGRAPH '01: Proceedings of the 28th annual conference on Computer graphics and interactive techniques*, pp. 433-442, 2001.

[6] Azuma, R.; Yohan, B.; Behringer, R.; Feiner, S.; Julier, S.; MacIntyre, B., "Recent Advances in Augmented Reality," *Computer Graphics and Applications, IEEE*, vol. 21, pp. 34-47, 2001.

[7] Magerkurth, C., Stenzel, R.,Streitz, N., Neuhold, E., "A Multimodal Interaction Framework for Pervasive Game Applications," presented at Artificial Intelligence in Mobile Systems, Seattle, 2003.

[8] C. Reynolds, "Steering Behaviors For Autonomous Characters," presented at Game Developers Conference, San Francisco, 1999.

[9] Glencross, M., Chalmers, A., Lin, M., Otaduy, M., Gutierrez, D., "Exploiting Perception in High-Fidelity Virtual Environments," presented at Siggraph - Full Day Course, Boston, 2006.

[10] Slater, M., "A framework for immersive virtual environments (FIVE): speculations on the role of presence in virtual environments.," *Presence: Teleoperators and Virtual Environments*, vol. 6, pp. 603–616, 1997.

[11] Witmer, B. G., Singer, M. J., "Measuring presence in virtual environments: A presence questionnaire," *Presence Teleoperators and Virtual Environments*, vol. 7, pp. 225–240., 1998.

[12] Slater, M., Usoh, M., "Small group behaviour in a virtual and real time environment: A comparative study," *Presence Teleoperators and Virtual Environments*, vol. 9, pp. 37–51, 2000.

[13] Boyd, J., Hushlak, G., Jacob, C., "SwarmArt: Interactive Art from Swarm Intelligence," presented at ACM international Conference on Multimedia, New York, 2004.

[14] Graf, B. "SharpSteer," 2007, pp. SharpSteer is a C# port of OpenSteer, http://www.codeplex.com/SharpSteer, April 2007

[15] Reynolds, C., "OpenSteer C++ Library," Sony Computer Entertainment America, 2002, pp. C++ library, http://opensteer.sourceforge.net/, April 2007

[16] Darken, R. P., John, L. S, "A toolset for Navigation in Vitual Environments," *Proceeding of the 6th annual ACM Symposium on User Interface Software and Technology*, pp. 157, 1993.

[17] J. Klima, "ECOSYSTM." New York, 2002, http://www.cityarts.com/ecosystm/ , April 2007

[18] D. Shiffman, "Swarm." New York University, 2003, http://www.shiffman.net/projects/swarm, April 2007

[19] Hutzler, G., Gortais, B., Drogoul, A., "The Garden of Chances: A Visual Ecosystem," *Leonardo*, vol. Vol. 33, pp. Pages 101-106, 2000.

[20] Picarougne, F., Azzag, H., Venturini, G., Guinot, C., "On data clustering with a flock of artificial agents," presented at ICTAI 16th IEEE International Conference on Tools with Artificial Intelligence, 2004.