Craig Reynolds' Steering Behaviors in Human Movement

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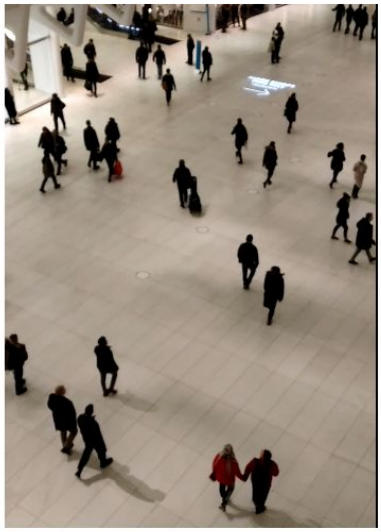
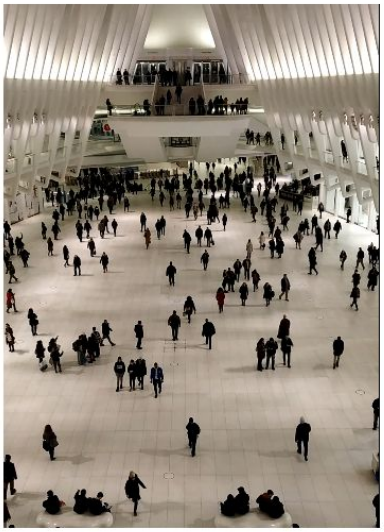
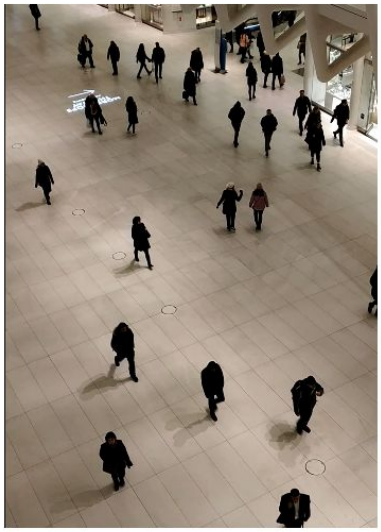

INTRODUCTION

Steering behavior typically resembles the set of fundamental principles which governs the decision making of an individual to maneuver itself and make changes in the direction of its movement based on the setting of its local environment or nearness to the relevant point of interest/aversion. This is an important field of study for game makers or animation artist to attribute characteristics of movements to their artificial agents. Since the inception of the artificial 2D-modeled world, steering behaviors have been a crucial element for the developers. Unlike pathfinding techniques which focuses on the most optimal plan to move across a complex environment and reach a designated target place, steering lacks the ability to act according to global constraints and concentrates on tackling local key points to operate efficiently in a dynamic environment where obstacles need to be avoided or a moving goal need to be persuaded. In a holistic way, it can be termed that steering behavior makes use of methods to detect objects in its environment, and by using their spatial information, make changes in its own movement direction to either approach or avoid these objects.

In 1980s Craig Reynolds presented extensive works on steering behaviors, which brought this into the center of attention for game/animation agents. His first work on steering behaviors was documented in 1986 which described how individuals in bird flock or fish schools make movements based on the presence and movements of its nearby fellow mates. Reynolds called these locomotive creatures *boids* and his this work is famously regarded as flocking work with Boids. By advancing over this work, in 1999 at the Game Developers Conference in San Jose, CA., Reynolds presented a paper on Steering Behaviors for Autonomous Characters. Till date, this paper along with its illustrations of various steering concepts, continue to remain a pivotal reference point for artificial agents developers. This paper illustrates solutions for autonomous characters in animation and games to navigate in their environment in life like manner with improvisations. Irrespective of the medium of agent's locomotion, with a combination of steering behaviors higher level objectives like persuading a target while avoiding collision with local objects can be easily achieved. Reynold divides the problem of motion into three distinct levels. The higher level of goal planning, middle level of steering and the last level of locomotion.

Similar to the motion of artificial agents in their local environment, which is claimed to be inspired from actual human/animal movement, the movement of people in an urban setting can be studied using the above mentioned three levels of motion. Hence, it will be interesting to observe the unbiased movement of people around any public place and find evidence of Reynold's steering behaviors in their motion. This can help us to understand the underlying principles which govern the movement of people and the way they interact with local objects present in the environment. To do this study we chose the central hall (Oculus) of World Trade Center Transportation Hub. The Oculus house part of the Westfield World Trade Center mall and serves as an intersection for exchange between the New York City Subway and New Jersey PATH transit system. The huge hall witnesses footfall of more than a thousand people at any time of the day and thus. Is a ideal venue to study the steering behavior in the motion of people. We recorded different video clips of movement in this place and through sophisticated algorithms from computer vision and deep learning detected motions of people in these video clips. The detected motions helped us to find evidence of Reynolds steering behavior in movement and understand various scenarios when these behaviors are used by humans.

OBJECTIVE

Similar to the steering behaviors of autonomous characters, a study could be conducted to observe the steering behavior of actual humans in a real urban setting. The understanding of these steering behaviors can help to better prepare the outlook/plan of urban places and optimize the interaction of people with the objects in the environment or make the purpose of their motion more convenient. With this in mind, we set the objective of this project to bring forward evidence of steering behaviors in human movement and understand how it pans out in an urban setting. We observe the motion of people, conduct space-time spatial analysis on their movements, determine the Craig Reynolds steering behaviors which can be observed in this movement of people and understand how these behaviors look in an actual public setting.

DATASET

To conduct this study we need movement trails of humans in a real urban setting with information of steering decisions used to make changes in the movement directions. There are multiple ways to capture these movement trails, one possible way is to follow people in actual urban places and record the movement using a GPS position recorder. The shortcoming we see in this approach is, because the movement would be mimiced and recorded, it is prone to lose the subtle changes made by humans to change the movement directions. To get an unbiased observation of people movement we choose to pick a place with a lot of people moving around, record their movement using a video recorder, then use an object detection algorithm to detect humans, and finally build their trails of movement. We found the central hall (Oculus) of the World Trade Center Transportation Hub to be an ideal place to make these observations as many people cross this place to meet, to shop in the Westfield World Trade Center mall, or make an exchange between the New York City Subway and New Jersey PATH transit system.

The video clips were recorded at evening hours of a weekday as many people accessed this place in this time period. The videos were captured from the top view to make the frame of the image as an approximation of space for the movement of people and the time was used as an independent dimension to understanding the sequence of changes made in the movement. Figure 1 shows the different angle at which the videos were recorded.

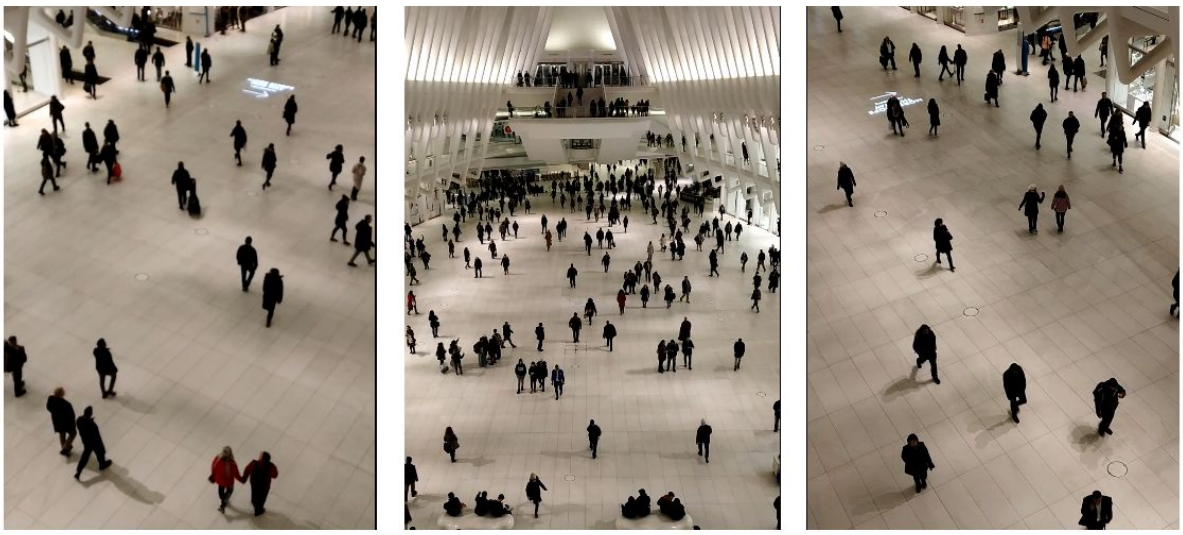

Fig.1. Different settings at WTC for data collection

METHODOLOGY

To understand the steering behavior of actual humans in a real urban setting, after obtaining the video, the study demands the following steps to be conducted:

1. Build a method to detect humans in the video frame.
2. Align the position coordinates of each individual human with its position coordinates in the subsequent frames to build movement trails.
3. Build a vector to point in the direction of the current velocity of a person.
4. Build a vector to point in the direction of the steering force of a person to determine the change in the direction of movement.
5. Using the movement trails, current velocity vector, and steering vector find evidence of Craig Reynolds steering behaviors in human movement.

Human Detector

To detect the humans in each frame of our videos, we take help of techniques from computer vision. Specifically, the Inception Net model based on the deep learning method was used to fulfill this objective. Inception Net model is trained on the Image Net Dataset which consists of one million images of thousand different category. The model returns bounding boxes for each

human in the frame and we use the center of these bounding boxes as the position coordinates of the particular human. An illustration can be seen in fig2.

Fig2. Human detection through Inception v2 model

Movement Trails

After obtaining each positional points of humans in each of our video frames, to every positional point in the current frame, we attribute the closest positional point in the subsequent frame. We do this repeatedly to prepare the movement trails of each individual human in our video.

An illustration of this can be seen in fig3.

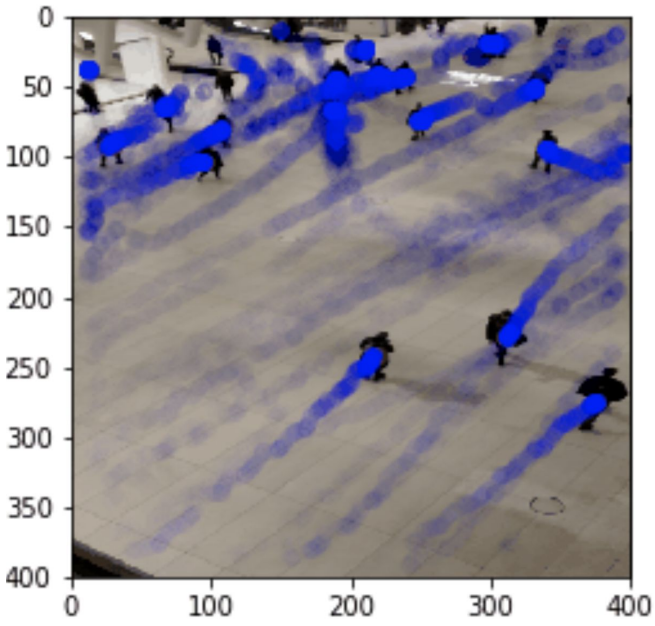

Fig.3. Movement trails

Current Velocity Vector

After obtaining the movement trails, to build the current velocity vector for any individual, we join the positional point coordinate of the individual with its positional point coordinate in the last frame. This helps us to get the vector for the direction of current velocity.

Steering Vector

Similar to the way we obtained the current velocity vector, we obtain the steering vector by joining the positional point coordinate of the individual with its positional point coordinate in the next frame. This helps us to get the vector for the direction of steering.

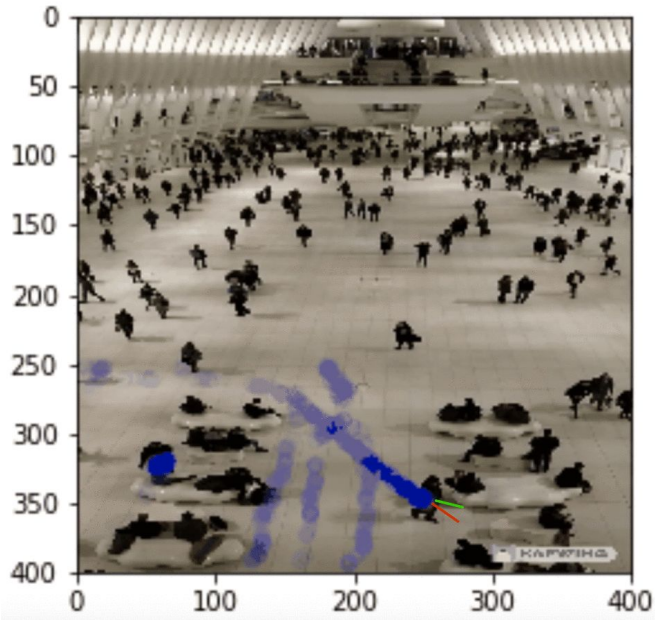

Fig.4. Current velocity vector (red) and steering vector (green)

CRAIG REYNOLDS STEERING BEHAVIORS IN HUMAN MOVEMENT

Seek and Flee

The seek steering behavior makes a human to change its direction of movement in order to steer himself towards a specified target position in the given environment. This behavior makes adjustments in the movement direction of the person so that its velocity is radially aligned towards the target. Analogous to seek steering behavior, flee steering behavior makes the person to steer away from the target. The evidence of seek steering behavior in an actual urban setting can be seen in movements where the person makes changes in its steering vector to reach the designated target.

Arrival

As the person approaches its designated target, it tends to slow down its velocity with increasing proximity to its target and eventually stops after reaching the target. This slowdown in the characters speed is known as the arrival steering behavior and can be seen in fig 5.

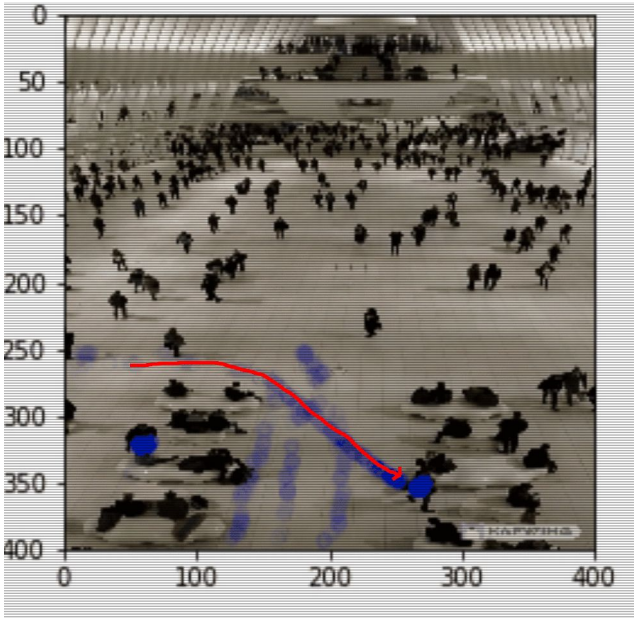

Fig.5. Arrival

Obstacle Avoidance

In any environment in order to meet the higher level goal plans, human tackles the local objects they encounter on their way. These objects can be stationary like bench, decoration, etc or moving like other humans. We as human smartly maneuver our movement to get around these objects and this steering behavior is known as obstacle avoidance which can be seen in fig 6.

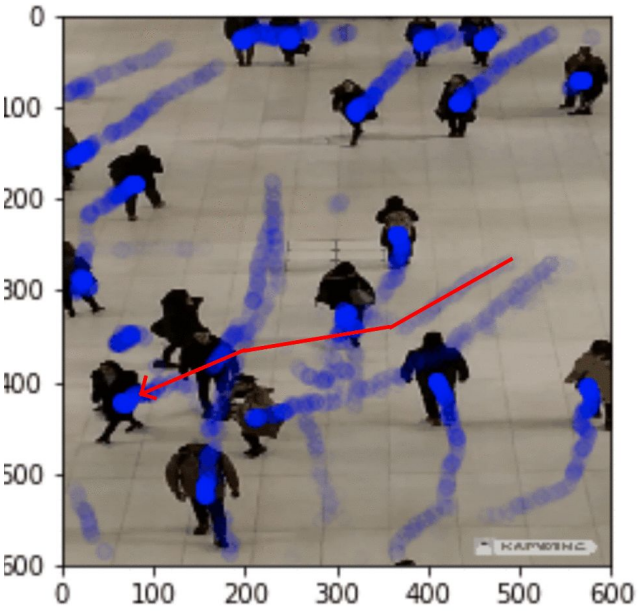

Fig.6. Obstacle avoidance

Path Following

The behavior which enables humans to steer along a predetermined path is known as path following. Often when people move through a hallway or corridor or any open place, in the same direction they subconciouslly follow same or parallel trails. This behavior does not neccessarily demand humans to move in a predefined lane yet we end up doing it. This steering behavior where humans follow others path or move parallel to each other is called path following and can be seen in fig.

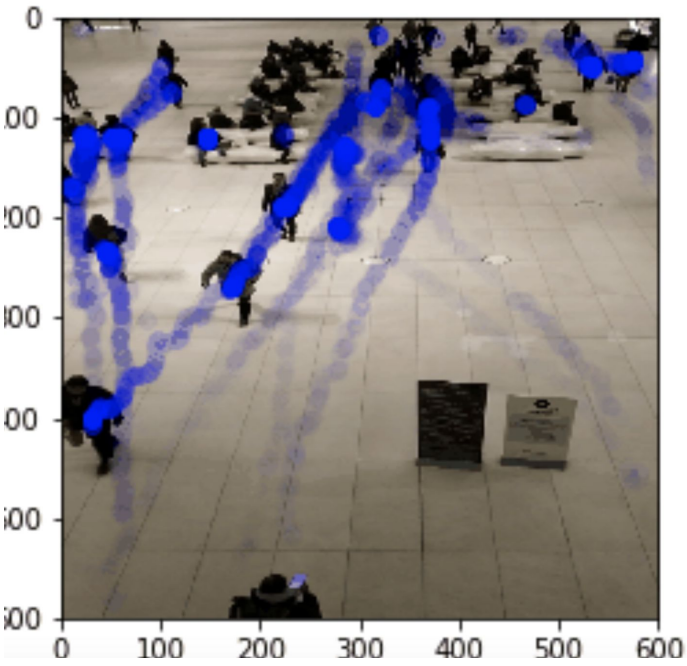

Fig.7.Path following and alignment (one/many persons behind the other)

Separation

When moving in a crowded place humans tend to maintain a certain separation in the form of a set distance from other humans moving near to them. This distance is maintained to avoid any unrequired collision in the environment. This steering behavior which enables human to keep them separated from each other is known as separation and can be seen in Fig.8.

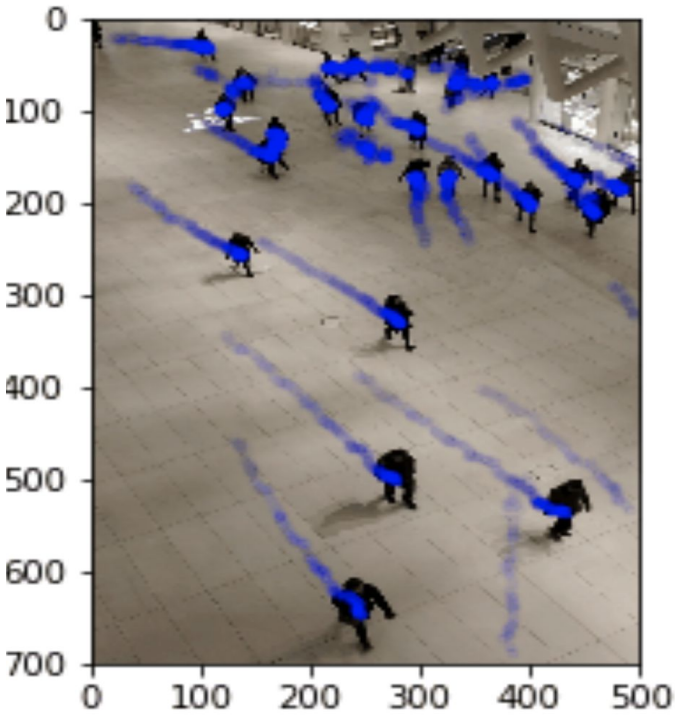

Fig.8.Separation (evidence of distance between two trails)

Cohesion

In public places when humans meet other known humans, they tend to approach them and make a group together. The steering behavior which provides the ability to humans to choere or approach and forms a group is known as Cohesion. Cohesion in an urban setting can be seen in moving groups

Alignment

When a group of humans moves in the same direction they often align themselves with other. This steering behavior which enables humans to sync their direction of movement with others is known as alignment. Alignment can be seen in Fig.7.

CONCLUSION

In this project we object to bring forward evidence of steering behaviors in human movement and understand how it pans out in an urban setting. We use video footage from the central hall (Oculus) where movement trails of a large number of people can be found. To do the study we detected humans in the footage, formed movement trails, current velocity vectors and the

steering vector. Using these elements of spatial analysis we found evidence of seek, arrival, obstacle avoidance, path following, separation, cohesion and alignment steering behaviors.

FUTURE WORK

Now that we have found evidences of Craig Reynolds steering behavior in human movement in urban setting, in the future work we will focus on simulating environments based on these steering behaviors. This simulation will be an attempt to find the most optimal arrangement of objects in any given urban environment.

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