Eye Tracking in a Digital Hanabi Game

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Abstract

Over the past few years, there has been accelerated development in the topic of artificial intelligence. Central to this area of computer science is the idea that AI agents will rapidly gain more intelligent, human-like, reasoning abilities as work in this field continues. With the advancement of technologies such as 3D motion sensors, gaze tracking devices, speech-recognition, and more, the world of digital game-play has also progressed rapidly in the last decade. However, there has yet to be significant research in applying these technologies to the AI's we create to play against or alongside humans- another field in which computer science has a long history. By integrating these two important aspects of computer science, we can get closer to simulating in an AI agent, the ability of reading a person's nonverbal cues such as body language; a tool of communication that humans use entirely subconsciously. To begin this integration, my project is to attach Tobii Eye-Tracking technology to an AI created to play the cooperative card game of Hanabi. With the gaze-tracking data, the AI will be able to make decisions based not only on game logic, but also on what cards a player is looking at, what parts of the game board is being focused on, and other nuances of the human-gaze during game-play. This experiment could potentially serve as a gateway into far more intelligent, and personal human-computer interactions, starting with a new species of game-playing artificial intelligence.

Introduction

Recognizing the intentions of other people through non-verbal communication is something often thought of as an inherently human trait. From facial expressions, body positioning, eye-movement, or other body language signals, most people use are able to observe and gain information about a situation based on these non-verbal cues [7]. However, as artificial intelligence quickly advances, and technology becomes increasingly commonplace in people's home and work spaces, we are beginning to see a shift in what is considered "human", and what computers and machines are capable of. While some research has been done on artificial intelligence agents that can read and interpret human body language, it still remains a relatively new and understudied are of computer science [9], although this feature of AI will no doubt be incredible relevant to many fields outside of computer science. With this project we are assembling preliminary research into how AI could access and utilize non-verbal communication techniques. To do so, we are implementing eye-tracking capability in a digital version of the cooperative card game, Hanabi. We will then implement an AI, created by Markus Eger to play a two-player version of Hanabi [4]. The AI will potentially be able to use the data about what cards a player is looking at, and when, to influence its knowledge of the game-state, and its decision making process on each turn.

Hanabi

Hanabi Hanabi (meaning "firework" in Japanese) is a cooperative game with 2-5 players, in which each player can see the cards of all other players, but not their own [2]. There are fifty cards in total, and each card has a rank and a color. There are five colors: red, green, blue, yellow, and white, and of each color there are:

- three cards with rank 1
- two cards with rank 2
- two cards with rank 3
- two cards with rank 4
- and one card with rank 5

The goal of the game is for the group to work together to build five sets, or "fireworks": one of each color, from one through five. With each correctly played card played being worth one point, the maximum score of the game is 25. On each person's turn they can choose to

- give a hint to the player of their choice about
  - all the cards of a certain rank in said players hand, or,
  - all the cards of a certain color in said players hand
- play a card, or
- discard a card

There are eight hint tokens, which are decremented and incremented throughout the game, and a 3 mistakes tokens, which are decremented each time a card is mistakenly played. A mistake is made when a player attempts to play a card, but it does not build off of any of the sets and is therefor moved to the discard pile.

The game is over once 3 mistakes have been made, or when all of the cards have been discarded or played. Discarding a card or correctly playing a five card? of any color wins you back a hint token. For a visual representation of Hanabi's rules, see [2] [1]. With each hint, and card played, players are able to get more information about the cards in their hand, and therefore make informed decisions about which cards to play or discard, and when [3].

Figure 1: Picture of the setup of a typical game of Hanabi (Source: Team Board Game).

Related Work

Artificial Intelligence for Hanabi

This project builds off of Markus Eger's Hanabi AI, which takes in to consideration how human's would go about playing Hanabi, and attempts to recreate that in the AI [4]. Humans communicate with intentionality, in conversation and in specific relation to Hanabi. This manifests itself in Hanabi as players hinting a certain trait about a card, with a specific goal for the other player in mind. For example, if player A hinted at player B's red cards, that most likely means that player A wants player B to do something specific (play, discard, keep in mind, etc.) with one of those red cards [4]. Eger is not the only person to create a Hanabi playing AI, although his is one of the only AI's that acts with intentionality. Eger's work is built heavily off of an AI built by Hirotaka Osawa [4] [6], which also uses a two-player version of the game.

Eye Tracking and Artificial Intelligence

Eye-tracking technology has advanced rapidly in the last few years, and a significant amount of research exists on the connection between player's gaze during game play and the decisions they make throughout the game. However, little notable research connecting eye-tracking data to any artificial intelligence agents has yet to be conducted. [7] houses a discussions of facial expressions and artificial intelligence, as well as human communication theory that could be applied to AI in future research. Some of the most interesting research that influenced this project was player's construction of mental models of a game throughout playing

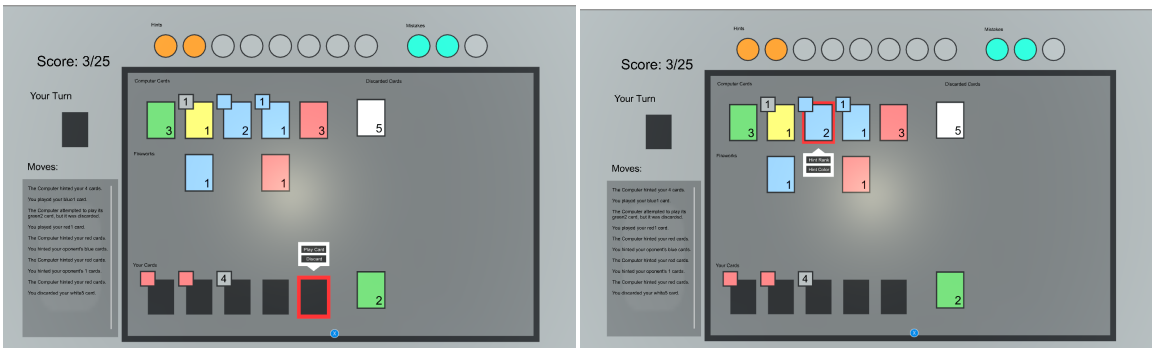
[1] https://drive.google.com/file/d/1vMiJdWU9vAniCzTTFS-uDan7cqstB6DE/view?usp=sharing

it, and how eye tracking can be used to study this creation [1]. There is also lots of work trying to deduce how eye movement occurs and related to behavior in everyday life [5]. This work is relevant to us because it gives us an idea of what we expect human gaze movement to look like in day-to-day settings, as compared to during game play.

Methods

The Hanabi AI created by Markus Eger was originally written in Python, and browser-hosted [4]. Creating an AI to play Hanabi can also be seen as a step towards intention recognition in artificial intelligence, as Hanabi is a cooperative game, and players must work together to create more complete knowledge of the game-state (i.e., the cards in their own hand) [6]. This means that the AI agent must act with intention or towards some goal. In this case, its goal is to correspond with human players through a restricted set of rules for communication [4] [6]. We believe that by collecting eye-tracking data from human players, we can inform the AI's ability to deduce player intentions [8]. For example, if a player is looking between two of the computer's cards, and then hints about one, it could be deduced that the card not hinted about also has valuable qualities relevant to the state of the game. However, at this stage in our experiment, we are merely hoping to find out how player's gaze moves and changes throughout a game.

In order to connect eye-tracking and Hanabi, we needed a digital 3D environment. We are using the Tobii4C eye-tracker, and since Tobii already has a Unity SDK [2], we decided to create a version of the game in Unity3D, using C#. Because of time-constraints, developing a Unity version of Hanabi has been the bulk of this project so far.



(a) Play Options

(b) Hint Options

Figure 2: The game mid-play

The User Interface (UI) we created consists of a deck of cards, player (face down) and computer (face up) hands, hint and mistake tokens, and a log of past moves. When a hint is given on a specific card, the hint box showing the hinted field appears on all cards in the specified hand with the corresponding color or rank. A hint token is also decremented at this time. When a card is played correctly, it moves to the appropriate firework set and the score is incremented by 1 point. When played mistakenly the card moves to the discard pile, and a mistake token then gets decremented. Finally, when a card is discarded, it moves to the discard

[2]https://developer.tobii.com/tobii-unity-sdk/

pile and a hint token is regained. After each player's turn, a short sentence describing the move appears in the moves log to the left of the game board. The small blue circle depicted close-up in Figure 3 is the position of the human players gaze at any given moment in the game.

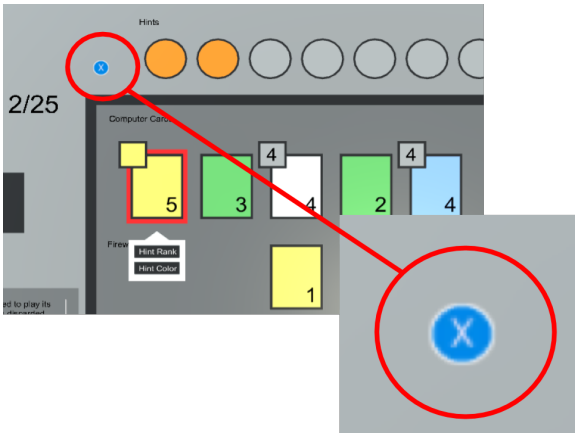
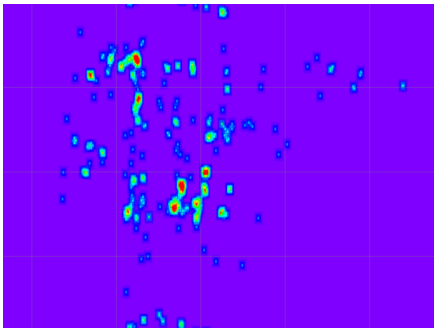


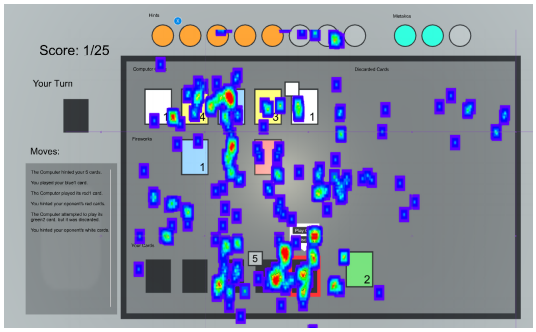
Figure 3: The screen position at which a player is looking at any given point during a game.

Results

After the game pieces and basic game logic were created, and the eye-tracking was implemented, we needed to develop a method for collecting a player's gaze movement throughout a game. We generated a "heat-map" system to keep track of this data. When the player presses the start button to begin the game, gaze points are recorded from the screen, and the corresponding pixels on a small blank image are incremented from blueish-purple, to red along an HSV Color scale. Points that get looked at more often appear red and yellow, while parts of the board that do not get looked at very often, or at all, stay within the purple/blue range. At the end of each game, the heat-map image is saved to a folder within the game.



(a) A picture of the eye-tracking heat-map



(b) The heat map overlayed with the game board it represents

Figure 4: A representation of the generated heat map, and what it corresponds to within the game.

From the heat map in figure 4 we can see that the player was looking at their hand, specifically the three rightmost cards, as well as the middle cards in the computer's hand. This would indicate that the player had relevant hints about the cards in the rightmost part of their hand, and/or that the computer had just give the player a hint. The appearance of a hint box on one of these cards would likely draw the player's eye, and increase the color of the surrounding area. The map also indicates that the computer has (or had) a playable card in the middle of their hand and the player was looking at it to determine whether to hint information about it to the computer.

Discussion

In general, the sort of data that we can glean from the heat-maps is vague, and players intentions can only really be guessed at. In the future, these maps could be paired with screen recordings of the games, as well as a time-stamped list of player actions to create a more complete understanding of how players gaze corresponds with decisions they make throughout the game [1].

Future Work

Moving forward, we plan to implement Markus Eger's AI into our Unity implementation of Hanabi. As of now, the computer follows a very basic set of instructions, such as playing the next card in a set if it appears in its hand, or hinting the same if it's in the player's hand. Our next step in respect to eye-tracking is to collect more eye tracking data from a broader range of people. This will require a more significant research plan, but we expect to find significant overlap when comparing this data with information about the player's decisions throughout the game. After more eye-tracking data collection and analysis, we would move towards integrating this information with the AI, and then performing tests to gauge how games score with the normal Ai compared to the AI with eye-tracking [4]. Another future path for the Hanabi project will be to provide more than two-player options, which would complicate the AI by giving it options about which player to give hints to. We believe this will make the game more enjoyable for human players; two-player games of Hanabi are often quick and play choices are sometimes limited. We also plan to update the UI by adding more appealing and intuitive designs for the card faces and backs, as well as for the hint and mistake tokens.

Implications for Other Fields

The information of where a player is looking during a game could be useful not only to AI's for Poker and other games that have components of nonverbal communication between players, but also for AI's in other fields. Enabling the AI to observe and make decisions based off of other players body language and subconscious actions will ultimately make game play more intricate and human-like [8] [7]. This trait of artificial intelligence also has many implications in other fields. AI's being able to interpret non-verbal communication brings a new element to artificial intelligence that has yet to be significantly researched. For area of study besides gaming, research in this area will bring a new level of personality and subtlety to human-computer interaction.

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