Man Versus Machine: Making Moves in the Game of Hex

Delainey Lindstrom-Humphries, Dr. Ryan Hayward, Emma McDonald, Elyse Hill, Arnoosh Golestanian and Noah Weninger

Department of Computing Science, University of Alberta

BACKGROUND

The Game of Hex

- Hex is a two-player strategy board game played on an 'n x n' rhombus shaped board[1] (Figure 1)
- Each player is assigned a colour and they alternate moves playing one piece at a time
- A player is able to place their game piece in any hexagon on the board as long as the hexagon is not already occupied by another piece
- In order to win a player must connect the two sides of the board that match the colour of their game piece before the other player is able to connect their two sides

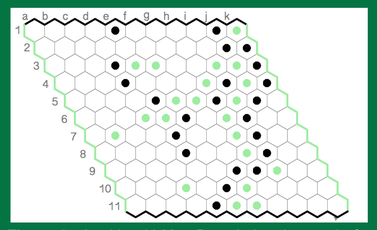

Figure 1: An 11 x 11 Hex Board showing a win for the player using the black coloured game piece

OBJECTIVES

Research Question

- How do humans choose moves in the game of Hex and how does this compare to the moves made by a computer

Research Purpose

- Gain a better understanding of how humans make decisions
- Determine how different aspects affect human decision making
- Analyze a random search algorithm used by a computer
- Compare the randomness of human and computer decision making

METHODS

Human Decisions

- To collect data about how humans make decisions in Hex I created and sent out an online survey[2] to test different decision-making strategies on a 5 x 5 Hex board
- The survey explored three main topics:
  1) intuition and random moves,
  2) moves versus thought through moves, and
  3) influence of prior knowledge
- For each topic the 65 respondents answered a series of questions by choosing what move they would make on the Hex board based off of the information given (Figure 2)

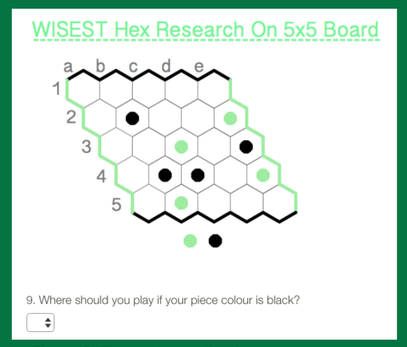

Figure 2: Example question from my survey

Computer Decisions

- Prior to testing I first wrote code that was able to:
  1) draw a Hex board,
  2) allow human moves,
  3) generate random moves, and
  4) prevent someone from playing in an already occupied spot (Figure 3)
- I then ran 150 trials in order to collect data on the most common first move made by the computer

```
    def selected(self,  x, y):
        for row in self.board:
            for hexagon in row:
                if hexagon.selected((x, y)) and not hexagon.clicked:
                    self.b.color("LightGreen")
                    self.b.shape("circle")
                    hexagon.stamp(self.moves)
                    self.moves += 1
                    self.get_cmove()
                    self.moves += 1


    def get_cmove(self):
        if self.moves < self.board_size**2:
            cnum1 = random.randint(0, (self.board_size - 1))
            cnum2 = random.randint(0, (self.board_size - 1))
            while self.board[cnum1][cnum2].clicked == True and self.moves < s
elf.board_size**2:
                cnum1 = random.randint(0, (self.board_size - 1))
                cnum2 = random.randint(0, (self.board_size - 1))
            cpos = self.board[cnum1][cnum2]
            self.b.goto(cpos.center_hexagon)
            cpos.clicked = True
            self.b.color("black")
            self.b.shape("circle")
            self.b.stamp()
```

Figure 3: Example of my code to allow human moves and random computer moves

Human versus Computer

- Once I had results from both the survey and computer trials I compared the data that related to choosing a first move in Hex

RESULTS

Human

- Through the survey I was able to collect a variety of results on human decision making in 5 x 5 Hex
- The most common first move made by humans with a varying knowledge of Hex was the middle of the board, c3. This move is proven to be one of the best first moves to start 5 x 5 Hex[3] (Figure 4)

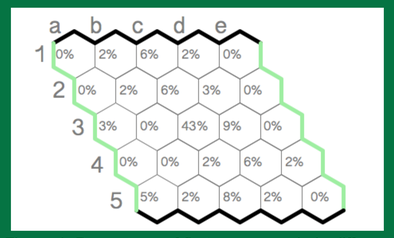

Figure 4: Percentage of first moves made in different positions on a 5 x 5 Hex board from survey results

- In the survey, when the respondents thought through a move more thoroughly, the correct answer percentage increased by 43% (Figure 5)
- When respondents had the opportunity to choose a move based on information they were given they choose a known good move 79% of the time
- When respondents were restricted from using the given strategy, respondents chose a similarly good move 64% of the time (Figure 6)

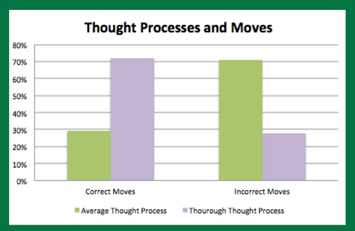

Figure 5: Graph comparing correct and incorrect moves using an average thought process versus a more thorough thought process from survey results

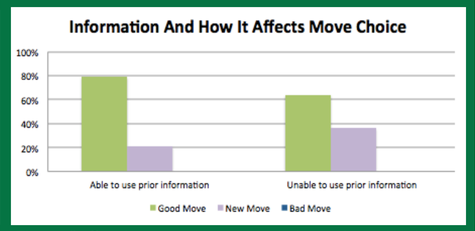

Figure 6: Graph comparing move choices when able to use prior information versus being unable to use prior information from survey results

Computers

- The random computer program trials found that the most common first move on my program was d3, with 8% of the first moves played there (Figure 7)
- From my computer trials, the average amount of first moves in each spot was 4%

Humans versus Computer

- Comparing the first moves made by humans versus the computer, 43% of the humans chose the same spot (c3) as their first move, this is in contrast to the random computer which resulted in the largest percent of moves made in the same spot (d3) to be 8% (Figure 8)
- The majority of moves made in row c were made by humans while the majority of moves made in the other rows were made by the computer

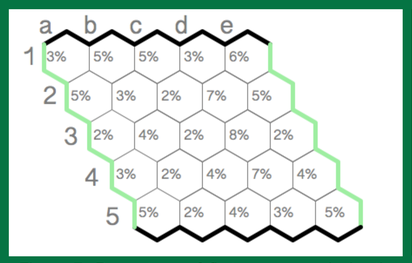

Figure 7: Percentage of first moves made by the computer on a 5 x 5 Hex board in different positions

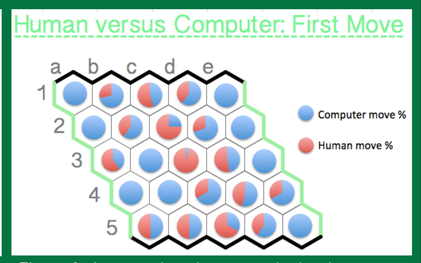

Figure 8: A comparison between whether humans or the computer made more first moves in different positions on a 5 x5 Hex board

CONCLUSION

Research Findings

- Humans tend to make better moves in Hex when they thoroughly think through the move
- Humans are able to apply known Hex strategies in different game situations
- The probability of my computer program to generate a certain move varies between positions on the board
- On a 5 x 5 Hex board, the most frequently selected spot for first moves made by humans surveyed was in row c, while spots in row d were most frequently selected by the random computer
- Even a seemingly random move made by a human in Hex has a purpose and background behind it, while my computer's random moves were based only on randomization between a set of guidelines defined in my code
- By giving my computer a set of instructions through code it is possible to have it play the game of Hex
- The moves my computer makes would be improved by implementing an intelligent search algorithm that allows it to make smarter moves similar to those made by humans in a game of Hex

ACKNOWLEDGEMENTS

I would like to thank the following people and organizations for their funding and support:

- WISEST
- Ms. Kowalchuk and Mr. Mahaffy
- University of Alberta Faculty of Science
- Canada Summer Jobs
- The Department of Computing Science at the University of Alberta
- My Principal Investigator Dr. Ryan Hayward
- My Lab Supervisors Emma McDonald, Elyse Hill, Arnoosh Golestanian and Noah Weninger
- My fellow WISEST students Alyssa Wong and Lexi Nash
- My lab mates from the HIP program

LITERATURE CITED

References

1. Gardner M. Hexaflexagons, Probability Paradoxes, and the Tower of Hanoi. Cambridge: Cambridge University Press; 2008
2. SurveyMonkey Inc. Palo Alto, California, USA. Available from : https://www.surveymonkey.com
3. Henderson P, Arneson, B, Hayward, R. Solving 8x8 Hex. Proc. IJCA-09. 2009: 505-510.