THEY KNOW: A PATHFINDING RATIONAL AGENT VIA KNOWLEDGE ACQUISITION MODELING FROM PLAYER BEHAVIOR AND ENHANCED A* ALGORITHM

Joshua Rei Aviles, Christopher John Hispano, Jaen Dave Lucas, Edwin M. Torralba :
Institute of Information and Computing Sciences, Department of Computer Science,
University of Santo Tomas, Manila, 1015, Philippines:
{joshuareiaviles, cjhispano, jaendave, edwinmtorralba}@gmail.com

ABSTRACT

Modern games have used Artificial Intelligence as a core element of game design and mechanics. Artificial Intelligence has thrived in many fields; however, the enhancement of pathfinding algorithms of AIs in games have remained stagnant. Moreover, numerous issues with regards to the exploitable plot of games have been raised by several gamers and game developers. The purpose of this research is to develop They Know - a survival themed thriller game with 4J MT-Adaptive A* - an adaptive and enhanced pathfinding algorithm created using A* as basis, to reduce the predictability of in-game agents by using the developed algorithm and by modifying agents with knowledge acquisition, to distinguish the personality and emotion of modern players based on the reaction of players to in-game situations, and to acquire data for determining the motivation of contemporary gamers for playing. The efficiency of the developed algorithm was compared with Lazy MT – Adaptive A* developed by Koenig (2007). Questionnaires developed by HEXACO, Power (2017), and Demetrovics (2011) were used as standards for acquiring data from the respondents to determine the respondents' personality, degree of predictability of the game, and the motivation of players in playing. Data were gathered from grades 11 and 12 students of the University of Santo Tomas – Senior High School.

KEYWORDS – 4J MT-Adaptive A*, Lazy MT-Adaptive A*, Knowledge Acquisition, Adaptive, Predictability

INTRODUCTION

"Do androids fantasize a life with robot maidens? Do they dream about electronic sheep?" – many minds have been plagued with questions regarding the extent of human capabilities of Intelligent Systems. Currently, video game players have been asking similar questions directed to NPCs – (1) "Do NPCs have feelings?", (2) "Can in-game Intelligent Systems develop personalities?", (3) "Do NPCs interact with the game as much as human players do?", and (4) "Can the characteristics of game Artificial Intelligence change and develop through interactions with players and the surrounding simulated environment?". Numerous advances with Artificial Intelligence have dominated the field of Information Technology and Computer Science; however, game AIs have remained underdeveloped, exploitable, and predictable. Contemporary game NPCs emit linear reactions and exhibit predictable routines that diminish the primary objective of Intelligent Systems which is to narrow the differences between humans and rational agents.

Since the evolution of games during 1970s, the game industry has dominated the market and perforated the individuality of people (Desjardins, 2017) [1]. The production of video games has physiologically and psychologically affected the growth of a person. For over 4 decades, an immense number of major advances have occurred in video games. From simple 2-dimensional graphics, games have adapted to 3-dimensional environmental design and are continuously progressing with the development of immersive graphical environment simulated through augmented reality technologies. As stated by Berman (2017), besides the simulation of game environment, a myriad of advancements has emerged through the game industry which include facial recognition, voice recognition, character gesture control, prodigious game graphics, high-definition screen displays, virtual reality consoles, augmented reality technologies, mobile gaming compatibilities, and games developed through cloud servers. Recent games such as *Hado*, made in Japan, have been making an extensive use of the current augmented reality technology by enhancing the location detection feature of games. Contemporary software programs for game development such as 3ds Max have been using normal mapping to provide characters and in-game objects with high-level definition for graphical details. According to Georgeson (2016), despite of the minor improvements of Artificial Intelligence in games, Non-Player Characters are still subject for development [2]. Although contemporary NPC designs have different

personalities, the characters display a static response to player actions and emit predictable routines which render the Non-Player Characters as lesser than a rational in- game agent.

This study intends to lessen the predictability of Non-Player Characters by managing the variance and environment of the game, directing player interaction, and developing an adaptive Intelligent System design for the game. The researchers will be developing *They Know* a survival themed game with an Intelligent System developed using 4J MT-Adaptive A* as the main moving target search algorithm with knowledge acquisition capability. The game will be developed using a 3-dimensional environment in order to narrow the gap between the game dimension and reality and maximize the gaming experience of prospective players. The amalgamation of the aforementioned algorithm combined with adaptive mechanism reduces the time complexity and increases the precision and unpredictability of the AIs of the game. Furthermore, this study intends to have a statistical description of - 1.) personality of players based on HEXACO dimensions of personality, 2.) the degree of unpredictability or uncertainty of the game, and 3.) the motivation of players in playing the game.

LITERATURE REVIEW

Comparison of Efficiency in Pathfinding Algorithms in Game Development

According to "Comparison of Efficiency in Pathfinding Algorithms in Game Development" written by Krishnaswamy (2009), the objective of the study is to assess the efficiency of three pathfinding algorithms, namely: A*, D*, and Dijkstra's algorithm [3]. The research was accomplished by tracking visitations made by a particular algorithm to a node in the search tree and examining the physical length of the traversable path in the game world. Based on the data garnered by the research, Krishnaswamy (2009) concluded that either D* or A* algorithms are the most efficient. The differences between the two algorithms are correlated to unobstructed space in the environment.

A* Pathfinding in Known and Unknown Mazes

According to a survey conducted by Zachariah (2015) entitled *A Survey on Optimal Path Finding Algorithms for Pursuing a Moving target,* the research authored by Koenig (2007) is currently the latest breakthrough with regards to moving target algorithms based on the A* algorithm [4]. the objective of the study is to examine how the agent can locate efficient paths by utilizing A* algorithm. The study is conducted by extending an incremental heuristic search method known as *Adaptive A** combined with the moving-target search algorithm to experimentally demonstrate that MT-Adaptive A* is more efficient than isolated A* searches and D* Lite.

Based on the data presented by Koenig (2007), which was obtained through the use of a Pentium D 3.0 GHz computer with 2 GigaByte Ram, the A* algorithm and variants of A* algorithms, such as the Lazy MT-Adaptive A* search, can always locate the appropriate path directing towards the moving- targets or goal states in both known and unknown mazes, unlike other pathfinding algorithms [5]. Therefore, the algorithm that will be used for comparison in this study is the Lazy MT-Adaptive A* Search.

Hexaco

According to Hill and Monica (2015), *The HEXACO model of personality and video game preferences* studied whether the HEXACO personality dimensions contradict with the preferences of gaming experience and how the association between the former and the latter is related to the aspects of game that gamers appreciate in general [6]. The HEXACO-60 was used in order to capture the basic dimension of personality of a participant. Hill and Monica (2015) further described the dimensions of HEXACO-60 as the following: (a) Emotionality – susceptible to negative emotions such as anxiety, (b) Honesty-Humility – exhibiting fairness and sincerity, (c) Agreeableness – friendly and cooperative, (d) Extraversion – sociable and exhibits dominance, (e) Openness to experience – imaginative, curious, and original, and (f) Conscientiousness – self-disciplined, reliable, and careful. The study aimed to establish a link between the basic personality of a person using the personality dimensions of HEXACO with the recent development of *BrainHex* which focuses on the personality dimensions of players developed by Nacke et al. The results of the research showed that the basic dimensions of personality, as shown in HEXACO, is indeed related with a person's gaming experience.

Motives for Online Gaming Questionnaire (MOGQ)

Majority of research focus on the risks of online gaming; however, the authors of the aforementioned study suggested that online games present new ways of satisfying the basic needs of a human living under the conditions of the modern society. The aim of the study was to reveal and was to reveal the motivational basis for gaming. The experimental stage of the research included 3818 persons recruited from various websites that host computer games. The method of research utilized was a combination of exploratory and confirmatory. Before conducting the study, the researchers developed a preliminary model and a questionnaire which illustrates the possible motivational factors for gaming. The results of the study identified the following motivational factors in playing a game – a.) social, b.) escape, c.) competition, d.) coping, e.) skill development, f.) fantasy, and g.) recreation. The seven dimensions of motivational basis for playing a game that resulted from the study covered the preliminary model created by the team; hence, MOGQ proved to be an adequate tool for measuring the motives of players in playing a game.

Measuring Uncertainty in Games

The study conducted by Power et. al. was based on various sources from games user research and digital archives. The method employed in the study was a combination of exploratory factor analysis and an established procedure for scale development by Paul Kline. The creation of the questionnaire started with a development of a question pool based on Greg Costikyan's sources of uncertainty, Pugh and Power's uncertainty questionnaire, and studies authored by Juul. In general, the refinement and validation process includes expert reviews, player interviews, and deploying the survey as an online questionnaire. The results of the study showed four factors as possible causes for uncertainty in games – 1.) disorientation, 2.) exploration, 3.) prospect, and 4.) randomness. The final output of the study is a validated tool for measuring the uncertainty of player in digital games.

METHODOLOGY

The approaches used in this research are experimental and statistical analysis methods. The researchers designed and developed a maze-survival game which focuses on the utilization of A* as the main algorithm for searching the location of and apprehending a moving target. The proposed design for the 4J MT-Adaptive A* Algorithm of the researchers was then compared to Koenig's Lazy MT-Adaptive A* by employing both algorithms as the AI design of the NPCs of the game. Based on the performance of the former and latter, the following were calculated and recorded to measure efficiency – (1) searches until target caught, (2) moves until target caught, (3) average expansions per search, and (4) runtime per search. Furthermore, inputs from respondents were also recorded to determine the personality type of respondents and the rate of the uncertainty of the game to justify the lessened predictability of NPCs in terms of the perspective of players.

In order to conclude the study, data were analyzed and interpreted using specific statistical analysis methods to determine survey questionnaire results and improvements in the performance of the researchers' 4J MT-Adaptive A* Algorithm compared to Koenig's Lazy MT-Adaptive A*. Moreover, a program developed using Python was used in order to apply statistical methods and evaluate the data gathered from the respondents of the study. The chosen population of the researchers for respondents are the Grade 11 and Grade 12 Students from the University of Santo Tomas – Senior High School. The target respondents of the researchers are at least 100 UST-SHS students. According to Bisits-Bullen (2014), many statisticians agree that a minimum sample size of 100 is required to produce a meaningful result in a survey [7].

After performing the comparison for the Lazy MT-Adaptive A* algorithm and the 4J MT-Adaptive A* algorithm, the researchers will conduct an Equal Variance or Independent T Test to determine if a significant difference in the comparison of algorithms exists. A significance level of 0.01 will be applied for all T Tests. The T Test will utilize the following formula:

$$t = \frac{\overline{X_1} - \overline{X_2}}{\sqrt{\left(\frac{(N_1 - 1)s_1^2 + (N_2 - 1)s_2^2}{N_1 + N_2 - 2}\right)\left(\frac{1}{N_1} + \frac{1}{N_2}\right)}}$$

N_1 = Number of items in the 1st sample set
N_2 = Number of items in the 2nd sample set
$\bar{X}_1$ = Mean of 1st sample set
$\bar{X}_2$ = Mean of 2nd sample set
s_1^2 = Variance of 1st sample set
s_2^2 = Variance of 2nd sample set

RESULTS AND DISCUSSION

Shown in Table 1 are the results of the comparison between the Lazy MT-Adaptive A* Algorithm by Koenig (2007) and the 4J MT-Adaptive A* Algorithm in the game environment averaged over 122 different scenarios. Both Algorithms were also compared when using a specific weapon type, 12 tests per weapon type were conducted. In each of the criteria, on average, the 4J MT-Adaptive A* algorithm displayed a better performance in locating and reaching the target player character, requiring less searches, expansions, moves, and run time than the Lazy MT-Adaptive A* algorithm. Overall, all criteria are significant at significance level 0.01.

Table 1. Comparison of Lazy MT-Adaptive A* and 4J MT-Adaptive A* Without Weapon

Algorithm	Average Searches until target is caught	Average Moves until target caught	Average Expansions per Search	Average run time per search (microseconds)
Lazy MT-Adaptive A*	16.54	50.43	471.59	1802.66
4J MT-Adaptive A*	14.37	41.84	375.43	1534.04
P-Value (α =0.01)	<0.00001	<0.00001	<0.00001	<0.00001

In the survey conducted with 103 respondents to determine the most prominent HEXACO personality category exhibited by UST-SHS students, Agreeableness was determined as the most prominent personality trait with 27 respondents aligned to this trait or 26.2% of the sample. Followed by: Emotionality with 21 respondents or 20.4%, Honesty-Humility with 19 respondents or 18.4%, Openness to Experience with 18 respondents or 17.5%, Extraversion with 14 respondents or 13.6% and Conscientiousness as the least prominent with 4 respondents or 3.9%.

In the survey conducted with 103 respondents to determine the most prominent motive for playing games exhibited by UST-SHS students, Recreation was determined as the most prominent motivation with 25 respondents aligned to this motive or 24.3% of the sample. Followed by: Competition with 19 respondents or 18.4%, Social with 15 respondents or 14.6%, Escape with 14 respondents or 13.6%, and Coping, Skill Development and Fantasy with 10 respondents each or 9.7%. As the most prominent motive for playing, Recreation is described as the motivation for playing games as a means for relaxation or leisure. Players who exhibit this motivation are more inclined to play games as a past time or hobby.

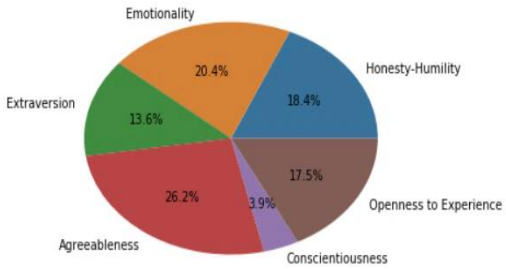

Figure 1. HEXACO Results

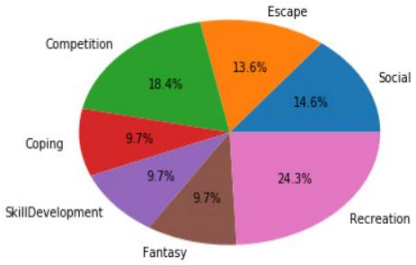

Figure 2. Motivation Questionnaire Results

In the survey conducted with 103 respondents to determine the Game Predictability of *They Know* using the questionnaire formulated by Power (2017), 44 respondents resulted with 70-79% unpredictability for the game.

Followed by: 60-69% with 17 respondents, 80-89% with 16 respondents, 90-100% with 8 respondents, 50-59% with 7 respondents, 40-49% with 5 respondents, 30-39% with 4 respondents, 20-29% with 1 respondent and 10-19% with 1 respondent.

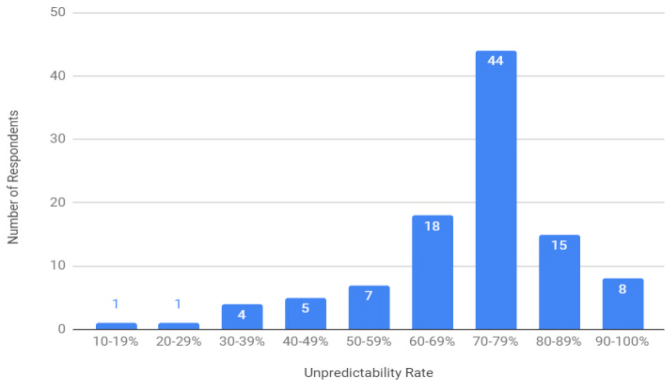

Figure 3. Game Predictability Results

Figure 4 shows the most common motive for playing for each HEXACO personality category. Agreeable player has recreation as the highest motive for playing a game while socializing as the least motive. Figure 5 shows the most common personality of players for each emotion. The data in the figure shows that the joy and sadness emotions are mostly detected from players with agreeableness personality and least detected from players with conscientiousness personality.

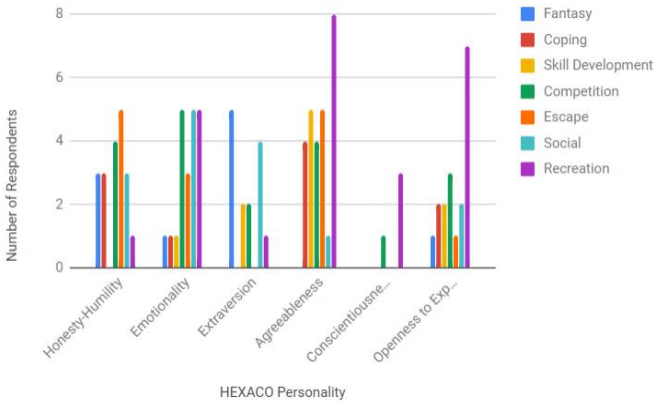

Figure 4. Personality Data with Motivation Data

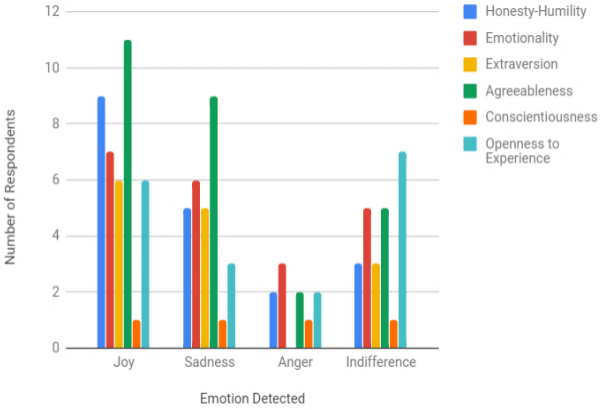

Figure 5. Emotion Data with Personality Data

CONCLUSIONS AND RECOMMENDATIONS

After conducting the study, the researchers were able to draw the following conclusions:

a) After evaluating the results provided by UST-Senior High School students from answering the Game Predictability questionnaires based on Power (2017), They Know earned a mean value of 70.33% in its unpredictability rate. Generally, the game is unpredictable to players.

b) The 4J MT-Adaptive A* algorithm is more efficient than the Lazy MT-Adaptive A* algorithm based on the criteria constructed by Koenig (2007).

c) Agreeableness is the most common HEXACO personality trait of UST-SHS students with a result of 27 respondents aligned to this trait or 26.2% of the total sample.

d) Recreation is the most common motive for playing of UST-SHS students with a result of 25 respondents displaying this motive or 24.3% of the total sample.

REFERENCES

[1] Desjardins, J. (2017, January 11). Infographic: The Evolution of the Video Games Market. Retrieved April 14, 2018, from http://www.visualcapitalist.com/history-video-games-market/

[2] Gerogeson, J., & Child, C. (2016). NPCS AS PEOPLE, TOO: THE EXTREME AI PERSONALITY ENGINE. University of London.

[3] Krishnaswamy, N. (2009). Comparison of Efficiency in Pathfinding Algorithms in Game Development. Technical Reports.

[4] Zachariah, R., Jadhav, R., Mishra, R., & Kishan, P. (2015). A Survey on Optimal Path Finding Techniques for Pursuing a Moving Target. IJLTEMAS,IV(II), 122-124. Retrieved April 14, 2018.

[5] Koenig, S., Likhachev, M., & Sun, X. (2007). Speeding up moving-target search. Proceedings of the 6th International Joint Conference on Autonomous Agents and Multiagent Systems - AAMAS 07. doi:10.1145/1329125.1329353

[6] Zeigler-Hill, V., & Monica, S. (2015). The HEXACO model of personality and video game preferences. Entertainment Computing,11, 21-26. doi:10.1016/j.entcom.2015.08.001

[7] Bisits-Bullen, P. (2014). How to choose a sample size (for the statistically challenged). Retrieved from http://www.tools4dev.org/resources/how-to-choose-a-sample-size/

ABOUT THE CONTRIBUTORS

Mr. Edwin M. Torralba is an instructor at University of Santo Tomas. He finished his degree in Bachelor of Technical Teacher Education major in Graphic Arts and Printing Technology at Technological University of the Philippines. Furthermore, he finished his masters in Educational Technology in Philippine Normal University – Manila.

Christopher John V. Hispano, Joshua Rei M. Aviles, and Jaen Dave R. Lucas are 4th year Bachelor of Science in Computer Science students who specializes in Game Development at University of Santo Tomas.