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ANALYZING THOUSAND YEARS OLD GAME TIGERS AND GOATS IS STILL ALIVE

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ABSTRACT

In this research, the concept of Game Refinement Theory is applied to quantify the entertainment value of the game of TIGERS AND GOATS. This paper explores the game to get some compelling estimates of Game Refinement (GR) value of the game at various stages. The comparison of value is done for the two popular variants of the game. Also, we have compared the value with respect to the difficulty level of the game and the winning scenario. The results indicate that the game becomes more of a serious game with the increasing difficulty. The paper focuses on one main question - Why did we lose one of the game variants while the other one is still well sought-after and if there is any history behind this? After doing some research, we found that the game variant AADU PULI ATTAM which has lost its popularity has much lower game refinement value than the popular variant (BAGH CHAL). With this, we also present the hypothesis on their timeline that BAGH CHAL is an evolved version of AADU PULI ATTAM.

Keywords: Aadu Puli Attam; Bagh Chal; Game Refinement Theory; History of Games; Tigers and Goats

INTRODUCTION

The history of games dates to the ancient human past (Georges, 1975). Games are an integral part of all cultures and are one of the oldest forms of human social interaction. Games are formalized expressions of play which allow people to go beyond immediate imagination and direct physical activity. Common features of games include uncertainty of outcome, agreed upon rules, competition, separate place and time, elements of fiction, elements of chance, prescribed goals and personal enjoyment. Games capture the ideas and worldviews of their cultures and pass them on to the future generation.

Moreover, games were important as cultural and social bonding events, as teaching tools and as markers of social status. As pastimes of royalty and the elite, some games became common features of court culture and were also given as gifts. Games such as Senet and the Mesoamerican ballgame were often imbued with mythic and ritual religious significance. Games like Gyan chauper and The Mansion of Happiness were used to teach spiritual and ethical lessons while Shatranj and Wéiqí (Go) were seen as a way to develop strategic thinking and mental skill by the political and military elite.

Dutch cultural historian Johan Huizinga (Huitzinga, 1944) argued that games were a primary condition of the generation of human cultures. Huizinga saw the playing of games as something that is older than culture, for culture, however inadequately defined, always presupposes human society, and animals have not waited for the man to teach them their playing. Huizinga saw games as a starting point for complex human activities such as language, law, war, philosophy, and art.

Hence it is interesting to know the evolutionary changes of old games which are still alive over the many centuries. One of such old games is TIGERS AND GOATS, a two-player

perfect information zero-sum game, which has been played on the same boards with almost the same rules for over thousands of years. However, if we consider the case of chess or any other games (Murray, 1913) (Georges, 1975), it is observed that games have gone through some major changes which affect its entertainment among people.

Little is known about the evolutionary changes of TIGERS AND GOATS from litterateurs. It is relatively simpler, i.e., a smaller size of the game tree when comparing with other complicated ones such as chess and Go. Then it was solved by computer analysis in 2009 while showing the game-theoretic value as the draw (Jin & Nievergelt, Tigers and Goats is a draw, 2009). Though it has been solved, yet that does not confirm why there have not been any significant changes made to the game.

However, a measure of game refinement can be employed to assess the degree of game sophistication. From the early studies using game refinement measure it is supposed that the history of chess variants may be divided into the three stages: the origin with moderate complexity and refinement, many diverging variants with high complexity and low refinement, and the modern sophisticated chess with low complexity and high refinement (Cincotti, H. Iida, & Yoshimura, 2007) (Iida, Takeshita, & Yoshimura, A metric for entertainment of boardgames: its implication for evolution of chess variants, 2003).

With the above background knowledge, we give our hypothesis for this study.

Hypothesis 1: TIGERS AND GOATS was originally designed with educational purpose. Tigers' side would learn skills to hunt goats, whereas goats' side would learn skills to keep goats from tigers. The rules were successfully designed to maintain a balance between educational and entertaining aspects. Therefore, it has been played on the same boards with almost the same rules for thousands of years.

This paper investigates important characteristics of TIGERS AND GOATS to prove Hypothesis 1. It compares the two major variants to find out why one is still popular whereas the other is losing its popularity in the region. It then shows some interesting variations regarding available valid moves during a goat win and a tiger win while telling why it is always interesting to play as a tiger.

TIGERS AND GOATS AND ITS VARIANTS

In this section, a historical overview of TIGERS AND GOATS and its variants is presented. Then the mathematical aspects of the game are defined. Furthermore, we have given the board description and then the rules of TIGERS AND GOATS.

A BRIEF SKETCH OF HISTORICAL OVERVIEW

TIGERS AND GOATS is said to be a thousand years old game. Some sources say that the game originated in the Himalayas, and others that it came from further south in India, where similar games have been played for centuries. Whatever its antiquity, the game is still popular today, with traditional brass sets with cast pieces still being made and sold across the world by Nepali craftsmen (Baghchal, 2018). Nepali tradition says that the game was created by Mandodari, daughter of Mayasura, King of the Asuras, and Hema, apsara water nymph. Mandodari (“soft-bellied”) is Queen consort of Ravana, King of Lanka, according to the Hindu epic Ramayana, and belongs to the Panchakanya, a group of five maidens the recital of whose names is believed to dispel sin. (The Ramayana is an ancient Indian epic, composed sometime in the 5th century BCE).

The other names that it is known by are AADU PULI ATTAM in Tamil, PULI-MEKA in Telugu, ADU-HULI in Kannada and BAGH-CHAL in Nepali, is a traditional board game of India and Nepal which is a kind of a disproportionate-strategy game. TIGERS AND GOATS

and its many variants had existed right from the time of great Empires. History has pointed to several pieces of evidence of this game being played in ancient temples across South India. The excavation by Archaeological Survey of India (ASI), Chennai, threw up evidence of how the natives influenced the Dutch inhabitants of the fort. For one, the local Tamils taught the Dutch how to play AADU-PULI AATTAM; the grid used to play the game, comprising rectangles and triangles, was found engraved on a well-burnt brick (Raji, 2018).

MATHEMATICAL ASPECT

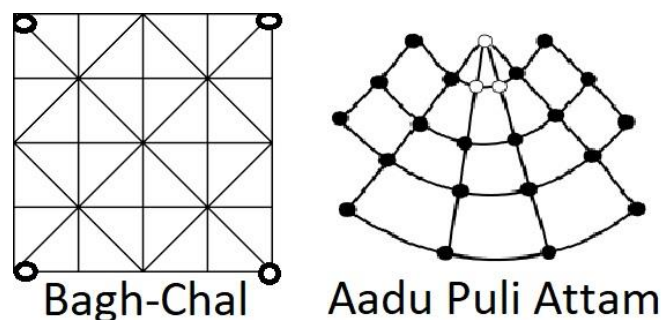
From the mathematical point of view (Shoham & Leyton-Brown, 2010) (Leyton-Brown & Shoham, 2008), BAGH-CHAL is a bipersonal (it involves two players), finite (regarding the number of available strategies or choices), dynamic (players do not simultaneously decide their strategies), sequential (players alternate turns), non-cooperative (players compete and cannot win or lose together), zero-sum, complete and perfect information game. According to Ballesteros (Ballesteros, 2005), whose classification is based on the game objective and the type of strategy employed to pursue it, BAGH-CHAL belongs to the family of tafl games, since it involves two unequal opposing forces which try to capture the other player's pieces. Other authors (Gutiérrez-Perera, 2014), considering the symbolic aspects, classify it as a hunting game since it involves a confrontation between animal predators and prey, which is idiosyncratic of the game's cultural context. The two forces have "different objectives and even different movement rules": specifically, prey cannot capture, a distinctive factor in contrast to war games, in which both forces can capture the opponent's pieces.

BOARD DESCRIPTION OF THE VARIANTS

AADU PULI ATTAM is a strategic, two-player (or 2 teams) tiger hunt game that is played in south India. The game is asymmetric because one player controls three tigers and the other player controls up to 15 goats. The Tigers 'hunt' the goats while the goats attempt to block the tigers' movements.

BAGH-CHAL is also asymmetric because one player controls four tigers and the other player controls up to 20 goats. It is played mainly in Nepal. This game is popular in current times.

TIGERS AND GOATS is played on a flat surface with two sets of pieces, one signifying a tiger and another that signifies goats. TIGERS AND GOATS on the board have different properties during gameplay. Both the players play once as a goat and once as a tiger. The player with the maximum win is declared the winner. The boards of both the variants are given in Figure 1. Note that the rules for both the variants are the same.



Note: The white circle in the board represents the initial positions of tiger

FIGURE 1. TIGERS AND GOATS variants using different boards: BAGH-CHAL (left) and AADU PULI ATTAM (right)

RULES OF TIGERS AND GOATS

Goats sides

Objective: The goats have to corner all the tigers on the board.

1. You have to place the goats on the board individually at the beginning.
2. You can move the goats only after you place all the goats on the board.
3. The goats can only move along the lines of the board and must be placed in the intersections.
4. You can only make the same move back and forth three times in a row.
5. A goat cannot be captured if there is no empty intersection for the tiger to jump.

Tigers sides

Objective: The Tigers have to swallow a given number of goats.

1. All the tigers are present on the board right from the beginning.
2. You can move only one tiger with each turn.
3. The Tigers can only move along the lines of the board to the next intersection.
4. You can only make the same move back and forth three times in a row.
5. Tigers cannot leap over two or more goats along a connected line.

EDUCATIONAL SIGNIFICANCE

An educational environment organized around games stimulates positive attitudes towards learning among students and facilitates cognitive achievement, as revealed by conceptions of future teachers in training. We can assume that strategy games may offer comparable benefits. Two fundamental processes take place in these games: 1) mental construction of the game tree, in which players use short-term memory, visuospatial skills, logical relations, heuristic strategies, analogy, and modelling; 2) best-next-move selection, where players use pattern recognition, logical relations, long-term memory, goal-based decisions, option evaluation, and decision making (Gutiérrez-Perera, 2014).

We quote the words from Melo and Hernández (Melo & Hernández, 2014).

“Recognition of play as an essential function of human knowledge evolution and development, and therefore of education, is fundamental, as to establishing its true pedagogical value and recognizing its merits in every dimension of the individual development.”

The placement phase involves a search whose game-tree complexity is estimated to be of the order 10^{41} . Ignoring symmetric variants, the number of possible positions during the placement phase is 6,633,059,000, while during the movement phase, it is 88,260,972 (Jin & Nievergelt, Computing Tigers and Goats, 2004). Size and structure of the state space significantly delayed the game’s computational analysis, even though it was finally determined that when played optimally on both sides BAGH-CHAL ends in a draw (Jin & Nievergelt, 2009).

STEM aspects of interest:

With this Playful Projects, educators can work on the following STEM aspects with students:

1. Move tree: subset graph of the extensive
2. Abstract codification systems: to annotate game development representing moves in a coded record of the game
3. tree nodes actually traversed.
4. Argumentation.
5. Deductive reasoning.

6. Spatial thinking: i. Orientation: localization and description of moves in a plane, cardinal points, technological tools (compass or GPS). ii. Representation: Cartesian axes and coordinates, floor plan, relation to maps and scales.
7. Predation: biological interaction in ecosystems. Predators and prey. Food chain and trophic levels.
8. Predator-prey mathematical model: Lotka-Volterra's equations.

ASSESSMENT METHODOLOGY

DATA COLLECTION

The methodology used to collect the Game Data is the combination of Survey and Game AI. We study the game from the historical perspective to understand the important elements of the game and why there are not any significant changes yet. We believe that the better way to do so is by a human survey so that we can induce the human factor in it and can understand the game better. Even though it is time-consuming, it gives the real insights into the gameplay. Games have always been played among humans to boost intelligence. Thus, it was only fair to take the human statistics rather than AI against itself. This way we could study it from novice to expert view and in some cases, the transition from easy to advanced player. We collected the data from the gameplay of 153 people for easy level and 127 for medium level. From our study, we also found that it is hard for people to reach the advanced level in most cases and defeat the AI. The number of people who played advanced level was relatively less, i.e., 76. To study the transition of players from novice to expert, we let them play the game for a period of 3 months. Out of 153 people, 120 could reach the medium level of play and only 47 could reach to advanced level. Other 29 people were already familiar with the game and had attained expertise in the game

GAME REFINEMENT MEASURE

Earlier works on game refinement theory resulted in the development of a logistic model of game outcome uncertainty based on the principle of seesaw games (Iida, Takeshita, & Yoshimura, A metric for entertainment of boardgames: its implication for evolution of chess variants, 2003) (Iida, Takahara, Nagashima, Kajihara, & Hashimoto, 2004). Further studies resulted in a mathematical model based on the game information progress for continuous movement games such as scoring sports (Sutiono, Purwarianti, & Iida, A mathematical model of game refinement, 2014) (Nossal & Iida, 2014). The second derivative, which is the acceleration in the sense of dynamics, is derived from the game information progress model to determine the game refinement measure.

The measure of game refinement (GR) for board games (Iida, Takahara, Nagashima, Kajihara, & Hashimoto, 2004) is given by Eq. (1).

$$GR = \frac{\sqrt{B}}{D} \quad , \quad (1)$$

where B and D stand for the average possible moves in a position and game length respectively.

Possible interpretation of game refinement (GR) measure was discussed in (Xiong, Zuo, & Iida, 2017). The game refinement theory was extended into force-in-mind (Iida, 2018). It clearly shows the reason why the zone value of game refinement (say 0.07 to 0.08) would enable people to feel the gamified experience. We show from (Iida, Takahara, Nagashima, Kajihara, & Hashimoto, 2004), in Table 1, game refinement (GR) measures for popular board games. We can find that the most popular board games have the GR values of 0.07-0.08. Thus, we identify it as the zone value where the games are the most interesting.

Also, games like Chess have been refined over the years and it now falls into the zone value of Game Refinement.

TABLE 1. Measures of game refinement for several board games

Game	B	D	GR
Chess	35	80	0.074
Chinese chess	38	95	0.065
Shogi	80	115	0.078
Go	250	208	0.076

COMPUTER ANALYSIS OF TIGERS AND GOATS

From the work done by Lim Yew Jin and Jurg Nievergelt (Jin & Nievergelt, Tigers and Goats is a draw, 2009).

We take some statistics such as average game length to determine the game refinement measure since it gives more optimal length. We take the average game length (D) as 39 from the computer analysis of TIGERS AND GOATS.

GAME INFORMATICAL ANALYSIS

First, we show the idea of Game Refinement Theory proposed by Iida et al (Takeuchi, Ramadan, Ayu, & Iida, 2014). This theory concerns optimization from a viewpoint of the game designer. Generally, the game attractiveness is evaluated based on user's performance by using a survey or questionnaire. While the game refinement theory shows a particular way to quantify the attractiveness by providing the common measurement — game refinement value, which is derived from a model of 'game progress'. The 'game progress' is twofold, which are known as game speed or scoring rate, and another one is game information progress with a focus on the game outcome. In sports games and video games, game speed has two factors: (1) goal and (2) time or steps to archive the goal. Game information progress represents how certain is the result of the game in a certain time or steps. If the outcome is more uncertain, the game will be more interesting. The game refinement theory has been applied in some well-known games in order to measure refinement values of the games under consideration. The refinement values of those games fall into the range from 0.07 to 0.08 (Sutiono, et al., 2015).

We have studied the game from expert to novice view. Since the game is not known much outside of the Indian subcontinent, the game does not have a big user base such as Chess or Shogi. We have manually collected the data from the people who play this game on all the levels: novice, medium, and expert.

We show, in Figure 2, the number of possible moves in each position during the game progress of an example game. The X-axis represents the turns in the game whereas the Y-axis represents valid moves available at each turn.

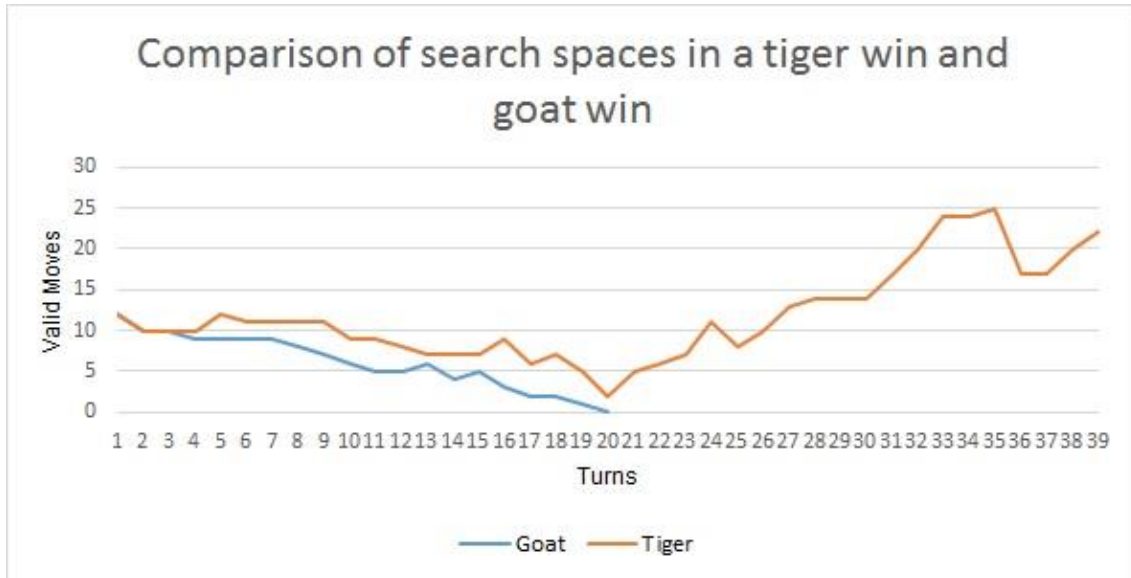


FIGURE 2. The number of possible moves in each position during the game progress

Remark 1:

TIGERS AND GOATS proceed in two phases: Placement Phase and Movement phase. The goats must try to advance in unison in order to trap the tigers. For the Tigers, two fundamental goals at any moment are looking for scissor-like moves and keeping as scattered on the board as possible, thus threatening more space for plausible captures and trying to avoid being blocked all at once.

Conjecture 1:

The game analysis indicates that if the game is processing in the win for goat, the number of possible moves gradually decreases. However, if the tiger is to win, the number of possible moves increases after a gradual decrease.

We computed the game refinement measure of the games when the goat wins and when the tiger wins. From our calculation, we found out that the game refinement value in the games where goat wins is slightly lower than the case where tiger wins.

TABLE 2. Measures of game refinement for Goat-win and Tiger-win

	B	D	GR
Goat win	6.1	40	0.0617
Tiger win	10.40	39	0.0827

To learn more about the game, we have studied the game of BAGH-CHAL at different levels ranging from Easy to Advanced.

TABLE 3. Measures of game refinement for BAGH-CHAL with focus on three different levels

Level	B	D	GR
Easy	10.442	40	0.081
Medium	7.884	39	0.072
Advanced	9.299	60	0.051

The following graph (Figure 3) shows compelling data representing the table above (Table 4).

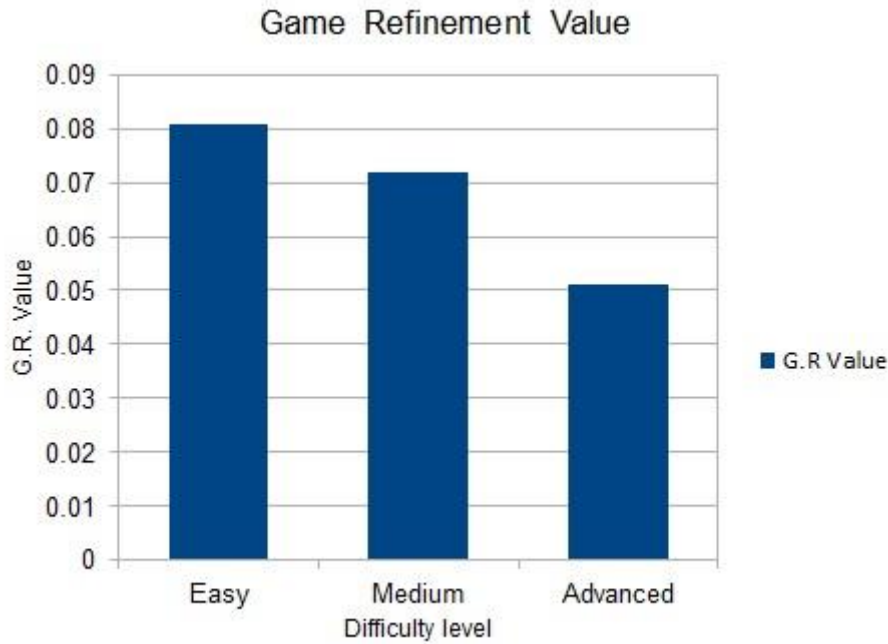


FIGURE 3. Estimate of Game Refinement Value at Different levels

It is interesting to observe how the slope decreases with the increasing difficulty. It indicates that as the level increases, the game becomes much of an educational game than just an entertainment game.

The game refinement value for the two popular game variants are in Table 4 below:

TABLE 4. Measures of game refinement for BAGH-CHAL (Nepal) and AADU PULI ATTAM (India)

Variant (Country)	B	D	GR
BAGH-CHAL (Nepal)	8.56	39	0.075
AADU PULI ATTAM (India)	3.14	50	0.035

It is riveting how the same game works in two different boards. The lower game refinement value signifies why AADU PULI ATTAM has just remained a game of the past and have lost its popularity. On the other hand, BAGH CHAL is still popular in most of Nepal and has been a great source of entertainment till date.

TIGERS AND GOATS AND PLAYER'S LEVEL

If the player is a medium level player of BAGH-CHAL then:

1. Tiger can force the capture of a single goat within 39 plies, i.e., in the placement phase.
2. Tiger can force to capture two goats within 40 plies but not earlier, i.e, by the end of the placement phase, but not earlier.

Whereas, in AADU PULI ATTAM, a tiger can capture a single goat in no less than 30 plies, i.e., in the placement phase.

If the player is novice level player, then it is easier for the player to win as a tiger.

EVOLUTION HYPOTHESIS OF THE GAME VARIANTS

Since there is not enough data available to prove the origin of the game. However, using game refinement theory, Iida et. al studied the evolutionary history of Chess. The GR value of chess has varied majorly through the years. The oldest variant of Chess called Chaturanga which was invented in the 4th century A.D. has the game refinement value of 0.024. Shatranj which was invented in the 6th century A.D. has the GR value of 0.0196. Chess in 16th century A.D. has the GR value of 0.0519. Currently, Chess has the GR value of 0.0739 (Iida, Takeshita, & Yoshimura, 2003). We can clearly see that the reason why chess is still popular is that of the changes in GR value. All the previous versions are lost in its history while the one in the GR-zone is much played.

Similarly, we can also predict the timeline of the game of TIGERS AND GOATS. AADU PULI ATTAM was invented before and BAGH-CHAL is the refined version of AADU PULI ATTAM.

Remark 2:

TIGERS AND GOATS has two well-known variants: AADU PULI ATTAM and BAGH-CHAL, as shown in Figure 1. Although we do not know which was invented earlier, it is found that BAGH-CHAL is still popular whereas AADU PULI ATTAM is losing its popularity in the region.

Conjecture 2:

The Game Informatical analysis indicates that AADU PULI ATTAM was born first, which was later refined as BAGH-CHAL.

CONCLUDING REMARKS

In this study, we have analyzed the game of TIGERS AND GOATS by using the game refinement theory as an assessment method. This theory shows the particular way to measure the attractiveness of the game under consideration. First, we have studied the most popular variant called BAGH-CHAL thoroughly. Initially, we compared the game refinement value of the games where goat and tiger are the winners, respectively. Results stated that if the game is processing in the win for goat, the moves gradually decreases. However, if the tiger is to win, the valid moves increases after a gradual decrease. Also, that the game refinement value in the games where goat wins is slightly lower than the game refinement value in the games where tiger wins. According to the difference in GR values between two kinds of games, the results show that the Tiger wins are more attractive rather than the Goat Wins. Further, we calculated the game refinement value at various levels of difficulty of the game. The slope of the game refinement value decreases drastically with increasing levels. This signifies that the game, in the beginning, is much more attractive than in the difficult levels. It becomes a serious and educational game as the difficulty of the game increases.

It also provides a hypothesis that the game variant has been evolved from AADU PULI ATTAM which had much lower GR value. The mythological story of Mandodari supports this hypothesis as well. Since, the game is said to be created by her, although the variant is unknown. We believe, it is Aadu Puli Attam as Mandodari was married to the King of Lanka, now Sri Lanka, which is much closer to South India than Nepal.

Finally, we compared two main variants of the game called BAGH-CHAL and AADU PULI ATTAM to find out why one variant is popular whereas the other is losing its popularity in the region. It was intriguing that the game refinement value for AADU PULI ATTAM is much lower as compared to BAGH-CHAL and average game ply value is much larger. This is

because AADU PULI ATTAM does not have any diagonals on the board which leads to some not-so-meaningful moves. On the other side, the design of BAGH-CHAL board consists of a lot of diagonals which allows the game to process at a faster speed keeping the player engaged.

Our future works focus on the application of the game refinement theory in various types of games to find the GR value of other lost games and their popular variations. In case we find some pattern, we hope to find the factor in the game which has much to do with the attractiveness such that we can revive the games. We will also use Game Refinement Theory to predict the evolution of games and theories.

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