Imarisha: Reinforcement Learning Toolkit For AfricanBoard Games

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***Abstract*—Popular board games go, shogi and chess, offer challenging test beds for research in planning and learning in reinforcement learning. However these environments are complex . The number of possible positions in a game of GO ranges from $10^{(}10^{48})$ to $10^{(5.310^{170})}$. Similarly the number of positions in a game of chess ranges from 10^{43} to 10^{50}. With the current state of the art Algorithms, a massive amount of compute is needed to get robust performance in these environments. The Imarisha learning suite provides a set of diverse, two player learning board game environments that vary widely in complexity. This games majorly from the African cultures provides us with a rich variety of complexity, from Ajua to FANORONA. The learning suite offers environments of increasing complexity for RL research. Researchers can use the environments provided as stepping stones when testing the scalability and efficiency of their algorithms on harder and harder problems**

***Index Terms*—Reinforcement Learning(RL), Board-games, Games.**

I. Introduction

Adding variety to the exciting class of strategy board games is key to improving diversification of Reinforcement learning strategy and scenarios. African board games provides this rich diversity of challenges but are not yet explored

When one imagines African board games, a number of things come to mind. There is of course the setting and the rules, as well as the number of players that can participate in one game. African board games were used to teach in ancient African customs and societies. They were popularized by the fact that many Africans at the time had little engagement with co-curricular activities and the fact that women performed most household duties. Many cultures in the African setting have however abandoned important facets of their social lives, especially such as ancient African games that were important to the community in teaching strategy, collaboration, problem-solving, communication and experimentation. In this age of electronic gaming, it is important for African games to retain their value and importance as has been the case with contemporary western games such Chess, Pool and monopoly. This paper focuses on the use of Reinforcement Learning to promote common African board games that seem to be waning in popularity in the millennial generation.

A. RL on African Board Games

Reinforcement Learning (RL) is a concept in machine learning that focuses on the understanding of an environment (mostly physical) and how best to utilize software to gain maximum rewards from the utilization of such an environment. RL is most concerned with the maximization of gain and the utilization of resources to the best of one's ability while in an automated environment [1]. In order to apply the concept to gaming, it is important to understand how best a game is played, as well as the different advantages that can be gained from utilizing alternative patterns. It is important for games to achieve the most possible virtual reality experience in order to enjoy a game. For a researcher, the issue is to generate as many possible scenarios as can be done so as to ensure that while the gamer is able to achieve several milestones, they do meet significant obstacles that would then ensure that they engage their reasoning to the best of their abilities. Above all, it is important for the game to include an aspect of learnability that the player can achieve after some time. Aspects such as predictability, dynamism and logic are critical in a RL environment. The Markov Decision process is a common structure used to design the logic of most games. In the African gaming setting for instance, it is common to have different scenarios that may be known to expert players but unknown to junior or amateur players. The decision trees designed by this algorithm take into consideration all the different aspects of play, and how they collectively contribute to the learning process anticipated by the game developers [2]. It is also a gauge on how best one can exercise their intellectual abilities such as recall and also, the consideration of the multiple sets of combination that can be attempted by an opponent in a play. Reinforcement learning techniques that exist in the market, take advantage of three main methodologies. These include; Deep Reinforcement Learning, Inverse Reinforcement Learning and Apprenticeship Learning [3]. Deep reinforcement learning is the use of deep neural networks without explicitly designing the state space. ATARI games by Google's DeepMind takes into consideration this approach, which is also referred to as end to end reinforcement [4] Inverse reinforcement does not include a reward function. Instead, the expert needs to infer this function from observation of behavior. The general goal is to mimic this observed behavior, while developing the optimal solution, which is close to the observed phenomenon [5]. In apprenticeship learning, the concern is to ensure that an expert demonstrates the target behavior. Not only does the expert observe common behavior, they develop their own versions that can be considered target behavior as well. The system then tries to recover this policy by observation. Apprenticeship learning is common in many adventure games, where the options outweigh the final intention by far [6] Several algorithms are also used for control learning. In the criterion for optimality algorithm, the algorithm must find a policy with maximum expected return. From the theory of MDPs it is known that, without loss of generality, the search can be restricted to the set of so-called stationary policies. A policy is stationary if the action-distribution returned by it depends only on the last state visited (from the observation agent's history). The search can be further restricted to deterministic stationary policies. A deterministic stationary policy deterministically selects actions based on the current state. Since any such policy can be identified with a mapping from the set of states to the set of actions, these policies can be identified with such mappings with no loss of generality [4].

II. Games and Rules

The Imarisha learning suite will focus several traditional African games. These include; senet, fanorona, doki, ajua, tsoro yematatu, gulugufe, and ajua.

A. Ajua

The Ajua game focuses on a ‘count and capture’ strategy. It is one of the oldest board games in Africa. Bao is based on a mancala board comprising four rows of eight pits each—in Swahili, pits are termed mashimo (singular: shimo), meaning ”holes”. Each player owns a half of the board comprising two adjacent rows. Some pits that play a special role in the game have specific names. The fourth rightmost pit in the ”inner” row of each half board is called nyumba (”house”) or kuu (”main”); in most traditional boards, it is visually distinguished by a square shape. The first and last pit of the inner row are called kichwa (”head”), while the name kimbi applies to both the kichwa and the pits adjacent to them. Every player has 32 undifferentiated counters (or ”seeds” according to the standard mancala terminology) that are termed kete (”shells”). Note that a similar equipment (a 4x8 board and 64 seeds) is shared by a number of other African mancalas, including Omweso (Uganda) and Isolo (Tanzania). When a capture occurs, the player takes all the seed from the captured opponent's pit, and relay sows them in his or her rows. The first seed must be sown in a kichwa; if it is sown in the right kichwa, sowing will proceed counterclockwise, while if it is sown in the left kichwa, sowing will be clockwise. For this reason, the right kichwa is also called ”counterclockwise kichwa” and the left one ”clockwise kichwa” [7]. The choice of the kichwa to sow from is initially left to the player, with a few exceptions. If capture has occurred in any kimbi, sowing must start from the closest kichwa. There are over 200 different versions of the game, in Africa, with each board accommodating two players at a time.

B. Gulugufe

This game is mostly common in the South African subcontinent. It has its roots in Mozambique. It is a strategy board game, where the intention is to capture all the pieces on the opponent's side. The goal is to capture all of the opponent's pieces, or be the one with more pieces when no more pieces can be taken by either player, or, stalemate the other opponent's pieces such that they are immobilized [8]. There are a total of 19 intersection points for the pieces to be played upon. Each player has nine pieces. One player plays dark, and the other player plays light, however, any two colours will suffice. The centre position is kept empty at the start of the Gulugufe game. Pieces are captured by hopping over them. A piece moves one space per turn onto a vacant intersection point following the pattern on the board. Captures are done by the short leap as in Draughts and Alquerque, where the adjacent enemy piece is hopped over onto a vacant point on the other side. The captures must be done in a straight line following the pattern on the board.

C. Tsoro Yematatu

This is another South African game, often played in Zimbabwe. The intention is to align three colored pieces on a triangular board, while preventing the opponent from achieving the same goal. Players first drop their three pieces onto the board, and then move them to create a 3 in-a-row which wins the game. It is similar to games like Tapatan, Achi, Nine Holes, Shisima, and Tant Fant. However, what makes this game unique is that pieces can jump over each other (without capture) which adds an extra dimension in the maneuverability of the pieces [9]. The board is empty in the beginning. Players decide what color pieces to play, and who starts first. Each player drops one piece per turn on any vacant point on the board. Players alternate their turns. Pieces cannot be moved until all six pieces have been dropped. Observe that after all pieces have been dropped, there is only one vacant point on the board. A piece can be moved one of two ways: a) A piece can move one space per turn onto a vacant point following the pattern on the board, or b) a piece can jump over another piece (friend or foe) adjacent to it, and land on a vacant point on the other side; the jump must be in a straight line and follow the pattern on the board. There are no captures in this game. The game can last a very long time, and if no one is still able to create the 3 in-a-row, the players can agree to a draw [9].

D. Doki

Doki is a two-player abstract strategy game that focuses on aligning three pieces in a row on rectangular board with different colored spots. The rules in Doki differ slightly with the rules in the Tsoro Yematatu game.

1) Players decide among themselves who starts first.
2) The board is empty in the beginning. Players take turn placing their stones onto the empty cells of the square

board. This is known as Phase 1 of the game or the Drop phase.
3) After all 24 stones have been dropped, Phase 2 or the Move phase begins. Players will then take turns moving their pieces orthogonally into an adjacent empty cell.
4) Players attempt to make a three-in-a-row with their own pieces. The three-in-a-row must be orthogonal and not diagonal. Furthermore, it must be strictly three pieces in a row, and not four or more pieces in a row; four or more pieces formed in-a-row are illegal. If a three-in-a-row is made by a player, he or she can remove one enemy piece from the board which is not part of a three-in-a-row itself.
5) If a player can no longer make three-in-a-rows with their remaining pieces (e.g. if the player only has two pieces left), he or she is the loser, and the other player is the winner [9].

E. Senet

Senet is a board game from ancient Egypt, whose original rules are the subject of conjecture. The ldest hieroglyph resembling a senet game dates to around 3100 BC. The name ‘senet’ implies ‘game of passing.’ [8] The senet game board is a grid of 30 squares, arranged in three rows of ten. A senet board has two sets of pawns (at least five of each). Although details of the original game rules are a subject of some conjecture, senet historians Timothy Kendall and R.C Bell have made their own reconstructions of the game. These rules are based on snippets of texts that span over a thousand years, over which time game play is likely to have changed [8]. Therefore, it is unlikely these rules reflect the actual course of ancient Egyptian game play.

F. Fanorona

Fanorona is a board game for two players. It is played with black and white pieces placed on a board. The board is a rectangular grid of nine lines by five, with some diagonal lines marked. The picture shows the board at the start of the game. The two players each have 22 pieces of their colour on the board. One player has the black pieces while the other has the white. White moves first, then Black, and so on with the players taking turns. To win the game, you have to take all your opponent’s pieces or to leave a position where they can’t move. If neither player manages to win, then the game is a draw [10]

III. Environment

This research of board games and creating its environments is still ongoing but once completed, we will open source the environment to encourage addition to the RL environment options and study of complex strategy board games.

A. Reset

```
'''
Reset
This method Initializes the board game
after or before a game cycle
'''

  def reset(self):
       do initialize
      end
```

B. Render

```
'''
Render
This method displays the state of the
board game
'''

  def render(self):
      display current state of board game
      end
```

C. Step

```
'''
This method takes action on the
board game
'''
  def step(self):
      take an action on board
      end
```

D. Get reward

```
'''
This method gets the reward from
action
'''

  Get get_reward(self):
      this method get the reward from action
      end
```

IV. Figures and Tables

A. Complexity

TABLE I
GAME COMPLEXITY

Game	Board-size	State space z	Tree-complexity	Branching-factor
Ajua	> 8	> 2	*	*
Gulugufe	13	6	*	*
Tsoro Yematatu	7	3	*	*
Doki	30	14	*	*
Senet	30	*	*	*
Fanorona	45	21	*	*

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