A Proposal for the Exploration of Computational Heuristics Through Competitive Scrabble

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I. Background

Scrabble is a popular board game where players try to maximize point tallies by playing dictionary words on a board. Certain letter combinations and board tiles are worth more than others. It borrows from the general crossword puzzle mechanics where words can be played "through" or "off" each other, filling in the board.

Scrabble can be played with 2-4 players, however most Scrabble tournaments are 1-on-1. We will only be considering such 1-on-1 games. Scrabble has a robust competitive scene, with the World Championship prize pool sitting at $20,000.

Scrabble is an interesting game in the sense that you want to maximize the value of your individual play, but also boasts a strategic depth where you need to set yourself up for future plays, while limiting your opponent's opportunities to build a lead you cannot surmount. The triple board lane, elusive blank tile, and many other game quirks makes the following question interesting: **How does one optimally play Scrabble?**

II. Available Research

This project is not the first time someone has asked this question. Brian Sheppard's paper *World-Championship Caliber Scrabble (2002)* is considered the peak of the field's study. In it, he creates an AI called **Maven** that can play Scrabble at a "superhuman level". **Quackle** is an open source version of Maven, with some tweaks in how gameplay is done; it actually finished ahead of Maven in a tournament.[1] Some research since then has been done into improving Quackle's endgame through **Q-Sticking**, a method where you try to force the opponent to hold onto an unplayable Q or V.[2]

However, it appears the field has largely been stagnant, with many resolving that the best Scrabble AIs can probably beat the best humans, most of the time.

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[1] https://www.cross-tables.com/tourney.php?t=5423&div=1
[2] https://scholarworks.sjsu.edu/cgi/viewcontent.cgi?article=1574&context=etd_projects

This doesn't mean that top Scrabble AIs are perfect. The best humans can come close to beating them and the AIs miss optimal moves, called BINGOs, at a higher rate than some top professional players.[3]

Maven also makes some assumptions that may simply be wrong and could improve AI performance. The largest of which is that board dynamics are irrelevant. Maven contends that the tiles on the board, whether or not that opens or closes opportunities for particular word plays, don't actually matter when it comes to playing optimally.

It is this assumption that I seek to investigate with my senior project.

III. Project

I contend that the state of the game—from which squares are available, to how rich the bag is with certain tiles, and more—all factor into how optimal a play is. There are a lot of truths that pro-players use today that, without diving too deep into Scrabble terminology, Maven mostly hand waves away.

Currently, Quackle uses many fixed values to judge how optimal a play is, ignoring the dynamism of the game entirely. In particular, it does this when calculating the equity of a move through its **leave** value. The "leave" is which tiles you resolve to keep on your rack and not play on the board when it's your turn. It is crucial to keep certain tiles until the right moment presents itself and to give them up when the time is right.

There are other areas where I think more parameterization based on what the current board and bag state is could be inserted, but refining how Quackle calculates its leave values will be the initial focal point.

I will integrate these changes into the open source version of Quackle and judge how they perform against the base version of Quackle, with the goal of statistically proving that my changes made a positive difference in the Scrabble AI's performance.

[3] https://medium.com/@14domino/scrabble-is-nowhere-close-to-a-solved-game-6628ec9f5ab0

IV. Deliverable Timeline

It is difficult to say week by week when certain things will be done; software estimates are infamously poor. Instead, here is what I will seek to accomplish:

I. Continue researching how top humans play Scrabble, identifying the board states that they try favor and bag tile densities (how much of each letter is in the bag) that they prefer. I will identify particular areas where I could parameterize this. (1-2 weeks)
   A. Investigate other games that may have similar, human-driven strategy plays like Poker. A strategy is "human-driven" when it ascends the game itself (i.e. bluffing in Poker) and is done by humans to gain an advantage over other humans. AIs have difficulty doing this, and recent advances may have been made in that field.

II. Build a dummy player into Quackle that proves I have an understanding of the codebase. Find a silly part of the parameters to edit so I can visually see how its performance has changed.

III. Integrate a change I researched based on board and bag state into this dummy player.

IV. Measure over the course of a set of games how my AI does against Quackle's.
   A. Investigate automating this – right now Quackle using a GUI to do all the games, but there may be a way to do it via CLI.

V. Iterate on steps III-IV, making new changes based on results and ideas obtained in I.

VI. Conclude that the Maven team was right – board and bag state are largely irrelevant – or find that they were flawed in their assumptions.

VII. If time allows, investigate if any improvements to data structuring and move generation can be made – the nuts and bolts of how Quackle operates.

VIII. Write up findings