PROBLEM SOLVING STRATEGIES IN BOGGLE-LIKE GAMES

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Introduction

George Polya's seminal work "How to Solve It" describes general methods for approaching and solving mathematical problems. The book begins with Polya's four principles for solving a problem: understand the problem, make a plan, carry out the plan, and look back. Much of the remainder of the book is devoted to an encyclopedic listing of different heuristics for use in mathematical problem solving. Polya's work can also be applied in problem solving settings outside of mathematics. For example, to clarify the role of his four principles in tackling a new problem, Polya explores the following non-mathematical question: what single English word can be formed by rearranging all the letters in "dry ox tail in rear"?[1] In a similar vein, this paper will explore applications of problem solving strategies in tackling another problem from outside of mathematics; namely, that of finding words in a Boggle-like game.

Background

Boggle is the name of a word game designed by Allan Turoff and released by Parker Brothers in 1972. For a description of the rules and some of the mathematics they entail, the reader is referred to (Ash, 1987). In the present article, we will use *Boggle word* to mean any entry in the Scrabble Tournament Word List with three or more letters.[2] A *Boggle board* is defined to be a 4x4 array of letters, where words are formed by tracing paths from letter to adjacent (i.e., horizontal, vertical, diagonal) letter, with the one caveat that the same entry cannot be used more than once. Finally, a *Boggle-like game* is one in which the goal is to find Boggle words on a Boggle board. For clarity's sake, when discussing words within a given board we will use majuscules (i.e., capital letters). As an example, consider the following array of letters:

A M D F

E S I G

R TN L

S AB E   **Figure 1**

Thus, the above Boggle board contains RAT, DIM, and STARE, but does not contain BASS or INTEREST.

Boggle has found its way into a variety of media, with references on television programs such as *Friends*, *King of the Hill*, and *Seinfeld*. The game was also mentioned in a 2010 episode of NBC's *30 Rock*, when Liz Lemon (played by Tina Fey) remarks, "I've been stuck inside playing online Boggle. It's messing with my head. STAR. RATS. ARTS. TARS..."

As addressed in the above scene, there are numerous Boggle-like games available online, such as Zynga's Scramble with Friends for the iPhone, BitWordy on Facebook, and Word Racer on Yahoo! Games.3 Because each of these variations has slightly different rules, this paper will mostly concern our more general definition of Boggle-like games.

Before proceeding any further, we note that even inexperienced players are likely to use some sort of strategy when searching for Boggle words. That is, it is unlikely that a player will randomly select a path on the board and then check whether or not it gives an acceptable word. Instead, most players will perform some sort of verification in conjunction with the search process. For example, a path that begins with a T is unlikely to be continued with an adjacent X, and most players would outright reject all paths beginning with TX-. Experienced players may utilize other, more complex heuristics to find Boggle words. We outline several of these in the following section.

Polya's Principles for Boggle-Like Games

Understand the problem

To be clear, the problem at hand is that of finding Boggle words given a 4x4 array of letters. On the most basic level, one must understand the rules of our Boggle-like game. Which words are valid and how does one form a word? Understanding the rules can be further complicated when one plays variations of Boggle that have slightly different rule-sets; a point we will address in the discussion section.

The next component to understand is the layout of the given board. What is the distribution of consonants and vowels? For example, if there is a J in a corner that is surrounded by consonants, can word searches disregard this letter? Is there an S on the board that could be used to pluralize words? Are there prefixes (e.g., RE-) or suffixes (e.g., -ING) on the board? More generally, are there two or three letter strings that are commonly found at the start or end of words (e.g., STR-)? Is there some way to know at a glance how "dense" a board is?4 Different layouts will call for different strategies.

Boggle-like games are generally played in rounds that last a short amount of time, using a game clock that begins when the board is revealed. In order to find words to the best of one's ability, a balance must be struck between time spent on understanding the board and searching for words. Once the player understands the landscape of a board, there are certain strategies that can be used to aid word search; we outline a handful of these below.

Make a plan and carry it out (Strategies for word searching)

(Simpler Case) Presented with a 4x4 board, one way of reducing the problem to a simpler one would be to look at a 3x3 sub-board. It would be unlikely even for an experienced player to recognize a 3x3 sub-board as having appeared previously; however, having fewer letters to navigate may facilitate the process of word finding. The problem can be further reduced by looking at 2x2 sub-boards. Note that a 2x2 sub-board is fundamentally different from larger square boards, in that all four letters are adjacent to one another. As an example, consider the 2x2 sub-grid located at the bottom left hand corner of Figure 1:

R T

S A

Thus, all anagrams and sub-anagrams of A, R, S, T can be formed. For the anagrams, this would be the four Boggle words listed by Liz Lemon in the previous section (ARTS, RATS, STAR, TARS) as well as TSAR. For the sub-anagrams, this would be ARS, ART, RAS, RAT, SAT, TAR, TAS.

(Contraction) Another strategy is to remove letters from the start or end of words that have already been found in order to generate new words. For example, having found the word STARE in Figure 1, one could remove the E and form the word STAR. Because the board contains STARE, any one of its "contractions" will be contained as well. The other possibilities in this case are TARE, TAR, and ARE.

(Extension) Whereas contraction uses the removal of letters to find Boggle words, one could also extend already found words by inserting letters. This sort of strategy motivates the preliminary search for prefixes and suffixes, but need not restrict to these cases. Returning to Figure 1, the word RAT can be extended in several ways: RAT, RATS, RATE, RATES, and RATING.

(Rearrangement) As already mentioned, the strategy of looking at 2x2 sub-boards uses anagrams and sub-anagrams. More generally, one can consider anagrams of any found word. Sometimes these rearrangements will be on the board and sometimes they will not. For example, having found the word RETINAS in Figure 1, one might search for its anagrams. In this case, most of these anagrams are not playable (e.g., NASTIER, RETAINS), though the word RETSINA is. Anagrams formed by reversing the order of a word's letters are particularly helpful, in that a Boggle word is playable if and only if its reverse is as well. For example, the word TIME is playable precisely when EMIT is, and vice-versa.

(Change of perspective) In some versions of Boggle-like games, one may be allowed to rotate the board by 90 degrees. Looking at the board from this new perspective may be helpful in seeing new relations between letters and words.

S R E A

A T S M

B N I D   **Figure 1 rotated 90 degrees clockwise**

E L G F

(Combining multiple strategies) Finally, one can approach the problem of finding Boggle words by combining the different strategies listed above. For example, in searching the board in Figure 1, one might first see RETINA, then extend to RETINAS, then anagram to RETSINA, then reverse the letters to find –ANISTER. While this last string of letters is not a Boggle word, an experienced player may recognize it as an ending for three different words: BANISTER, CANISTER, and GANISTER. Indeed, BANISTER (and BANISTERS) can be formed in the example board.

Look back

After searching for Boggle words using heuristics such as those mentioned above, there are several questions to ask oneself in looking back on a particular board. Which words were not found? Of these words, which ones were not known and which ones simply went unnoticed? Of the words found, which other words could have been obtained using strategies such as

contraction, extension, or rearrangement? Were there parts of the board that were underexploited? Were there word shapes that were tougher to see (e.g., avoiding diagonally adjacent letters)? How might one go about remembering new words? What other strategies are there for learning words?5 What other strategies are there for finding Boggle words?

Discussion

There are several obstacles to applying the strategies listed in this paper when competing against other players in Boggle-like games. Although the games tend to be quite similar to one another, differences such as scoring system, round length, and letter distribution can significantly alter strategy. For example, in the Parker Brothers Boggle game, only unique words are counted towards one's score. At the end of a round, each player reads aloud his or her word list, discounting words that at least two players found. Thus, as the number of players increases, obscure words are likely to become more valuable, possibly changing one's general strategy.

Round length among different games typically ranges between 30 seconds and 3 minutes. For faster games, the strategy of searching 2x2 sub-boards may be less effective, as shorter words are generally lower scoring than longer words. A player that is able to generate numerous 3 and 4 letter words quickly may still be unable to defeat a player that can find a few longer words in a short round. Similarly, the amount of time spent characterizing board type (e.g., vowel/consonant distribution, prefixes, suffixes) at the start will need to be adjusted depending on total round length.

Letter distribution can also vary among different Boggle-like games. Even among Parker Brothers produced Boggle, the letter frequencies have changed over the years. For Zynga's Scramble game, there is a lower bound for points possible on 4x4 boards. By restricting to a particular Boggle-like game – for which letter distribution is known – one may be able to provide a fuller analysis that draws upon the probabilities of different words appearing.

It is important to note that a number of elements besides heuristics come into play during the problem solving process. In "Mathematical Problem Solving," Alan Schoenfeld argues for four categories of knowledge and behavior (Schoenfeld, 1985). In addition to heuristics, these are resources, control, and belief systems. Though Schoenfeld states his definitions in a mathematical problem solving context (Schoenfeld, p. 44), we can easily adapt them for our own problem of finding words in Boggle-like games.

Resources are the body of knowledge that an individual is capable of bringing to bear when searching a particular Boggle-board. They include factual knowledge (e.g., RETSINA is a Boggle word) as well as procedural knowledge (e.g., a string of letters is playable on a Boggle board if and only if its reverse is). *Heuristics* are rules of thumb for effective word searching (e.g., reversing an already found word and adding a letter, such as RETSINA to BANISTER). *Control* deals with resource management and allocation during a Boggle round (e.g., how long to spend looking for suffixes at the start of a 30 second round). Finally, *belief systems* are one's Boggle world view, the perspective with which one approaches Boggle-like games and searches for words.

Each of Schoenfeld's first three categories have been addressed already, to some extent, within this paper. Thus, we conclude the discussion section with a brief consideration of the role of belief systems in finding words in Boggle-like games. Schoenfeld gives three examples of student beliefs and their consequences for mathematical problem solving (Schoenfeld, p. 43); we provide analogs below for our own context:

Belief 1 Searching for Boggle-words has little to do with real thinking or problem solving. *Consequence* When searching a Boggle board, players will only utilize primitive strategies, without invoking complex heuristics such as the ones listed in this paper.
Belief 2 Boggle-words are found early on in a round, if they are found at all. *Consequence* As the end of a round nears, players give up on searching for more words.
Belief 3 Only geniuses are capable of great success in Boggle-like games. *Consequence* If you (a typical player) are not a natural "Boggler," too bad. If you forget a word's anagrams, you will not be able to figure them out on your own. You must settle for a list with fewer and shorter words.

The beliefs that exist among players and their effects on game-play are open avenues for consideration and study. Perhaps by further investigating belief systems, as well as the other three categories defined above, we can reach a deeper understanding of successful word searching in Boggle-like games.

Conclusion

In this paper, we considered how problem solving strategies can be used to play a general class of word games. Drawing upon the frameworks of problem solving theorists George Polya and Alan Schoenfeld, we described some of the theory underlying word finding in so-called Boggle-like games. What other heuristics are used to find Boggle words and what beliefs are held by players, at both the expert and novice level, remain as open questions. Regardless of future research, we hope that these games can continue to captivate players and provide them with intellectual challenges.

Notes

1. In order to anagram "dry ox tail in rear," Polya suggests first separating the letters into vowels and consonants.

2. At this time, there is not one, single wordlist that is accepted for Boggle play. As a result, we suggest adopting the wordlist currently used for North American Scrabble play.

3. http://www.zynga.com/games/ (Scramble); https://apps.facebook.com/123117007789010/ (BitWordy); http://games.yahoo.com/games/rules/wordracer/basics.html?page=ww (Word Racer).

4. By "dense" we mean roughly that a board contains many words and has a high possible score. For players that are unsure of how to quantify these terms, most online Boggle games provide a full list of possible words at the conclusion of a given round. Over time, players can gain a sense of which boards are especially dense given a particular game's letter distribution and scoring system.

5. One particularly helpful tool for learning Boggle words is the application Zyzzyva, which can be downloaded for free from http://zyzzyva.net/.

Reading List:

Ash, Christopher. *Boggle*. Mathematics in School, Vol. 16, No. 1 (Jan., 1987), pp. 41-43.
        Retrieved from http://www.jstor.org/stable/30214170.

Carlisle, Rodney P. *Encyclopedia of play in today's society*, 2009.

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