Bulls and Cows: Strategies and Techniques*

Team 11†

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November 16, 2018

Abstract

This paper describes the strategies and techniques followed by the program written by Team 11 for the *Bulls and Cows* code-breaking game condcuted as part of the course CS 211 Data Structures and Algorithms Lab.

1 Introduction

The game of Bulls and Cows is a two-player game, in which both the players choose a secret number and the opponent has to guess it. The one who guesses it in the least number of attempts, wins the game. If number of attempts are same for both the players, it is a tie.

2 Formalization

The player decides a four-digit secret number, no repetetions of digits allowed. The opponent tries to guess it, and is given number of matches after each attempt. If the matching digits are in their right positions, they are bulls, if in different positions, they are cows.

*This is a report on the course project for the course CS 211 Data Structures and Algorithms Lab

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2.1 Rules:

- The secret number should have distinct digits and should not start with 0.
- A guess is also a four-digit number but can start with 0 and has repetetions allowed.
- A bull occurs when a digit is in the same position in both the guess and in the secret number, whereas a cow occurs when a digit is present both in the guess and in the secret number, but in a different position.
- In case of a guess with repeated digits, if the repeated digit occurs in the secret code in the bulls position, it is counted as a bull and not as a cow. For example, if for a secret number of 3480, a guess of 3395 is made, then the answer to the guess would be 1 bull, 0 cow.

2.2 Response

The reply to the guess attempt is given as two different digits in which the first digit is the number of bulls and the second, the number of cows. The criteria for deciding bulls and cows is already explained.

3 Algorithm and Strategy

There are basically two strategies, simple and extended. Our code uses the simple strategy.

We use the concept of pruned set here. A pruned set is one where using on the outcomes of a guess, impossible combinations are eliminated. For example, if the code is 5026 and we guess 3026, we get a response of (3b, 1c), and the possibilities are pruned to 1026, 3026, 4026, 5026, 7026, 8026, 9026 only.

4 Average guesses required

The simple strategy takes 6.0736 average number of guesses, i.e. the answer is definately known in the seventh guess. The algorithm that uses simple strategy takes maximum seven number of attempts to crack the code. The

extended strategy has even less average number of guesses, 5.8930, which means it can find the secret code in maximum of 6 attempts. [2]

5 The better algorithm

The primitive algorithm and extended algorithm have a slight but important difference in average case scenario. However, a large amount of processing power is needed for the extended approach, due to the NP-hard nature of the problem.

A vast number of approaches and strategies for the game still remain un-solved. Nonetheless, Bulls and Cows poses a very interesting challenge to recreational mathematicians, computer engineers, and psychologists alike. [1]

6 Conclusion

The project given to us by our instructor, Prof. Sandeep R.B., was a very interesting one, not just int terms of writing the code, but also in terms of competitions between teams. We didn't just implemented the code, but also came to know about various theoritical aspects of the game while surfing the internet for ideas.

So, we now theoritically know that there are powerful algorithms available that can crack the secret code in not more than 6 attempts. But due to several constraints (lack of knowledge at the right time and implementation errors etc.) we could only go ahead with the simple strategy.

At the end, it was both a challenge and a fun to complete this project which exposed us to a completely new set of ideas and also enhanced our theoritical knowledge apart from coding.

References

[1] John Francis. *Strategies for playing MOO, or "Bulls and Cows"*. Elsevier Science, 2015.

[2] Namanyay Goel and Aditya Garg. *A Mathematical Approach to Simple Bulls and Cows*. Elsevier Science, 2015.