Available captures for the rook; a performance analysis on a parallelized version of the problem

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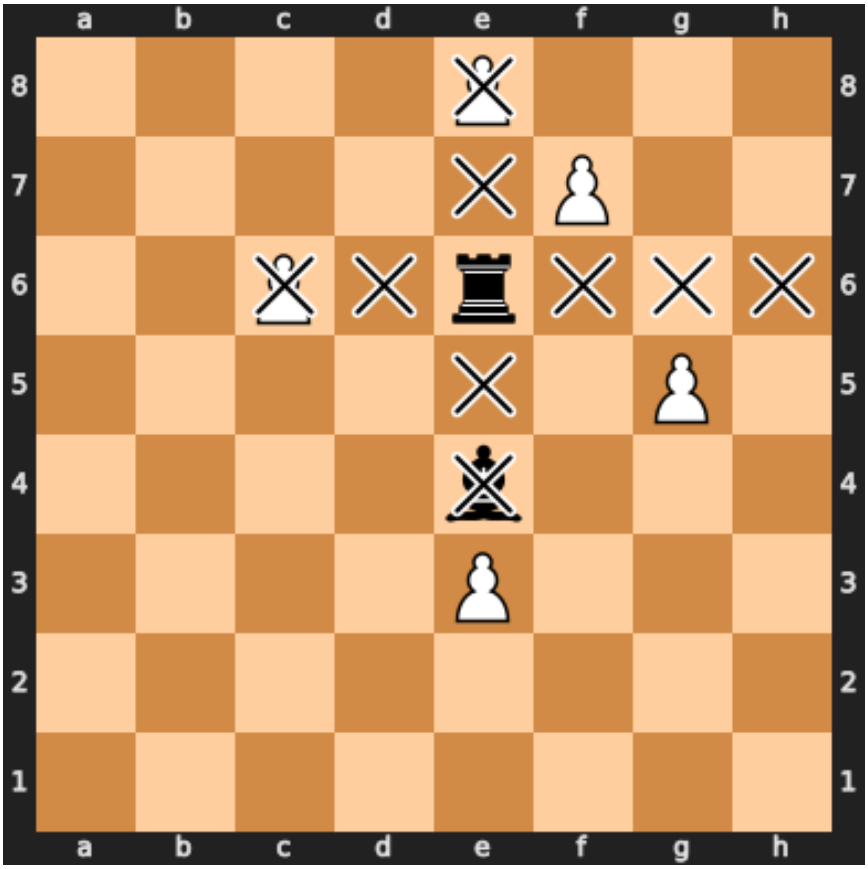
1 Foreword

This document has been generated from an `org-mode` file. The source can be found here (Source), and a PDF version here (PDF). I aimed to have both the GitHub-ready org-mode file and the PDF to be readable, but unfortunately, GitHub doesn't support mathematical expressions to be rendered natively on the preview; so, in order to view correctly the mathematical formulas throughout the analysis, I recommend reading the PDF version.

2 Introduction

This project aims to implement a solution for the problem of the number of available captures for the rook on a chessboard: on a chessboard, where pieces are either **a black rook**, **black bishops** or **white pawns**, how many pawns can the rook capture?



In this example, the rook can only capture 2 pawns: e8 and c6. The pawn on e3 is blocked by the bishop on e4.

3 Base algorithm

The base algorithm is quite simple: given a board and the position of the rook, we need to iterate on the squares in the 4 directions: if the first piece encountered is a bishop, there is no capture on this position; and if it's a pawn, there is a capture. The result is the sum of the number of captures.

```
/// Computes the number of pawns the rook can capture in the
/// board's current configuration.
pub fn get_rook_captures(&self) -> usize {
    let start = self.get_rook_position();
```

```
    // Looking at all directions (up, down, left, right):
    Direction::all()
        .iter()
        .map(|d| {
            match start
                // we look at the line in that direction
                .line(*d, self.size)
                .iter()
                .filter_map(|p| self.get_piece(p))
                // and get the first piece on the line:
                .next()
            {
                // If there aren't any, then there
                // is no capture
                None => 0,
                Some(k) => match k {
                    // If it's a bishop, no capture either
                    PieceKind::Bishop => 0,
                    // If it's a pawn, we capture it
                    PieceKind::Pawn => 1,
                    // If it's another rook, no capture
                    PieceKind::Rook => 0,
                },
            }
        })
        // ... and we sum the number of captures.
        .sum()
```

4 First attempt at parallelization using Rayon

We can attempt to parallelize the algorithm in a straightforward manner, by looking at the 4 different directions in parallel. This version of the algorithm is quite similar to the sequential one: using Rayon's powerful parallel iterators, we can simply iterate in parallel on the directions.

```
/// Computes the number of pawns the rook can capture in the
/// board's current configuration, in parallel.
pub fn get_rook_captures_par(&self) -> usize {
    let start = self.get_rook_position();
```

```
Direction::all()
    // We use a parallel iterator here
    .into_par_iter()
    .map(|d| {
        match start
            .line(d, self.size)
            .iter()
            .filter_map(|p| self.get_piece(p))
            .next()
        {
            None => 0,
            Some(k) => match k {
                PieceKind::Bishop => 0,
                PieceKind::Pawn => 1,
                PieceKind::Rook => 0,
            },
        }
    })
    .sum()
```

4.1 Theoretical performance analysis of the parallel version

Let's analyze the parallel algorithm. We first formally define a board as a 2-dimensional space of size N^2. There are 4 parallel branches, each iterating on successive squares of the board. Deciding on the capture is $\mathcal{O}(1)$, so the exploration of a line takes $\mathcal{O}(N)$ at most.

We then have a work of $W = \mathcal{O}(4N)$, and a depth of $D = \mathcal{O}(N)$. It is obvious here that having more than 4 processors for the task is going to be detrimental for the performances.