Seam carving algorithm

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Homework 01

Code

Algorithm and task description

Seam carving is an algorithm for **content aweare image shrinking**.
We have been tasked to parallelize the process using OMP.

Algorithm is divided into three sections of image manipulation and calculation:

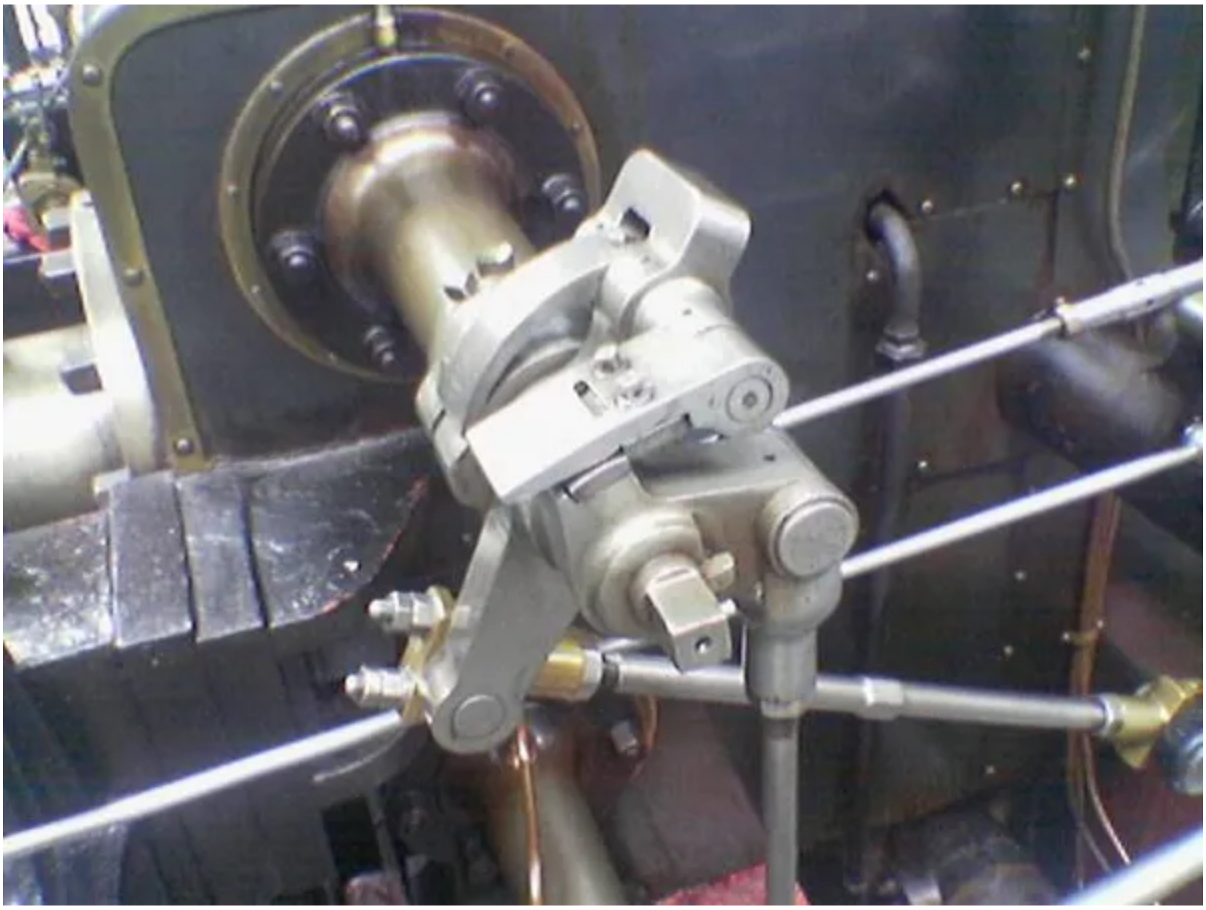
- Energy calculation
  - Calculates the importance of image parts using a **sobel kernel** based edge detection
- Seam identifcation
  - Identification of lowest energy paths. Calculates the cumulative cost of all vertical paths so that they can be removed in the next step.
- Seam removal
  - Removes the pixels following the cheapest path and stiches the image back together

The steps are repeated n times, where n is the amount of pixels the image is shrinked for.

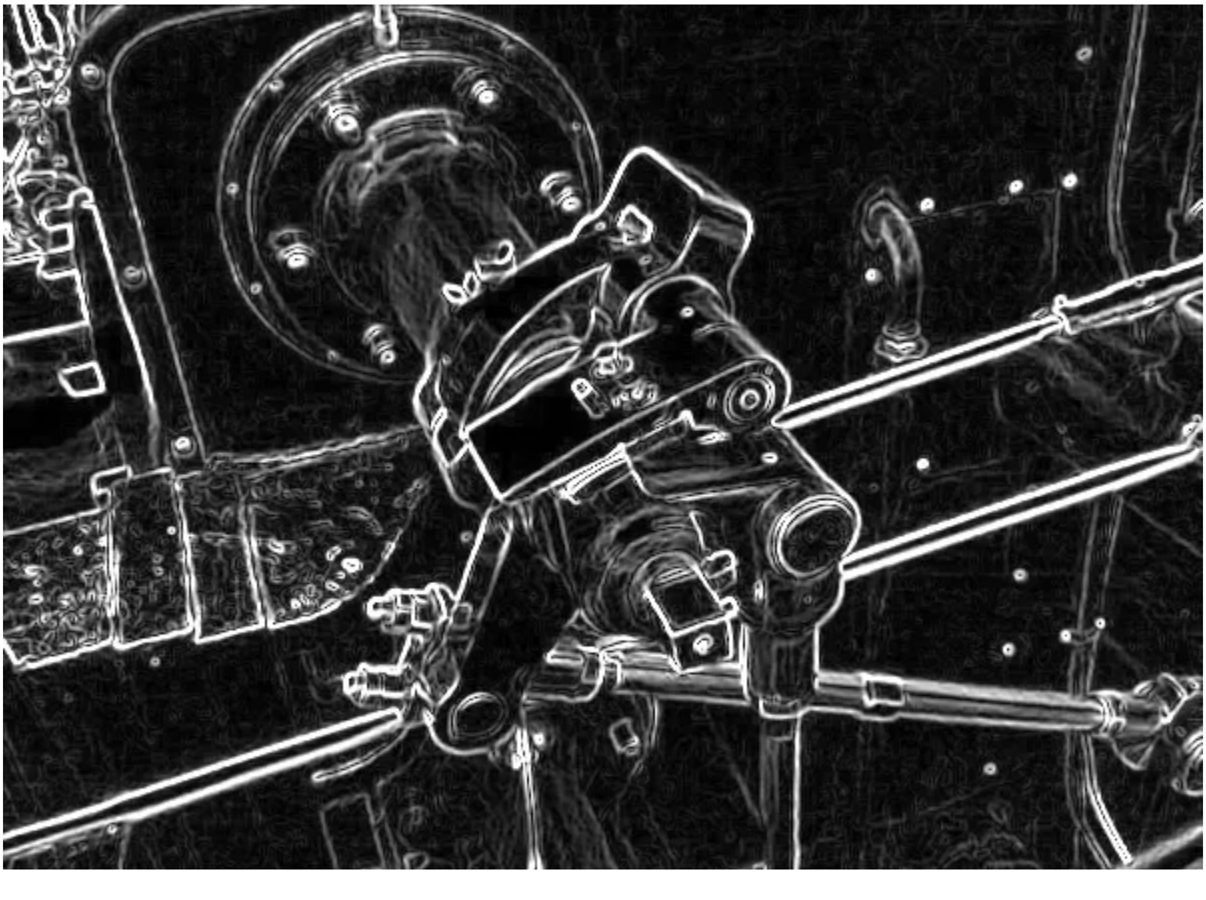
Visual representation

Every steps mentioned is visualized on the provided example image valve.png

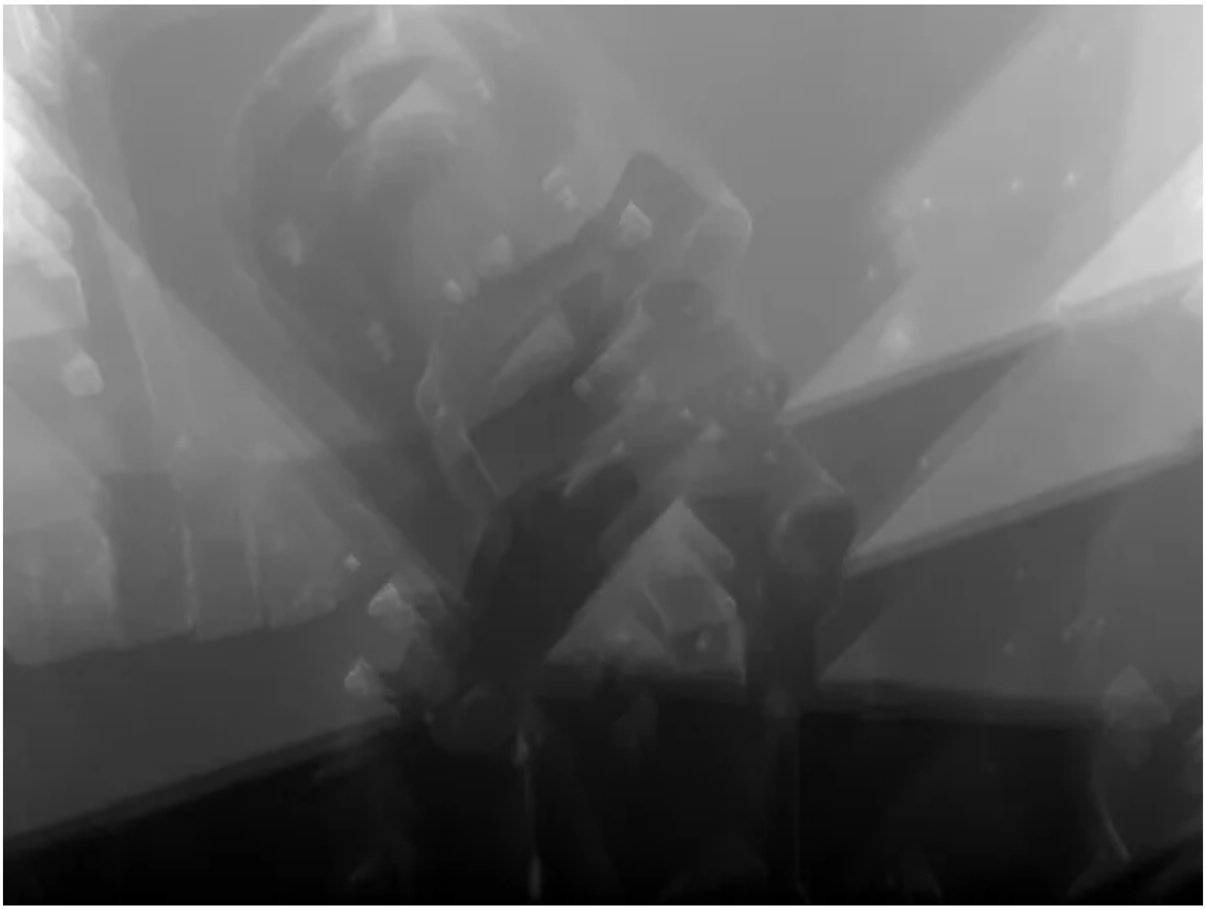
Base image



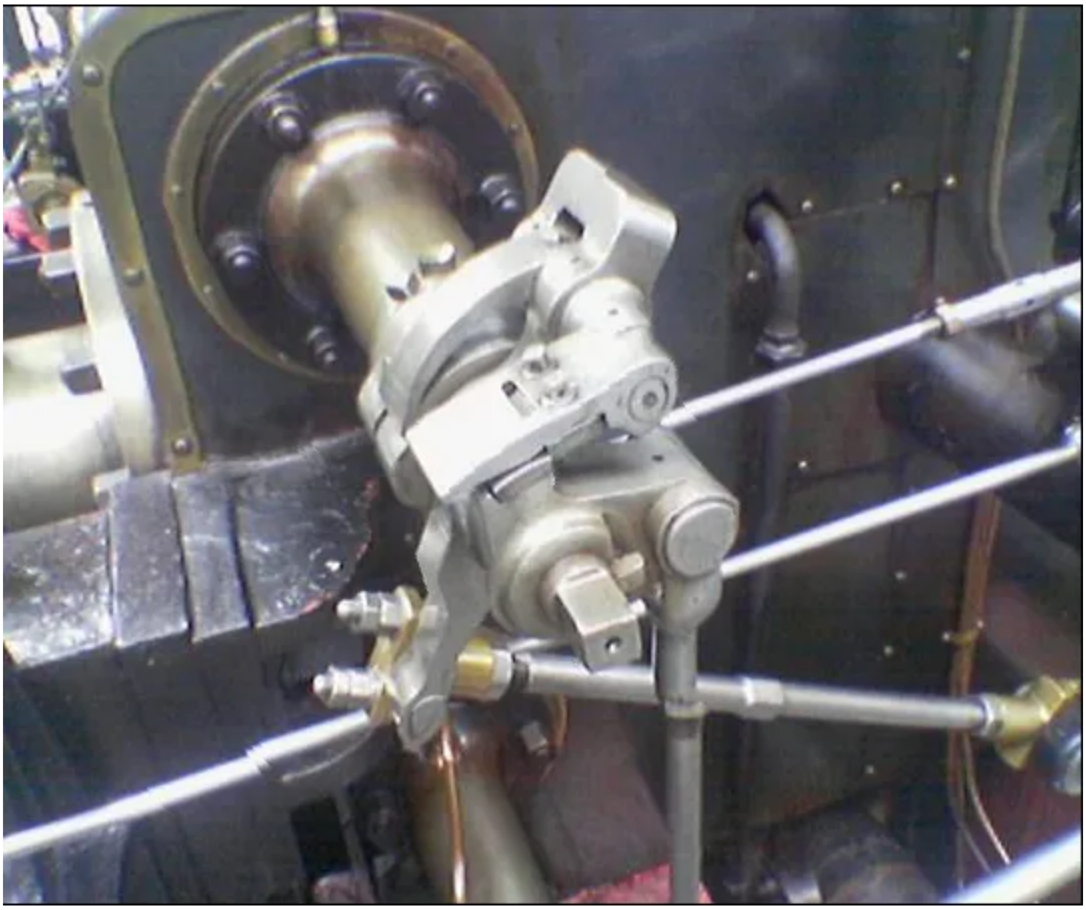
Energy calculation using edge detection



Cumulative energy visualized



Final carved image



Parallelization

The task was to optimize the process for parallel computation as much as possible using c++ framework **Open MP**.

Each step of the process was parallelized using a different technique.

Energy calculation

The first step was the easiest and most efficient to run in parallel.
Each pixel can be calculated independently without with the only dependency being the original image. This allowed us to use the so called **embarrasingly parallel** approach, where the x and y for loops were collapsed using `omp parallel for` directive.

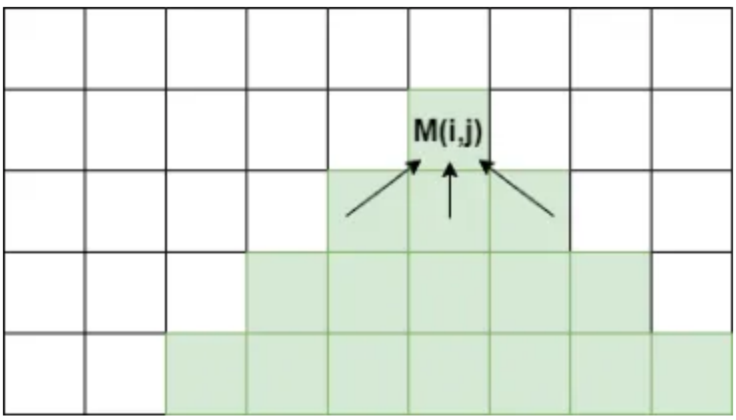
```
#pragma omp parallel for collapse(2) schedule(dynamic)
  for (int x = 0; x < in.getWidth(); x++) {
    for (int y = 0; y < in.getHeight(); y++) {
```

This allows every thread to process its own pixel, which gives a theoretic maximum of $w * h$ threads to run in parallel.

We believe that this is the best approach and gives no further space for improvements, due to its efficiency and simplicity of the task.

Seam identification

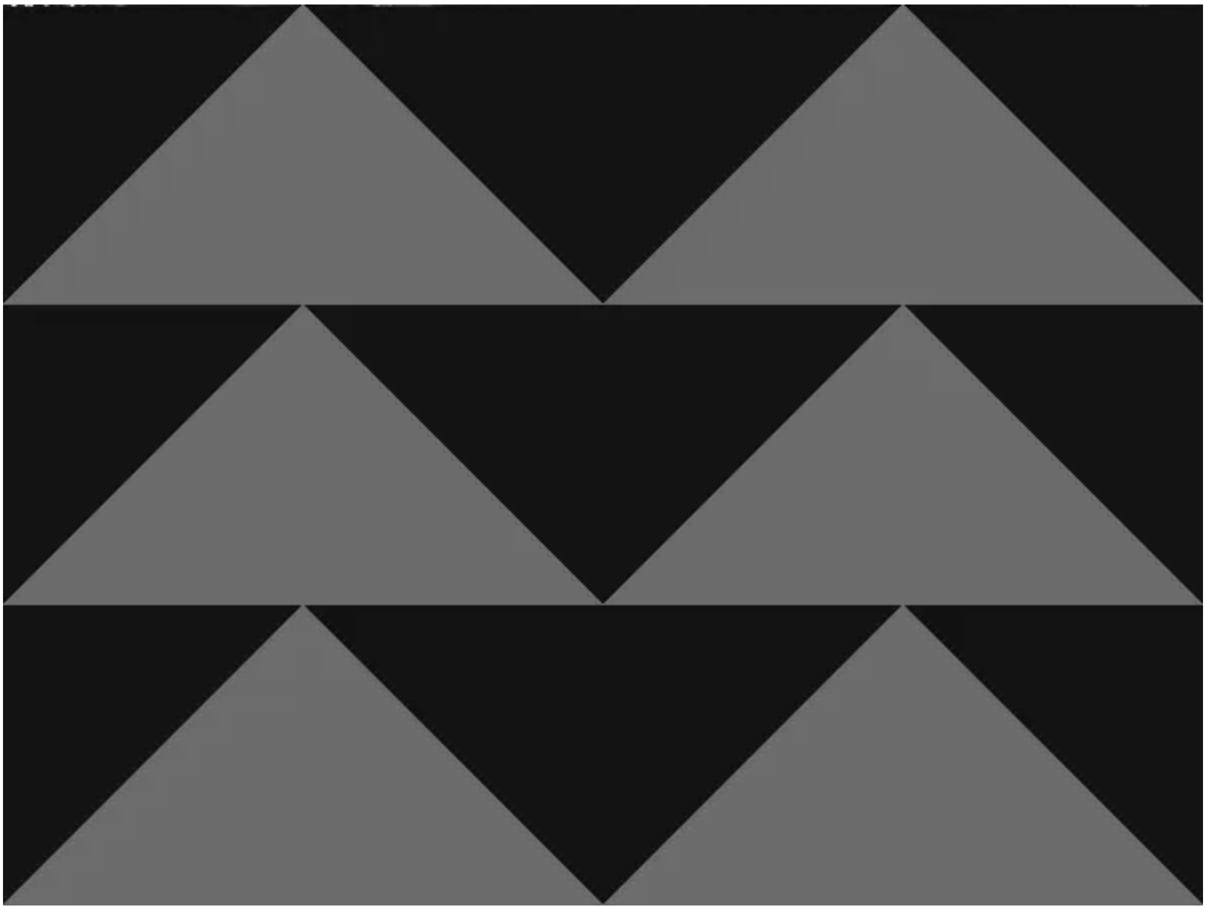
This step was the most difficult to optimize.
Seam identification computes the cheapest path from the pixel at `i,j` to the given pixel which depends on precalculated triangle *(green)* below the pixel.



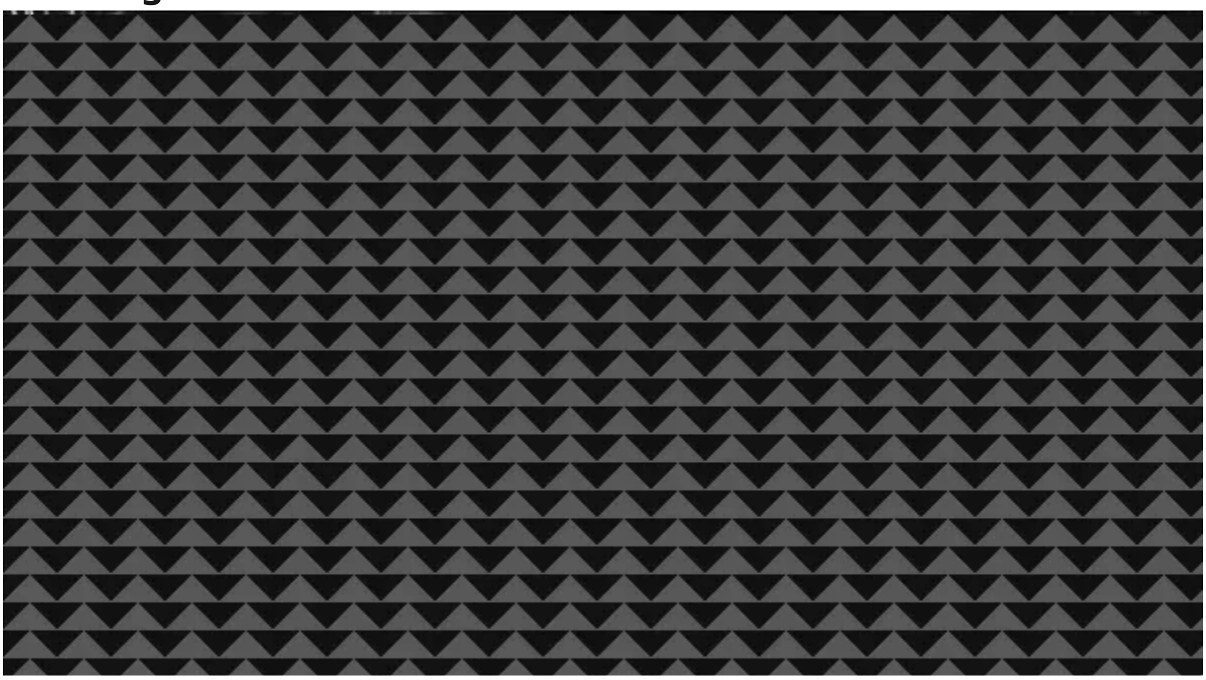
This prevents us from using the same approach as before, where all dependencies were met at the beginning.

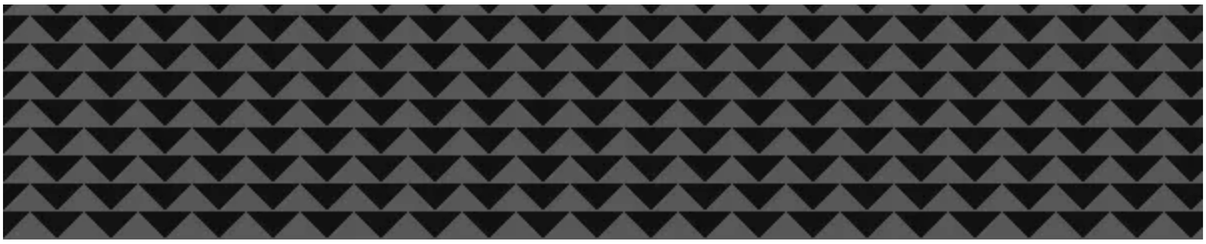
A triangular division of work was used, as proposed by the exercise.
The number of threads working on the task is nou bound by the **density of the triangular grid**. Examples of **2 triangles** and **22 triangles** per row are provided.

2 triangles

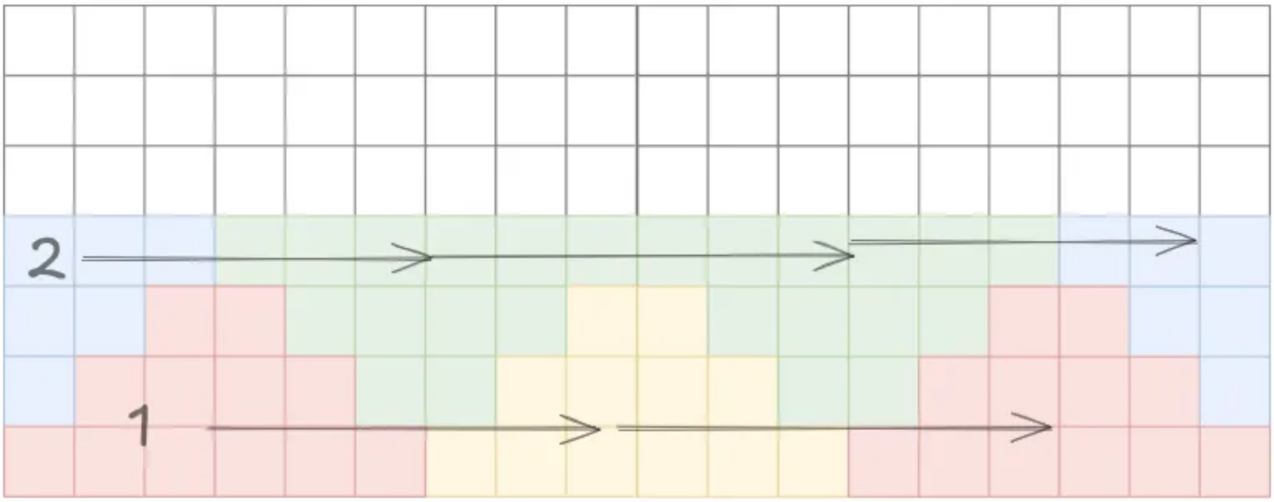


22 triangles





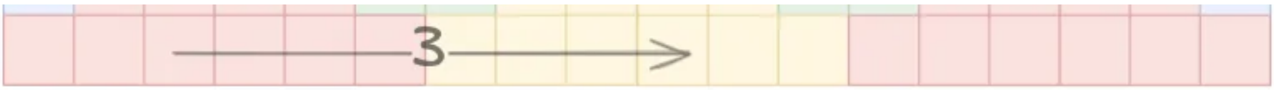
Each thread computes one upward (ligh) triangle in a row, which satisfies all the dependencies for the downward (dark) triangles, which are again divided across the same amout of threads.



OMP barrier is used inbetween two calculations to assure that all dependencies are met before computing the next batch of dark driangles.

This is considered one **strip** that the whole image is divided into. Processing of every strip is done sequentially since this is the only way to meet the dependecies for calculating pixels above the current strip.

There is a possible optimization, where a thread could start processing the down-facing triangles **as soon as nearest two upward-facing ones are complete**, but due to difficult implementation, this optimization is not included in the project.



Seam removal

Seam removal is a process that is mostly copy-speed bound.
The only optimization that we could do, was parallelizing the copying of every row, simmilarly to first task.

We used the `#pragma omp parallel for` for optimizing the for loop over the vertical axis of the image.

```
const int height = in.getHeight();
#pragma omp parallel for schedule(static)
for (int y = 0; y < height; y++) {
```

Results

We have timed the cumulative runtime along with the time it took for each section to complete.

Image Size	Mode	Energy (ms)	Seam Process (ms)	Seam Energy (ms)	Cumulative (ms)
720x480.png	Sequential	15	1	3	3725
720x480.png	Parallel	11	2	2	2774
1024x768.png	Sequential	37	3	9	7318
1024x768.png	Parallel	29	3	5	5519
1920x1200.png	Sequential	119	13	30	23032
1920x1200.png	Parallel	60	6	12	13618
3840x2160.png	Sequential	607	52	117	99077
3840x2160.png	Parallel	360	30	60	59000
7680x4320.png	Sequential	2285	200	480	428455
7680x4320.png	Parallel	1431	94	245	230231