Comparing WebAssembly and JavaScript for a web based photo editor

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What is the project about?

For a long time, JavaScript was the only method for doing computation in web browsers, however in 2017, Web Assembly was introduced as an alternative [1].

Definition (Web Assembly)

Web Assembly is a language that allows for the execution of languages that compile to assembly on the web

Research Question

Finding in which cases Web Assembly offers a benefit over JavaScript, by implementing image processing algorithms using both mechanisms.

Deliverables

- **Basic aim**
  Compare the performance of one complex algorithm between Web Assembly and JPEG, for a complex algorithm, it should not simply loop over the pixels of the image, and instead be performing more sophisticated techniques.
- **Intermediate aim**
  Extend the basic aim to multiple complex algorithms.
- **Advanced aim**
  Look into tweaks that can be used to improve performance, such as compile time optimizations for Web Assembly.

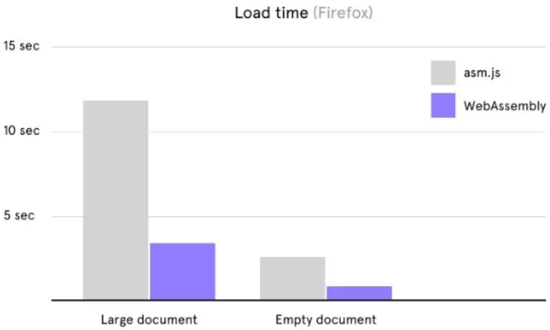
What has been done by others?

Using Web Assembly for image processing — Next.js [2]

NEXT.JS

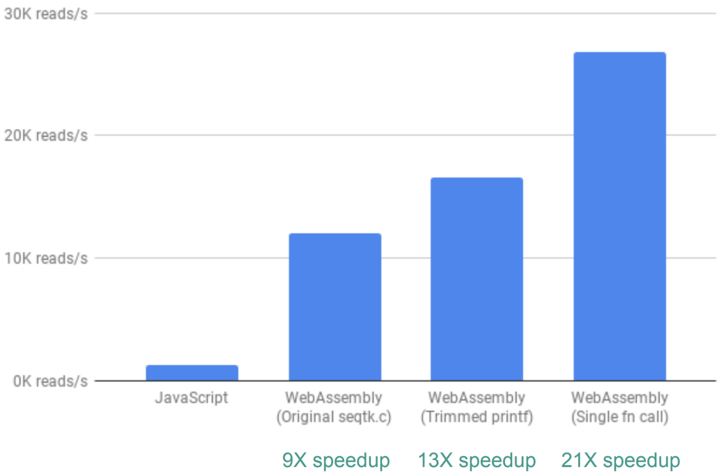
96.5 MB $\Rightarrow$ 69.2 MB

Performance of Web Assembly — Figma [3]



3× faster load times

Performance of Web Assembly — Fastq.bio [4]



Performance of Web Assembly — Compared to native [5]

Benchmark	Field	Native time(s)	Google Chrome time(s)
bzip2	Compression	370	864
mcf	Combinatorial	221	180
milc	Chromodynamics	375	369
namd	Molecular Dynamics	271	369
gobmk	Artificial Intelligence	352	537

How does it compare?

- Studies haven't been done on the performance of web assembly for image processing, just some metrics found during development of one project
- Often comparisons are being made between asm.js and Web Assembly, comparing native implementations gives a more fair comparison

My Solution

Choosing a language for Web Assembly

- Most languages have some support for Web Assembly
- Web Assembly doesn't include a garbage collector so languages that don't need them are preferred
- Lots of development work has been put into the Rust ecosystem regarding web assembly

Choosing problems

- Common image processing tasks
- Range of computational complexity

Platform

- Want results to be equivalent to Google Chrome (64% market share [6])
- Node.js uses the V8 browser engine (the same as Google Chrome)

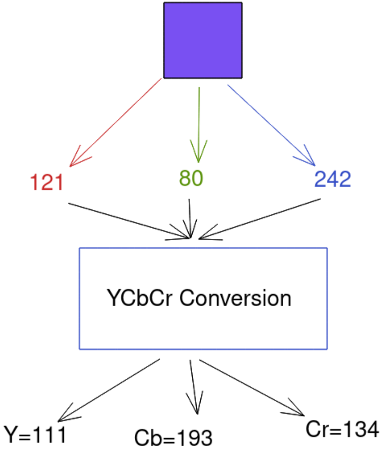
Brightness

Contrast

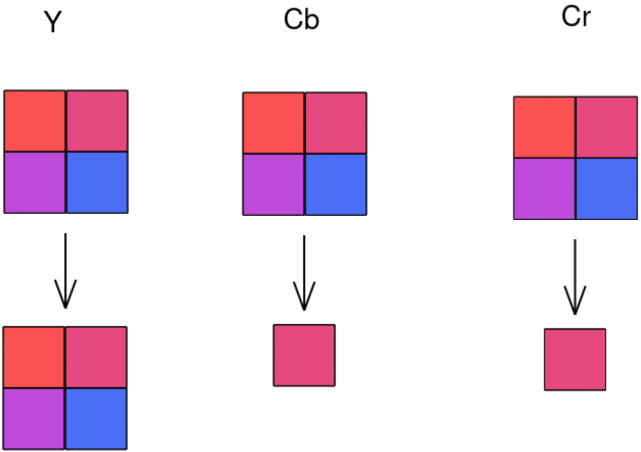
 

Gaussian Blur

JPEG — YCbCr Conversion [7]



JPEG — Downsampling



JPEG — DCT [8]

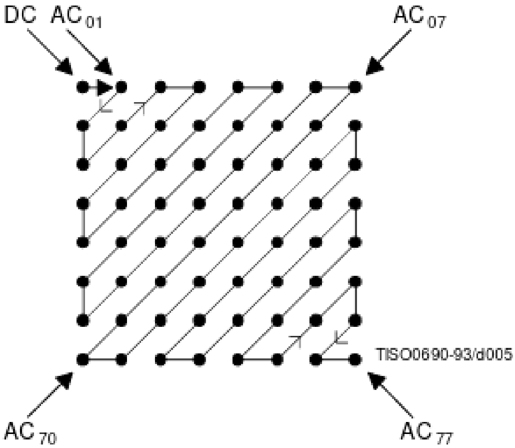
$$T_{i,j} = \begin{cases} 1/\sqrt{N} & \text{if } i = 0 \\ \sqrt{\frac{2}{N}} \cos(\frac{(2j+1)i\pi}{2N}) & \text{if } i > 0 \end{cases}$$

N is the dimension of the matrix (here 8)

JPEG — Quantization

$$\begin{bmatrix} 16 & 11 & 10 & 16 & 24 & 40 & 51 & 61 \\ 12 & 12 & 14 & 19 & 26 & 58 & 60 & 55 \\ 14 & 13 & 16 & 24 & 40 & 57 & 69 & 56 \\ 14 & 17 & 22 & 29 & 51 & 87 & 80 & 62 \\ 18 & 22 & 37 & 56 & 68 & 109 & 103 & 77 \\ 24 & 35 & 55 & 64 & 81 & 104 & 113 & 92 \\ 49 & 64 & 78 & 87 & 103 & 121 & 120 & 101 \\ 72 & 92 & 95 & 98 & 112 & 100 & 103 & 99 \end{bmatrix}$$

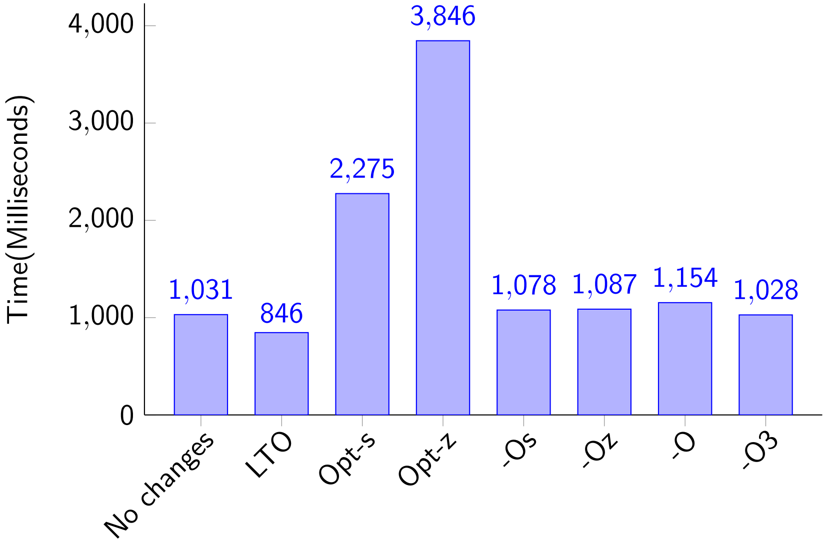
JPEG — Zigzag



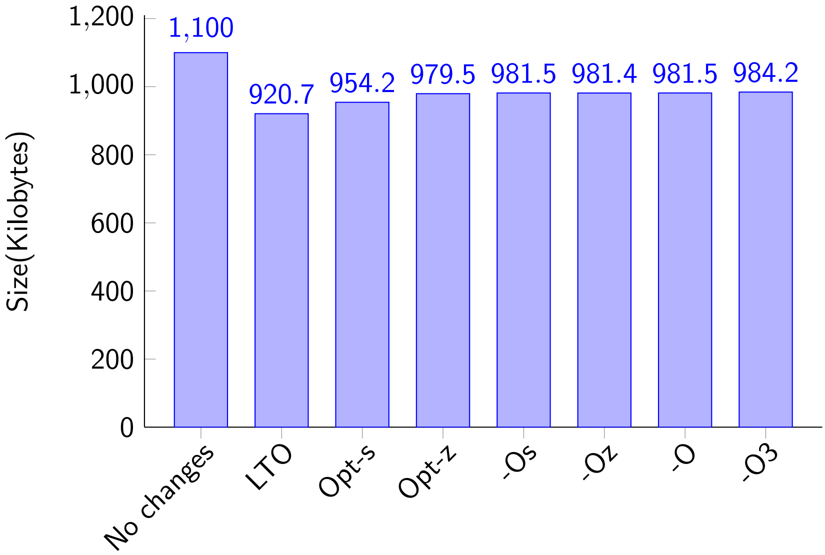
Web Assembly Optimizations

1. Link Time Optimization
2. Rust compiler opt-level
   - "s" : optimize for size
   - "z" : optimize aggressively for size
3. `wasm-opt`
   - `-Os` : optimize for size
   - `-Oz` : optimize aggressively for size
   - `-O` : optimize for speed
   - `-O3` : optimize aggressively for speed

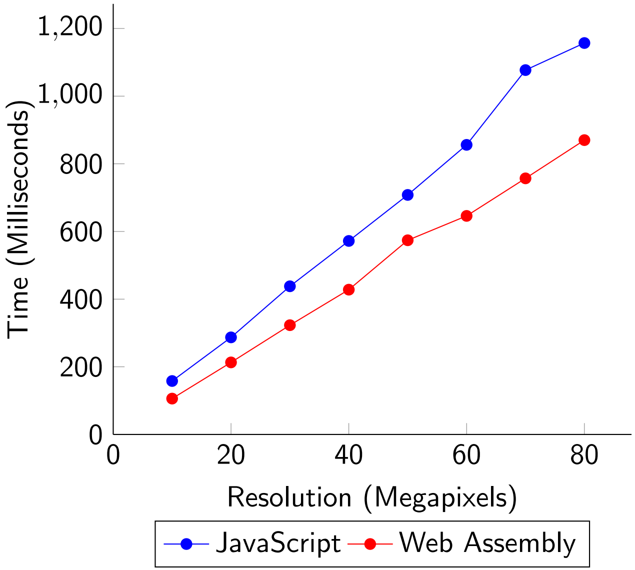
Web Assembly Optimizations - Time



Web Assembly Optimizations - Size



Verifying the results

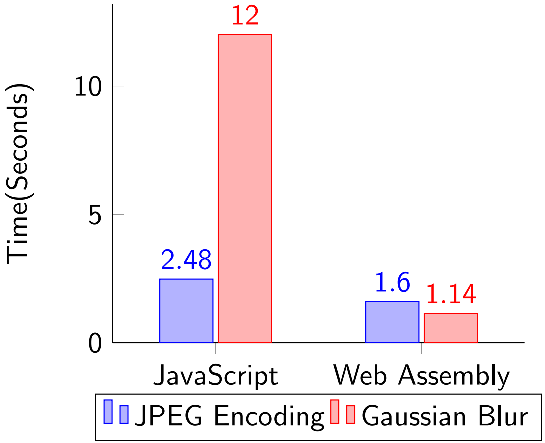


Results

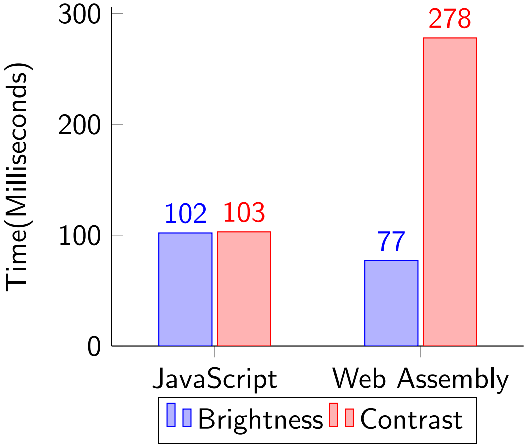
Interesting metrics

- Run time
- Memory consumption

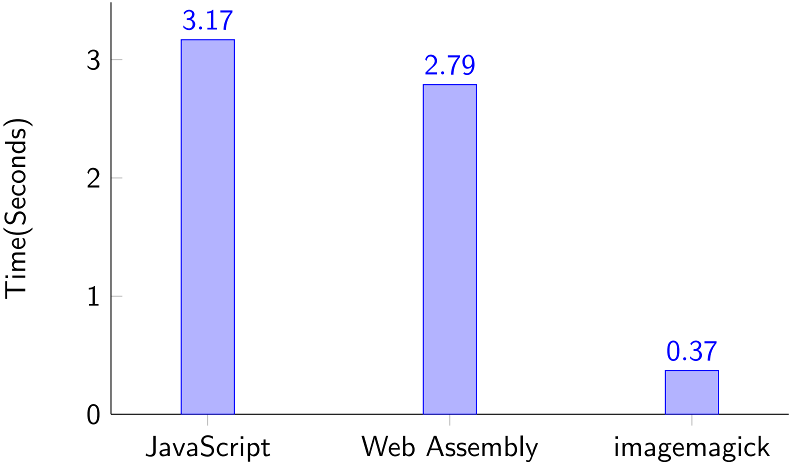
Complex Algorithms



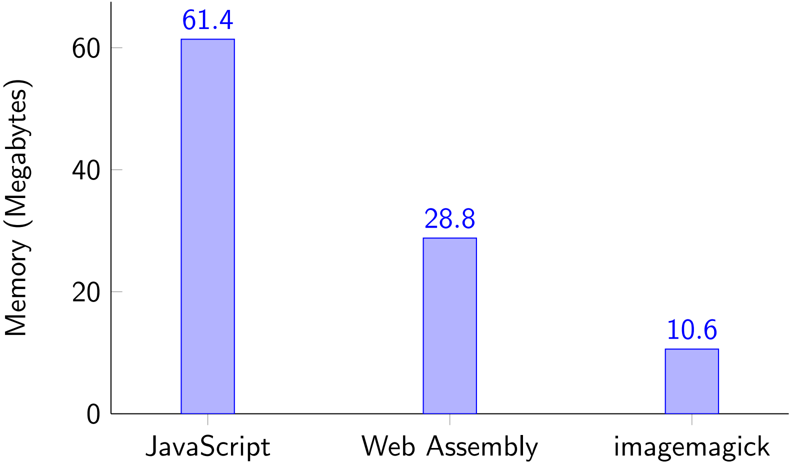
Simple Algorithms



Time for the full process



Memory consumption of the full process



Evaluation

- ✓ Faster
- ✓ Lower memory consumption
- ✓ Static types
- ✗ Static types
- ✗ Slower than native
- ✗ Need to use multiple languages
- ✗ Libraries have had less development

Further Work

- WebGPU [9]
- Different methods
- Different languages

References I

[1] Andreas Haas et al. "Bringing the web up to speed with WebAssembly". In: *Proceedings of the 38th ACM SIGPLAN Conference on Programming Language Design and Implementation*. 2017, pp. 185–200.

[2] Joe Haddad. *Remove sharp for wasm variant*. Feb. 2021. URL: https://github.com/vercel/next.js/pull/22253.

[3] Evan Wallace. *WebAssembly cut Figma's load time by 3x*. en. URL: https://www.figma.com/blog/webassembly-cut-figmas-load-time-by-3x/ (visited on 10/28/2020).

[4] *How We Used WebAssembly To Speed Up Our Web App By 20X (Case Study)*. en. Apr. 2019. URL: https://www.smashingmagazine.com/2019/04/webassembly-speed-web-app/ (visited on 11/27/2020).

References II

[5] Abhinav Jangda et al. "Not so fast: analyzing the performance of webassembly vs. native code". In: *2019 {USENIX} Annual Technical Conference ({USENIX}{ATC} 19)*. 2019, pp. 107–120.

[6] Statcounter. *Browser Market Share Worldwide*. 2021. URL: https://gs.statcounter.com/browser-market-share (visited on 04/09/2021).

[7] *INFORMATION TECHNOLOGY – DIGITAL COMPRESSION AND CODING OF CONTINUOUS-TONE STILL IMAGES – REQUIREMENTS AND GUIDELINES*. The International Telegraph and Telephone Consulative Committee. 1993.

[8] Cabeen Ken and Gent Peter. "Image compression and the discrete cosine transform". In: *Math45 College of the Redwoods* (1998).

References III

[9] GPU for the Web Community Group. *WebGPU*. Standard. W3C, 2021. URL: https://gpuweb.github.io/gpuweb/.