Tracking Library for the Web

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Outline

Outline

Motivation

- The web browser environment is evolving fast
- Phones and notebooks devices have embedded web browser
- Entertainment solutions are gaining space on the web
- Vision is an accurate and low-cost solution

Problem definition

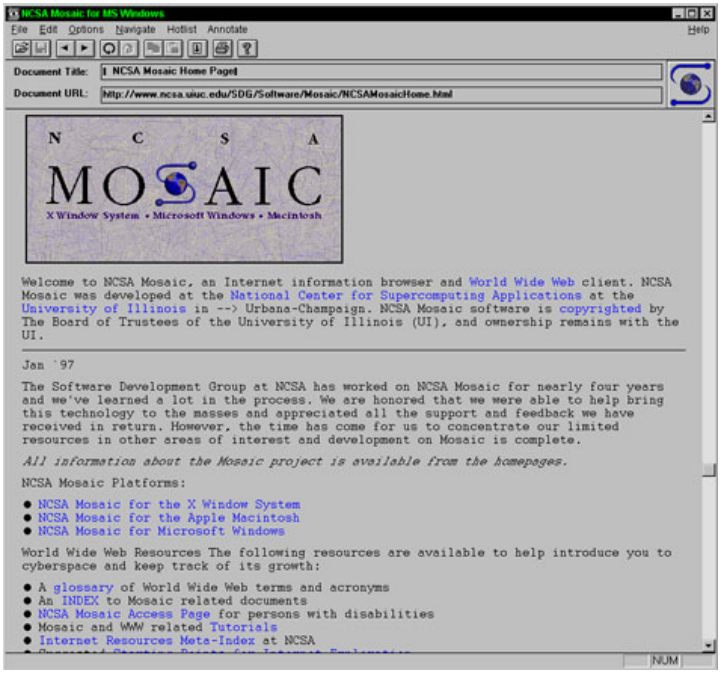
- Visual tracking requires video capturing and processing
- Video processing requires high computational complexity
- JavaScript is a language interpreted by all web browsers
- Interpreted languages have limited computational power

Objectives

- Facilitate user interaction with the web browser
- Accelerate the use of visual tracking in commercial products
- Implement a cross-platform tracking library for the web

Outline

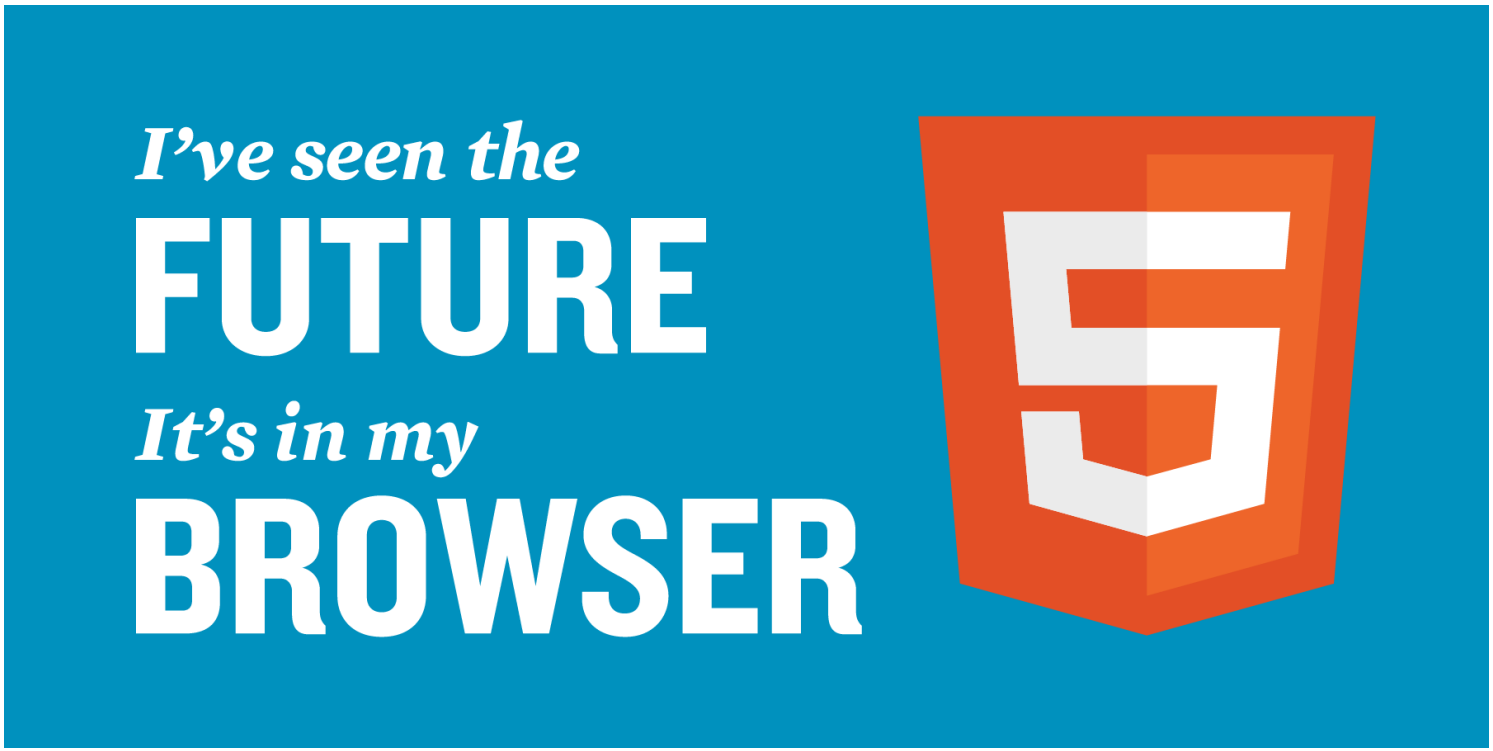
The beginning of the web



The beginning of the web

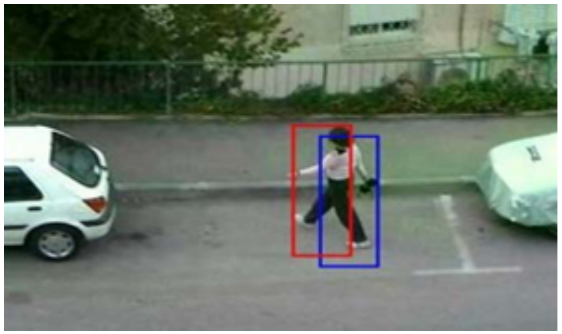
- Plain text and images were the most advanced features
- In 1994, the World Wide Web Consortium (W3C) was founded
- Companies were able to contribute to the W3C specifications
- Today's web is a result of the ongoing efforts of an open web

The modern web

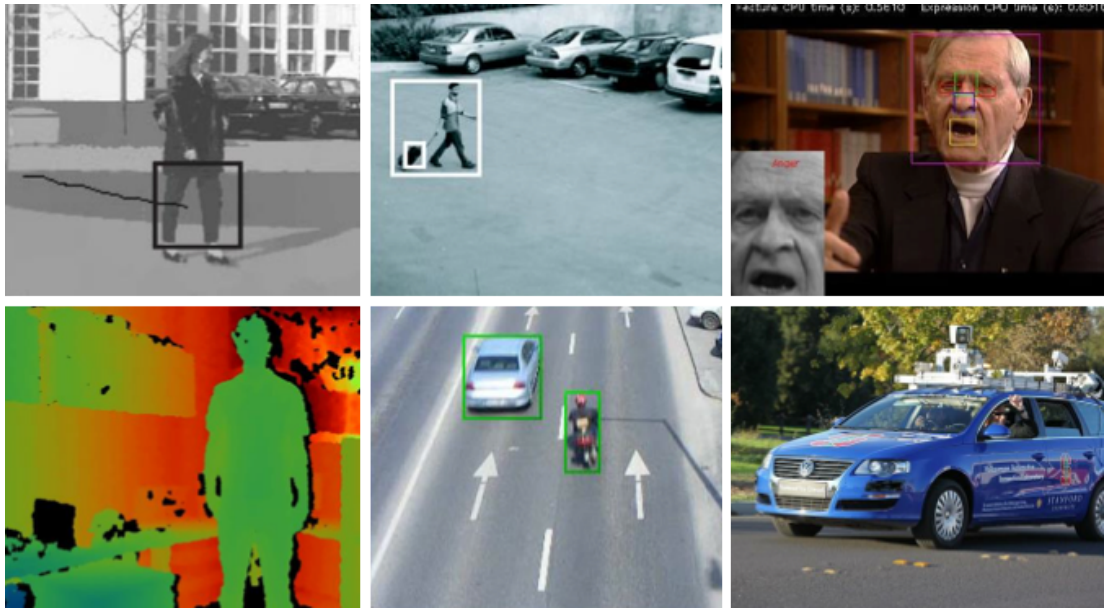


Browser technologies

Visual tracking

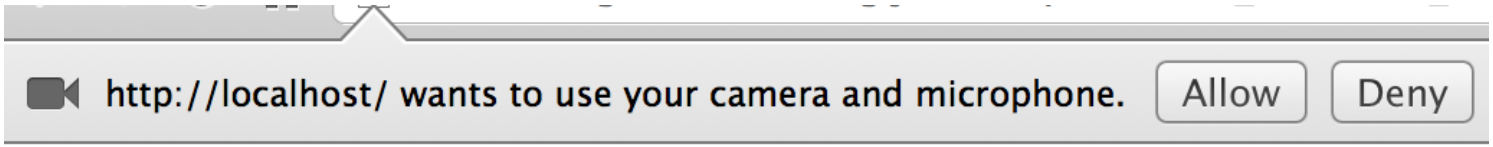


Visual tracking



Visual tracking workflow on the web

1. Request user web-cam access



1. Request user web-cam access

getUserMedia

<video>

[0 0 0 0 0 0 1 1 1 0 0 1 1 1 0 0 1 1 1]
[r g b a r g b a r g b a r g b a r g b a]

<canvas>

2. Capture web-cam stream

2. Capture web-cam stream

```
1
2       <script>
3         navigator.getUserMedia({ video: true }, function(localMediaStream) {
4           // Stream captured
5         }, onFail);
6       </script>
```

2. Capture web-cam stream

getUserMedia

<video>

[0 0 0 0 0 0 1 1 1 0 0 1 1 1 0 0 1 1 1]
[r g b a r g b a r g b a r g b a r g b a]

<canvas>

3. Reproduce web-cam stream into the video

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```
1
2     <video autoplay></video>
3     <script>
4       var video = document.querySelector('video');
5       navigator.getUserMedia({video: true}, function(localMediaStream) {
6           video.src = window.URL.createObjectURL(localMediaStream);
7           video.onloadedmetadata = function(e) { alert('Ready to go.') };
8       }, onFail);
9     </script>
```

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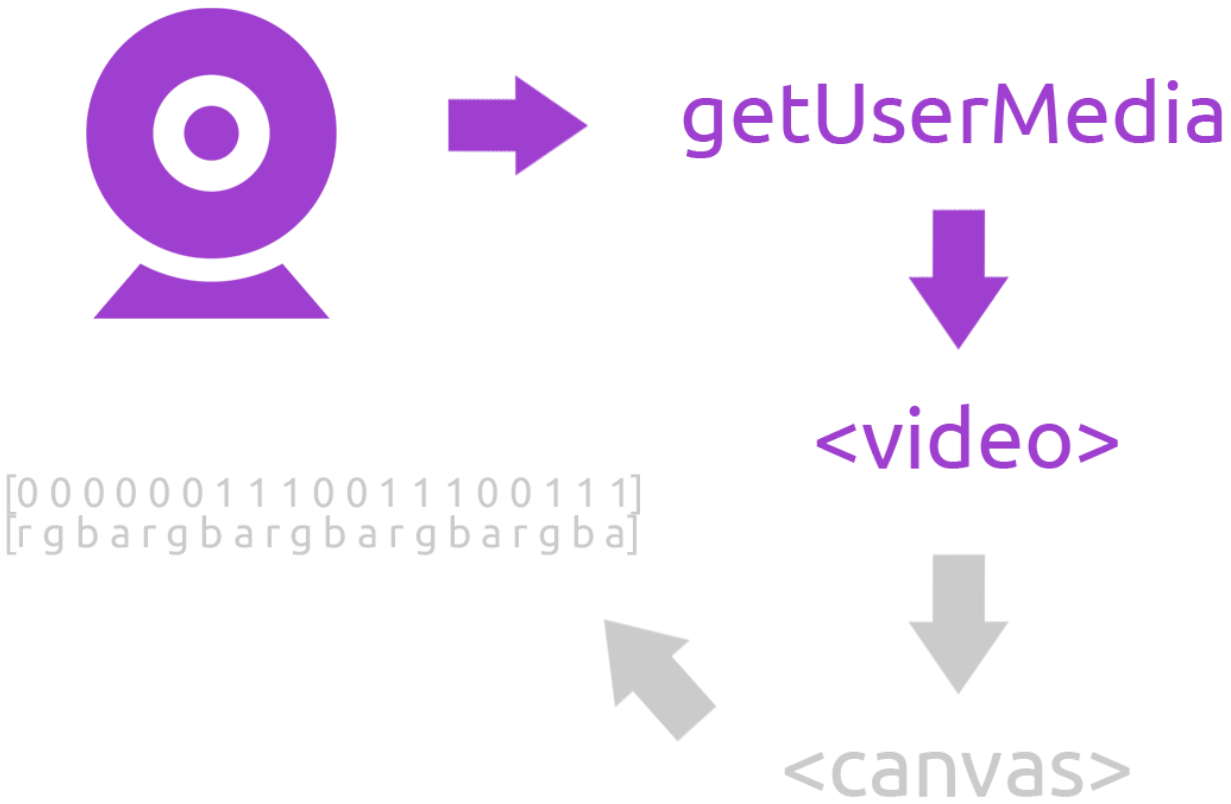
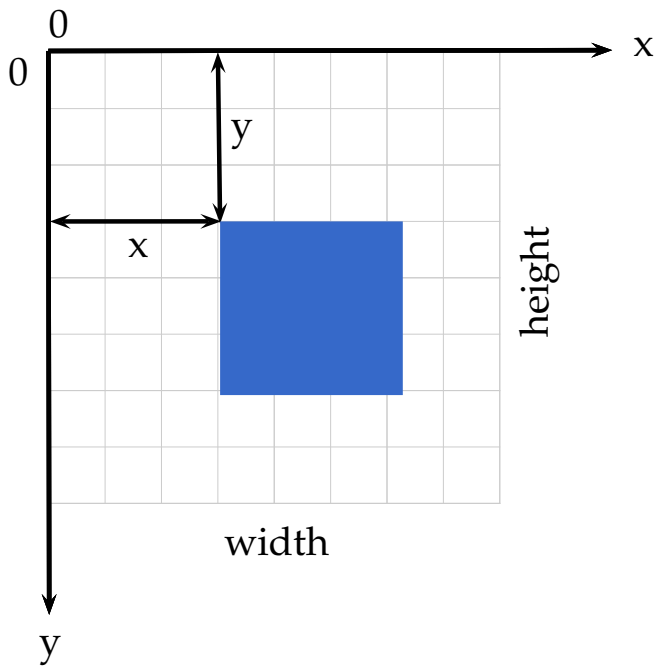


4. Process video data using canvas



4. Process video data using canvas

getUserMedia

<video>

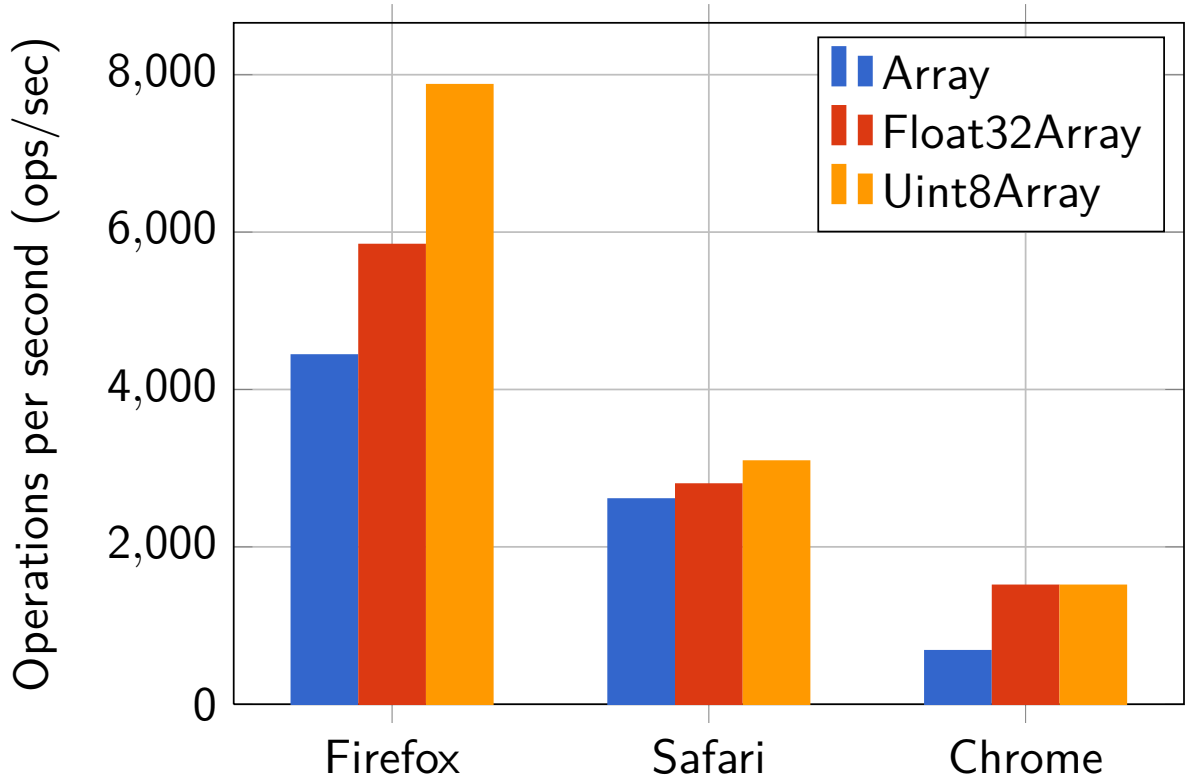
[0 0 0 0 0 0 1 1 1 0 0 1 1 1 0 0 1 1 1]
[r g b a r g b a r g b a r g b a r g b a]

<canvas>

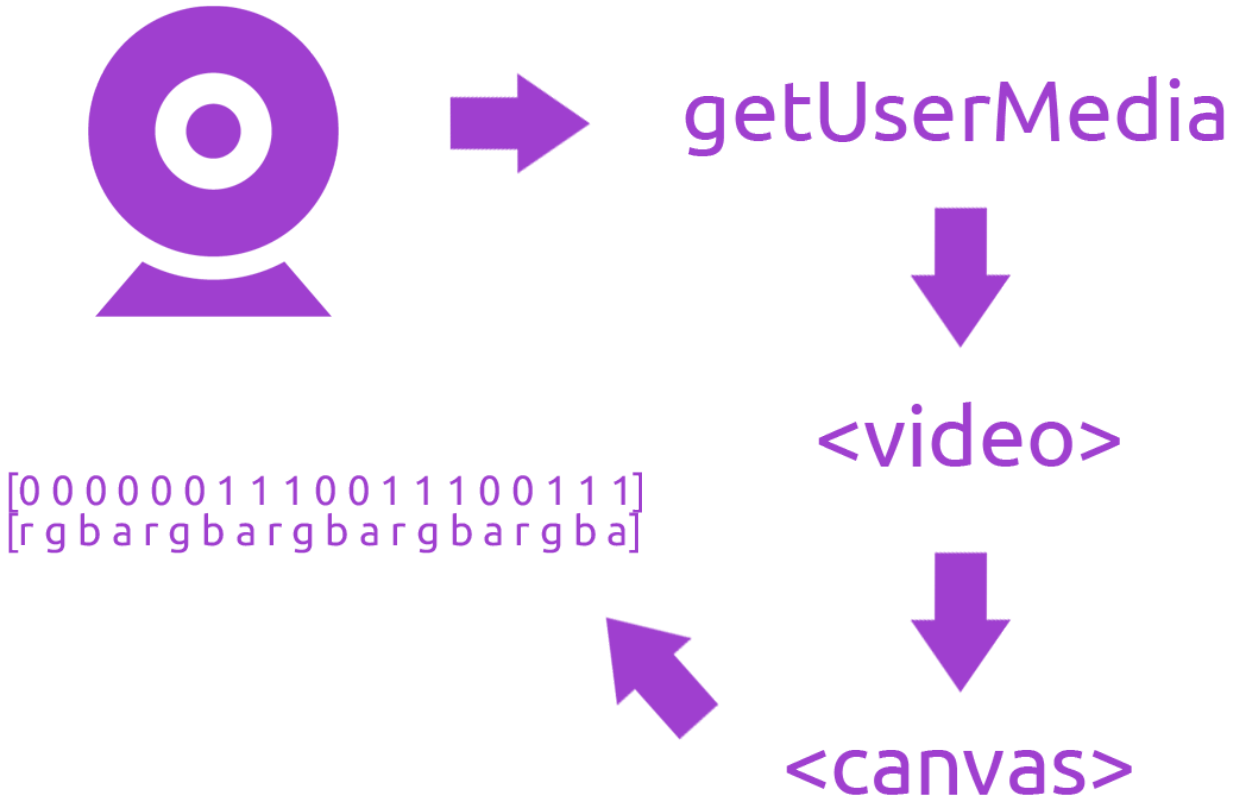
5. Access canvas data using JavaScript typed arrays

- In the past, raw data was accessed as a string
- Browsers needed a quick way to manipulate raw binary data
- Typed data structures were added to JavaScript
- JavaScript-typed arrays access raw binary more efficiently

5. Access canvas data using JavaScript typed arrays



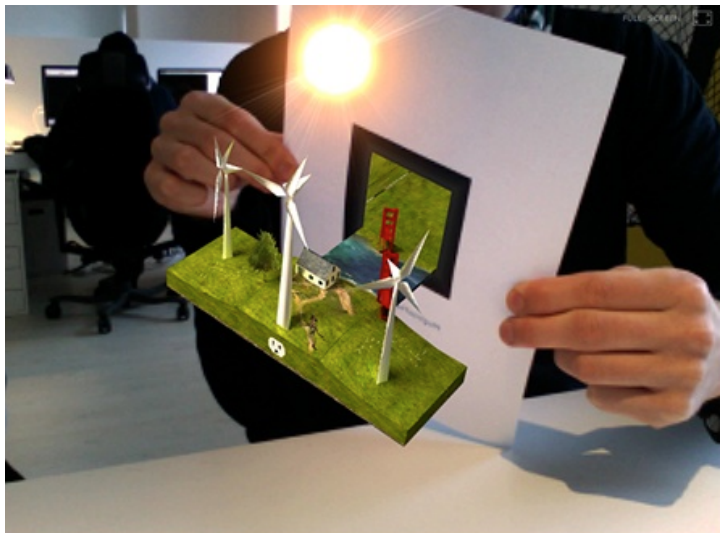
5. Access canvas data using JavaScript typed arrays



Outline

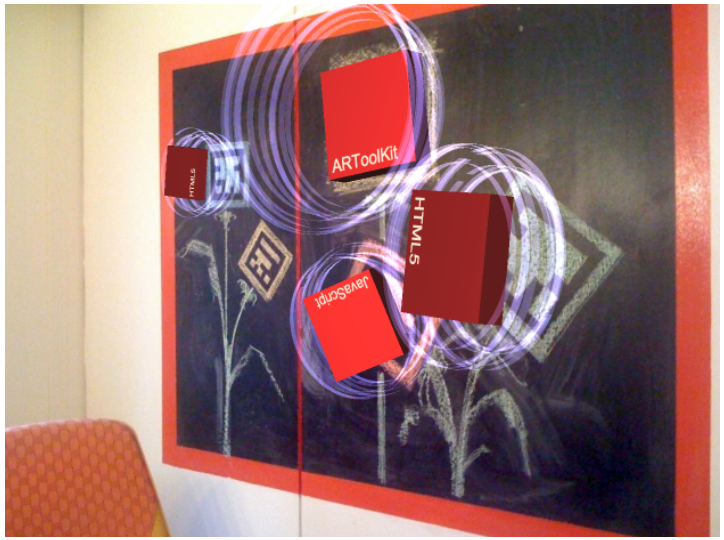
Related work

- FLARToolKit: a port of ARToolKit marker tracking library to ActionScript



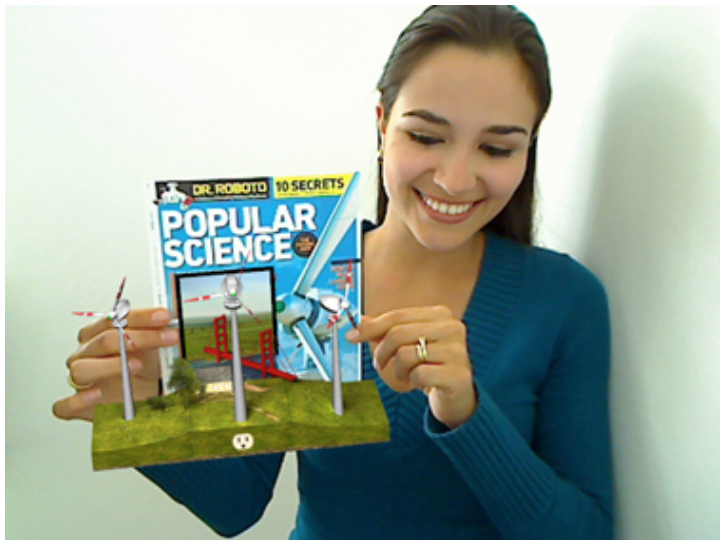
Related work

- JSARToolkit: is a JavaScript port of FLARToolKit

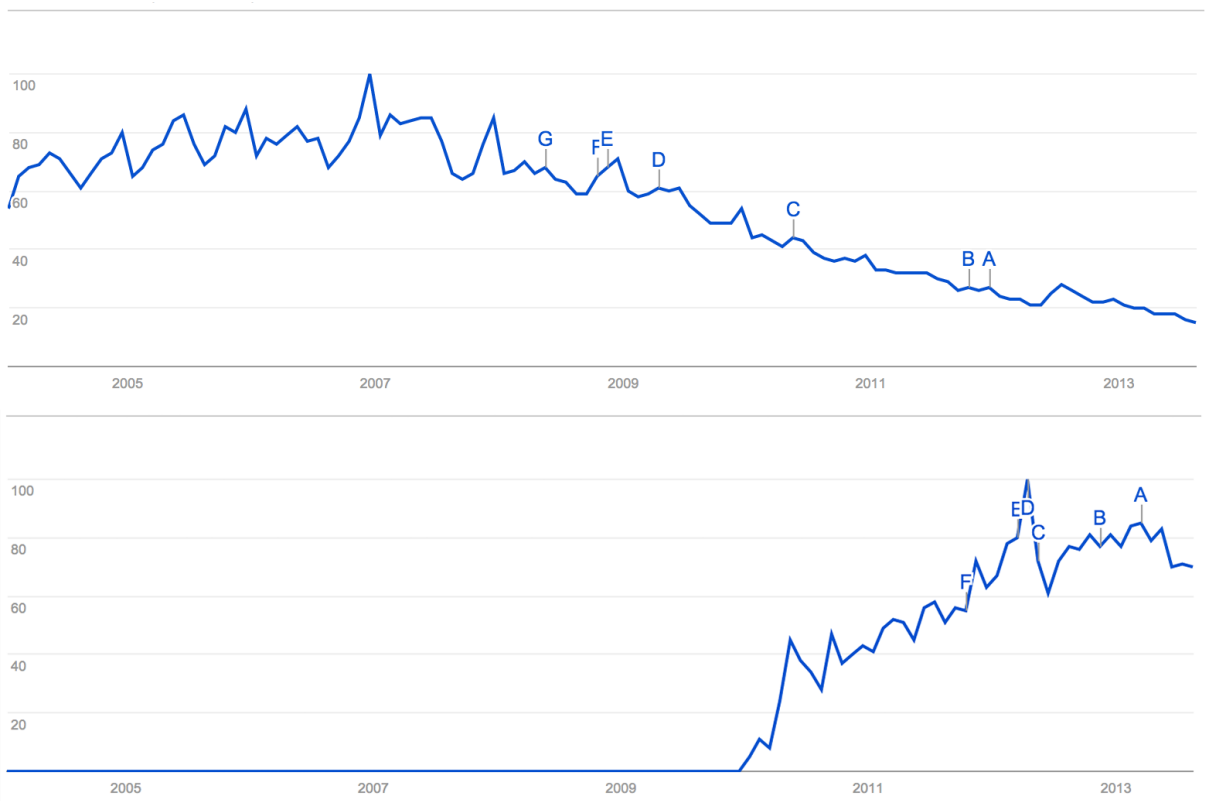


Related work

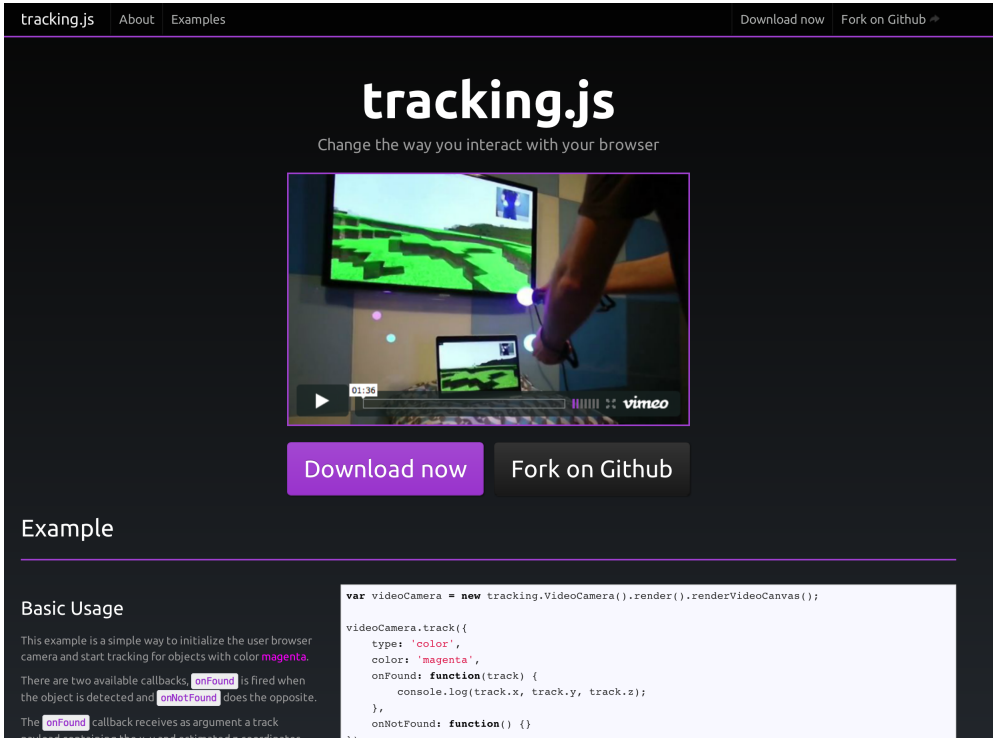
- Unifeye Viewer: a robust markerless tracking solution for the web to ActionScript



Flash vs HTML5



tracking.js


tracking.js
About
Examples
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tracking.js
Change the way you interact with your browser
01:36
vimeo
Download now
Fork on Github
Example
Basic Usage
This example is a simple way to initialize the user browser camera and start tracking for objects with color magenta.
There are two available callbacks, onFound is fired when the object is detected and onNotFound does the opposite.
The onFound callback receives as argument a track
var videoCamera = new tracking.VideoCamera().render().renderVideoCanvas();
videoCamera.track({
type: 'color',
color: 'magenta',
onFound: function(track) {
console.log(track.x, track.y, track.z);
},
onNotFound: function() {}

tracking.js

Tracking library for the web

Common infrastructure to develop visual tracking applications and to accelerate the use of those techniques on the web in commercial products.

Library features

1. Color tracking

Library features

1. Color tracking
2. Rapid object detection (Viola Jones)

Library features

1. Color tracking
2. Rapid object detection (Viola Jones)
3. Markerless tracking algorithm

Color tracking algorithm

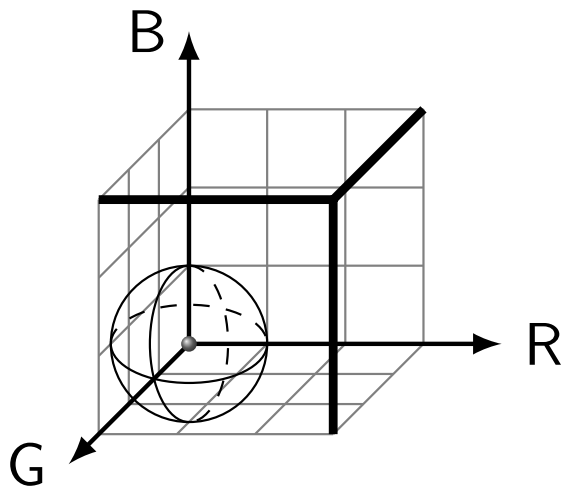
Figure : © http://www.flickr.com/photos/laynecom/8674644879/

Color tracking algorithm

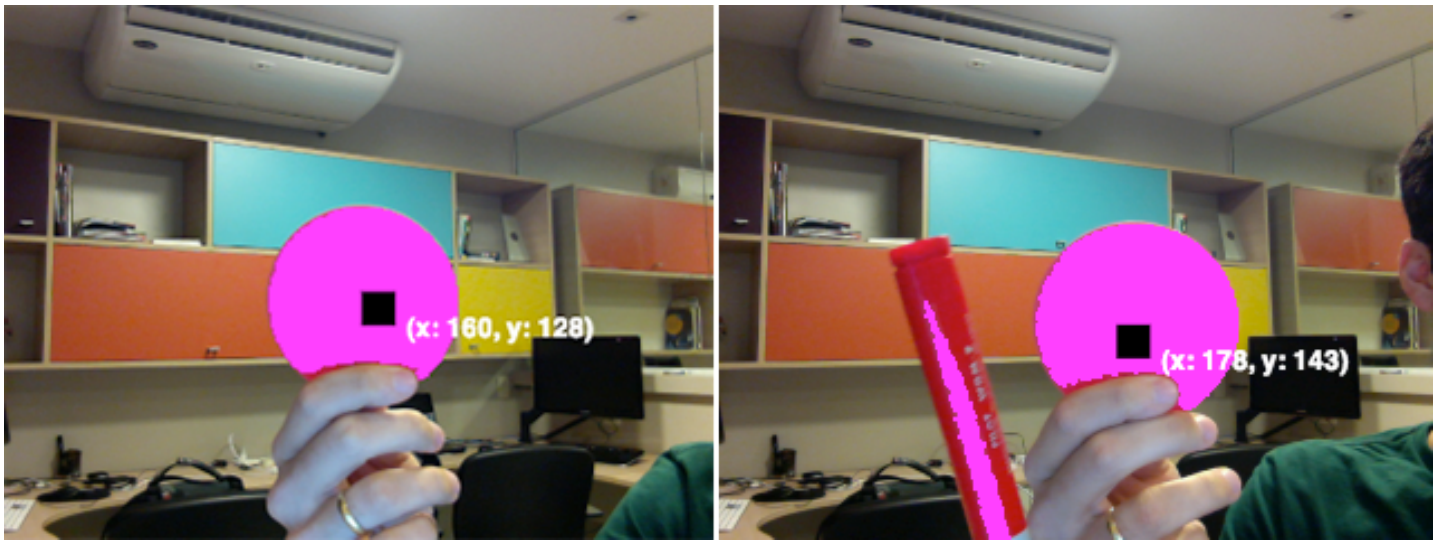
```
1  var videoCamera = new tracking.VideoCamera();
2  videoCamera.track({
3      type: 'color',
4      color: 'magenta',
5      onFound: function(track) {
6          // do your logic here.
7      }
8  });
```

Color tracking algorithm - Color difference evaluation

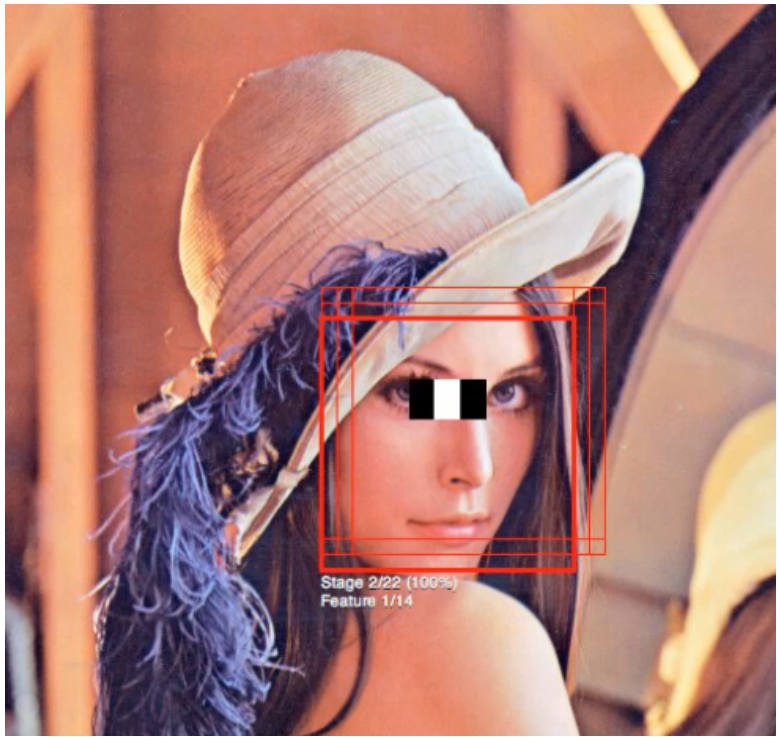
$$\|C_1 - C_2\| = \sqrt{(C_{1,R} - C_{2,R})^2 + (C_{1,G} - C_{2,G})^2 + (C_{1,B} - C_{2,B})^2}$$



Color tracking algorithm - Color blob detection



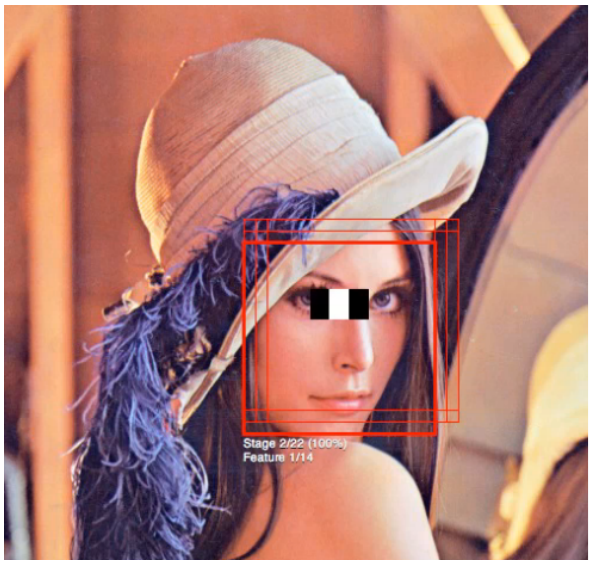
Rapid object detection (Viola Jones)

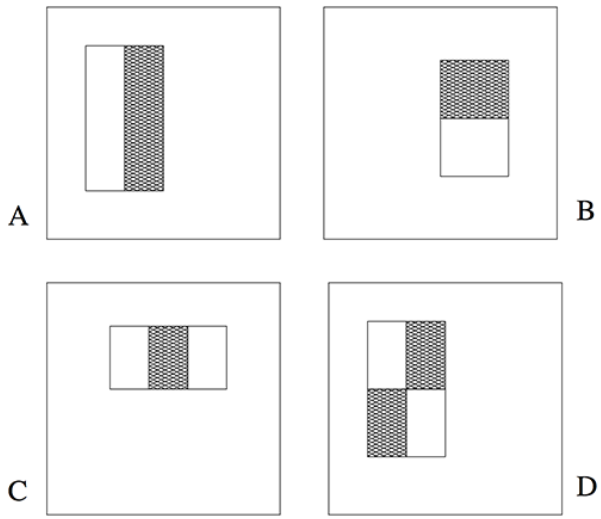


Rapid object detection (Viola Jones)

```
1  var videoCamera = new tracking.VideoCamera();
2  videoCamera.track({
3      type: 'human',
4      data: 'frontal_face',
5      onFound: function(track) {
6          // do your logic here.
7      }
8  });
```

Rapid object detection (Viola Jones)





Rapid object detection (Viola Jones)

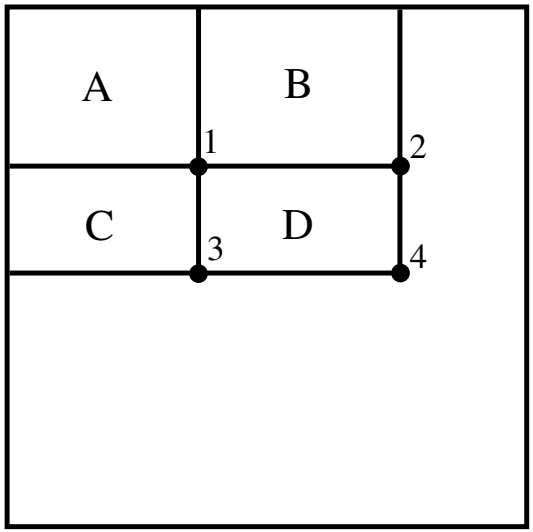
Integral Image

Rectangle features can be computed very rapidly using an intermediate representation for the image which we call the integral image.

The integral image at location x, y contains the sum of the pixels above and to the left of x, y, inclusive

$$ii(x, y) = \sum_{x' \leq x, y' \leq y} i(x', y')$$

Rapid object detection (Viola Jones)



Rapid object detection (Viola Jones)

Scanning detector algorithm

1. Create or scale a 20×20 squared block by 1.25 per iteration
2. Loop the block by Δ pixels over the image
3. For each block location, loop the tree and evaluate each stage
4. Positive stage evaluate next stage, otherwise stops the loop
5. If all stages were positive store the rectangle
6. Once the tree is done, group the overlapping rectangles
7. Find the best rectangle of each the group (merging phase)

Rapid object detection (Viola Jones)

1. Optimization: merging phase

Rectangles are used partitioned into a disjoint set data structure. On this work it was replaced by an alternative called Minimum Neighbor Area Grouping.

Rapid object detection (Viola Jones)

1. Optimization: merging phase

Rectangles are used partitioned into a disjoint set data structure. On this work it was replaced by an alternative called Minimum Neighbor Area Grouping.

2. Optimization: training data

OpenCV uses XML to store training data. This work proposes the usage of row-major order typed arrays.

Rapid object detection (Viola Jones)

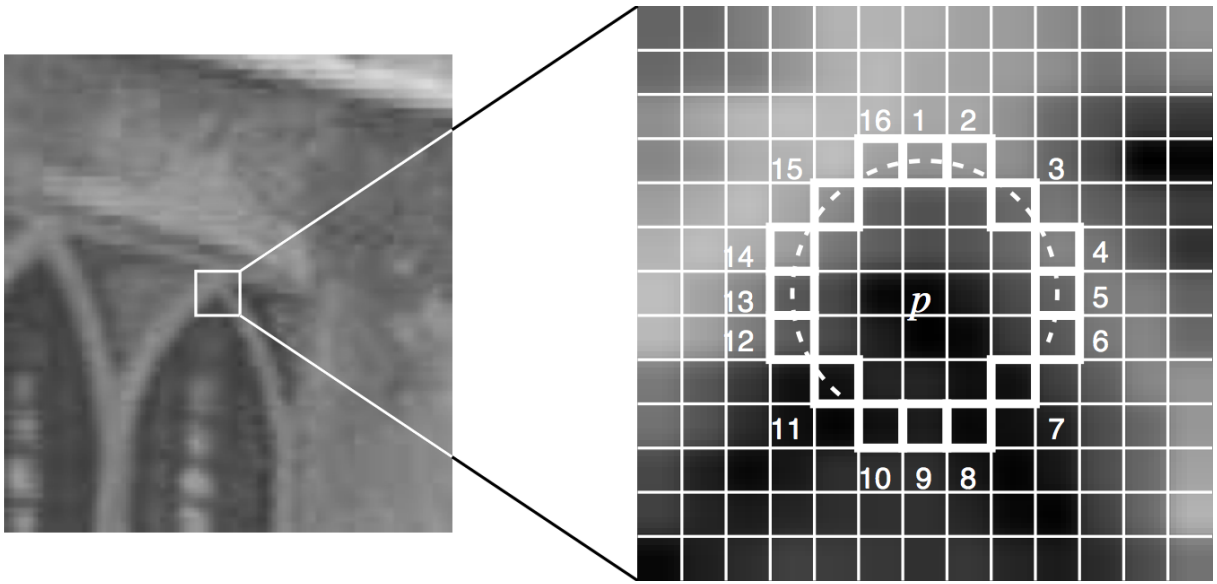
haarcascade_frontalface_alt.xml

```
<haarcascade_frontalface_alt type_id="opencv-haar-classifier">
  <size>20 20</size>
  <stages>
    <_>
      <!-- stage 0 -->
      <trees>
        <_>
          <!-- tree 0 -->
          <_>
            <!-- root node -->
            <feature>
              <rects>
                <_>3 7 14 4 -1.</_>
                <_>3 9 14 2 2.</_></rects>
              <tilted>0</tilted></feature>
            <threshold>4.0141958743333817e-003</threshold>
            <left_val>0.0337941907346249</left_val>
            <right_val>0.8378106951713562</right_val></_></_>
        <_>
          <!-- tree 1 -->
          <_>
            <!-- root node -->
```

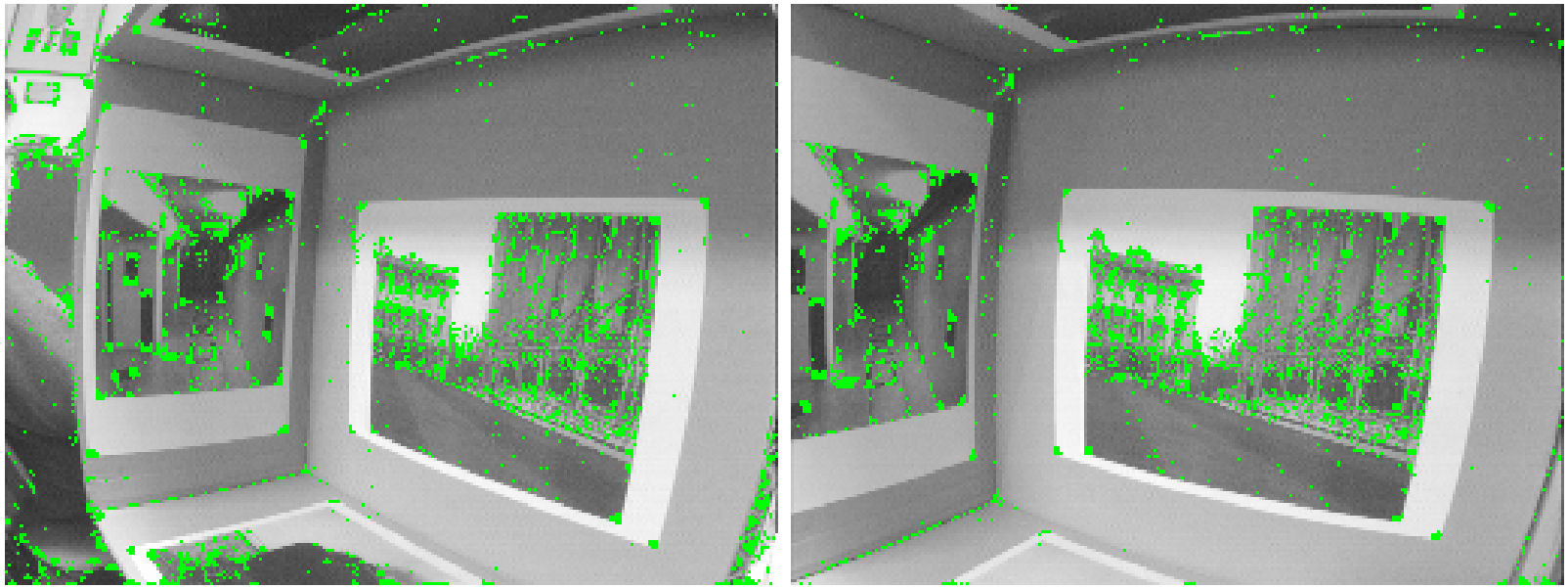
frontal_face.js

```
[[-1,0.822689414024353,[[3,7,14,4,-1,3,9,14,2,2,0.004014195874333382,0.0337941907346249,
0.8378106951713562],[1,2,18,4,-1,7,2,6,4,3,0.0151513395830989,0.1514132022857666,0.
7488812208175659],[1,7,15,9,-1,1,10,15,3,3,0.004210993181914091,0.0900492817163467,0
.6374819874763489]]],[0,6.956608772277832,[[5,6,2,6,-1,5,9,2,3,2,0.
0016227109590545297,0.0693085864186287,0.7110946178436279],[7,5,6,3,-1,9,5,2,3,3,0.
002290664939209819,0.1795803010463715,0.6668692231178284],[4,0,12,9,-1,4,3,12,3,3,0.
005002570804208517,0.1693672984838486,0.6554006934165955],[6,9,10,8,-1,6,13,10,4,2,0
.007965989410877228,0.5866332054138184,0.0914145186543465],[3,6,14,8,-1,3,10,14,4,2,
-0.003522701095789671,0.1413166970014572,0.6031895875930786],[14,1,6,10,-1,14,1,3,10
,2,0.0366676896810532,0.3675672113895416,0.7920318245887756],[7,8,5,12,-1,7,12,5,4,3
,0.009336147457361221,0.6161385774612427,0.2088509947061539],[1,1,18,3,-1,7,1,6,3,3,
0.008696131408214569,0.2836230993270874,0.6360273957252502],[1,8,17,2,-1,1,9,17,1,2,
0.0011488880263641477,0.2223580926656723,0.5800700783729553],[16,6,4,2,-1,16,7,4,1,2
,-0.002148468978703022,0.2406464070081711,0.5787054896354675],[5,17,2,2,-1,5,18,2,1,
2,0.002121906029060483,0.5559654831886292,0.136223703622818],[14,2,6,12,-1,14,2,3,12
,2,-0.0939491465687752,0.8502737283706665,0.4717740118503571],[4,0,4,12,-1,4,0,2,6,2
,6,6,2,6,2,0.0013777789426967502,0.5993673801422119,0.2834529876708984],[2,11,18,8,-
1,8,11,6,8,3,0.0730631574988365,0.4341886043548584,0.7060034275054932],[5,7,10,2,-1,
5,8,10,1,2,0.0003676738997455686 3,0.3027887940406799,0.6051574945449829],[15,11,5,3,
-1,15,12,5,1,3,-0.0060479710809886456,0.17984339594841,0.5675256848335266]]],[1,9.
498542785644531,[[5,3,10,9,-1,5,6,10,3,3,-0.0165106896311045,0.6644225120544434,0.
1424857974052429],[9,4,2,14,-1,9,11,2,7,2,0.002705249935388565,0.6325352191925049,0.
```

Feature detector (FAST)



Feature detector (FAST)



Feature detector (FAST)

1. Optimization: avoid machine learning

The steps required for machine learning involves extra math operations, such as *log*. The results were good without it.

Feature detector (FAST)

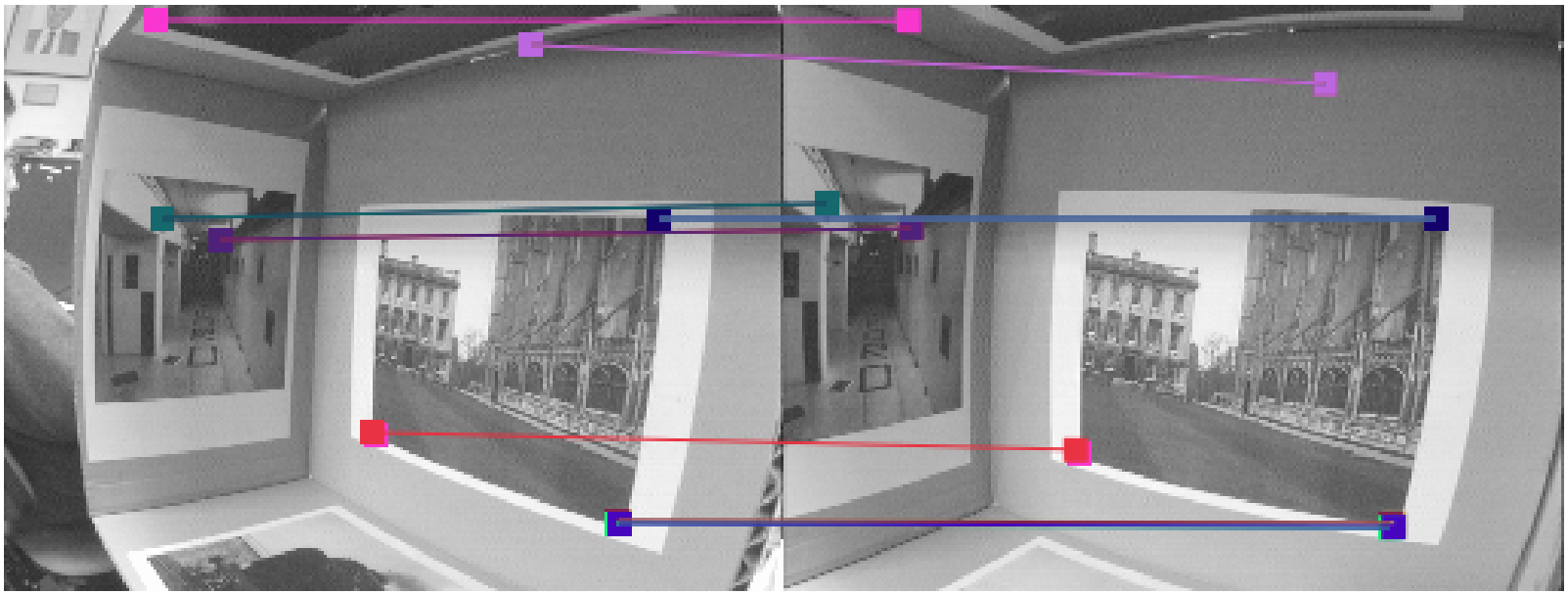
1. Optimization: avoid machine learning

The steps required for machine learning involves extra math operations, such as *log*. The results were good without it.

2. Optimization: avoid non-maximal suppression

To remove corners which have an adjacent corner requires extra access to the typed array.

Feature extractor (BRIEF)



Feature extractor (BRIEF)

To generate the binary strings it is defined the test τ on patch $\mathbf{p}$ of size $\mathbf{S} \times \mathbf{S}$ as:

$$\tau(\mathbf{p}; x, y) := \begin{cases} 1 & \text{if} \quad \mathbf{p(x)} < \mathbf{p(y)}, \\ 0 & \text{otherwise} \end{cases}$$

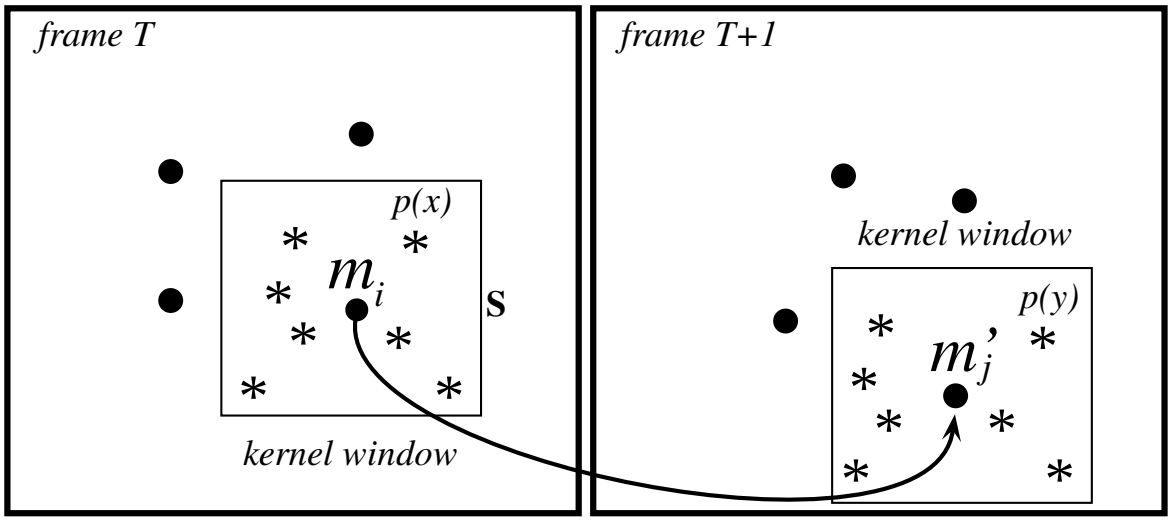
Feature extractor (BRIEF)

The n_d-dimensional bit-string is our BRIEF descriptor for each keypoint:

$$f_{n_d}(\mathbf{p}) := \sum_{1 \leq i \leq n_d} 2^{i-1} \tau(\mathbf{p}; x, y).$$

In this work $n_d = 128$ was used. The number of bytes required to store the descriptor can be calculated by $k = n_d/8$.

Feature extractor (BRIEF)



Feature extractor (BRIEF)

The weighted Hamming distance is computed by:

$$WHam(x, y) = \sum_{i=1}^{n} w_i(b_i(x) \otimes b_i(y))$$

$$b_1 = 0000000001...$$

$$b_2 = 0000000011...$$

$$b_1 \otimes b_2 = 0000000010...$$

$$WHam = 1$$

Feature extractor (BRIEF)

1. Optimization: avoid smoothing kernels

By pre-smoothing the patch, increases the stability and repeatability of the descriptors, but decreases performance.

Feature extractor (BRIEF)

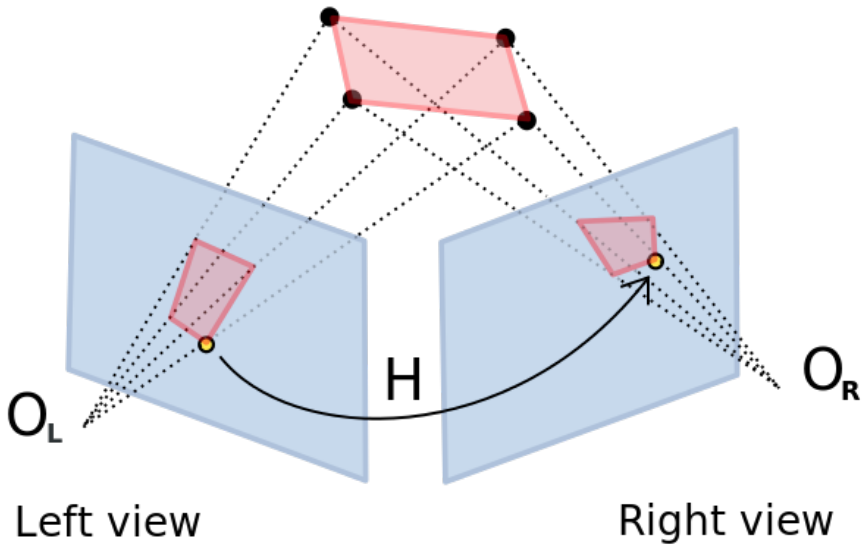
1. Optimization: avoid smoothing kernels

By pre-smoothing the patch, increases the stability and repeatability of the descriptors, but decreases performance.

2. Optimization: avoid Gaussian distribution

Computing the Gaussian distribution can be time consuming. Simply replaced by a uniform version of JavaScript Math.random().

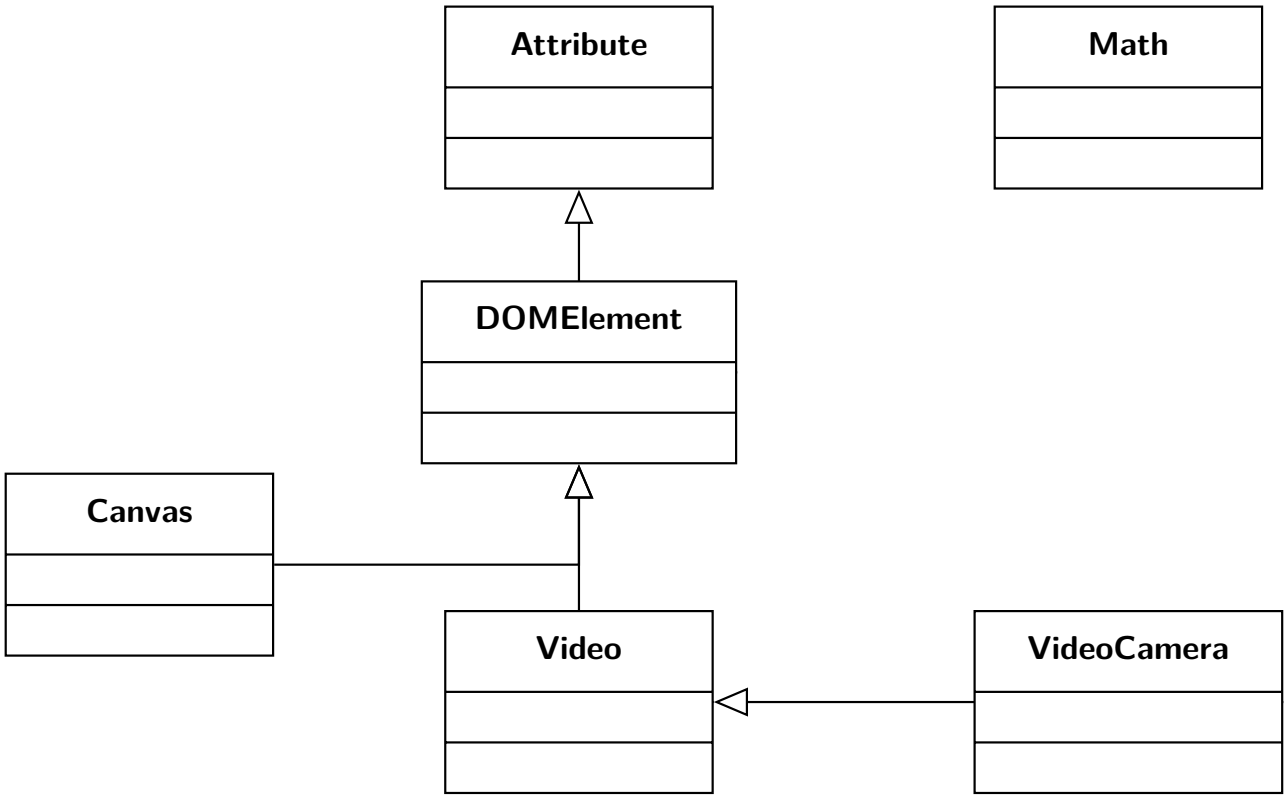
Homography estimation



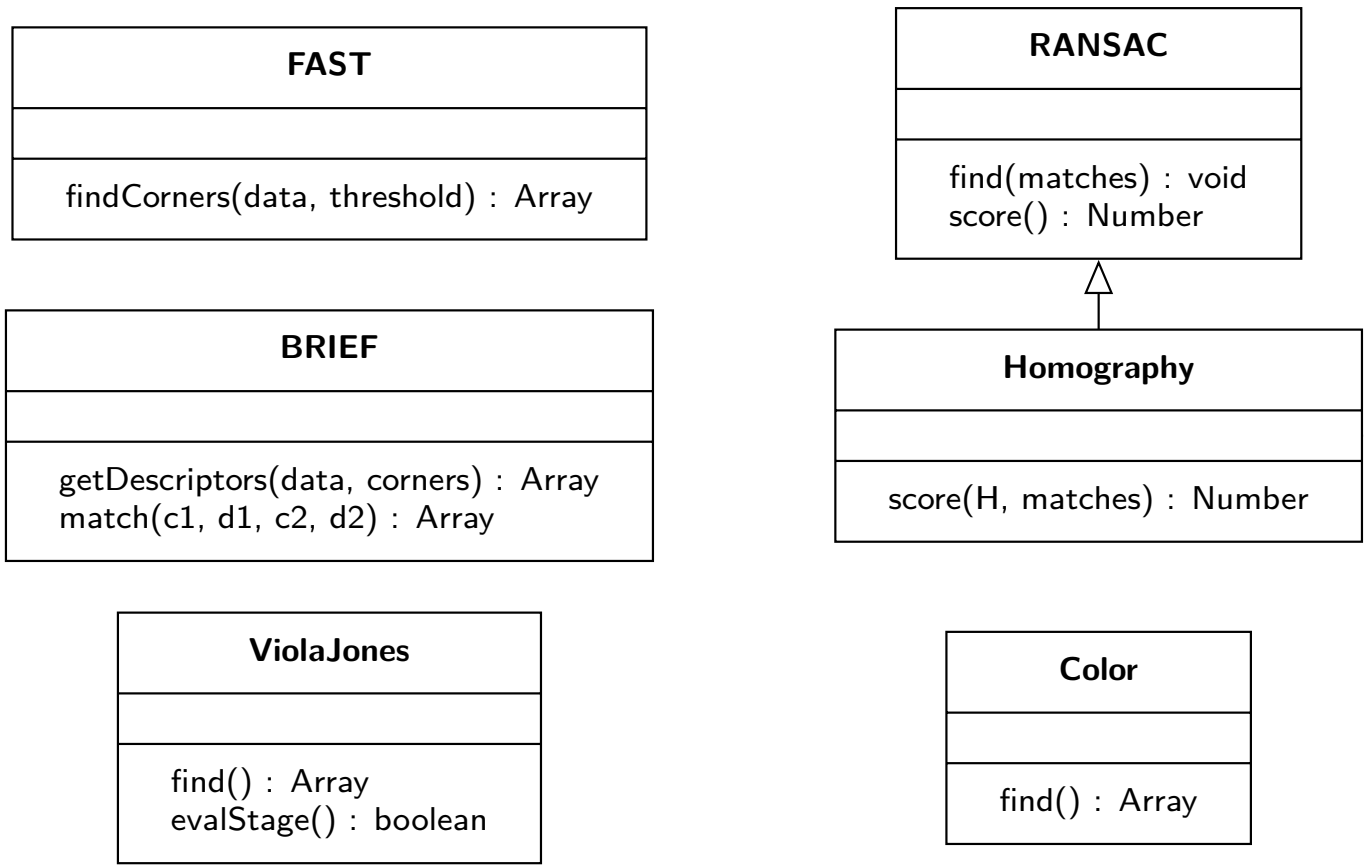
Random sample consensus (RANSAC)

RANSAC (Random Sample Consensus) is an iterative method to estimate parameters of a mathematical model from a set of observed data which contains outliers. It is the most commonly used robust estimation method for homographies.

Library modules - Base classes



Library modules - Visual tracking classes



Outline

Evaluation methodology

1. Examples

Evaluation methodology

1. Examples

2. Performance

Frames per second (FPS) metric. All tests were executed on Google Chrome browser version 28.0.1500.71, Mac OS X 10.8.3, 2.6 GHz Intel Core i7 16 GB 1600 MHz RAM.

Evaluation methodology

1. Examples

2. Performance

Frames per second (FPS) metric. All tests were executed on Google Chrome browser version 28.0.1500.71, Mac OS X 10.8.3, 2.6 GHz Intel Core i7 16 GB 1600 MHz RAM.

3. Partial occlusion robustness

Examples of how each technique behaves under partial occlusion.

Evaluation methodology

README.md

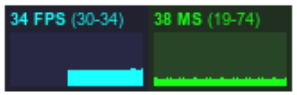
stats.js

JavaScript Performance Monitor

This class provides a simple info box that will help you monitor your code performance.

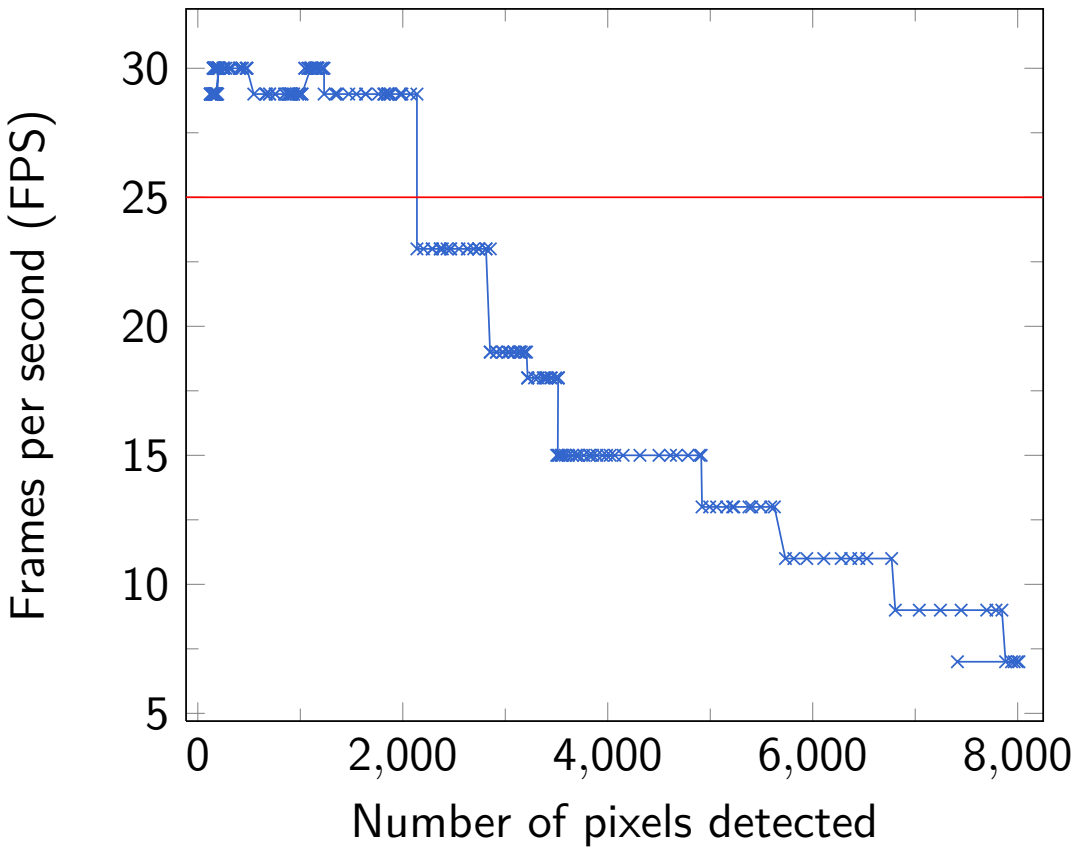
- **FPS** Frames rendered in the last second. The higher the number the better.
- **MS** Milliseconds needed to render a frame. The lower the number the better.

Screenshots

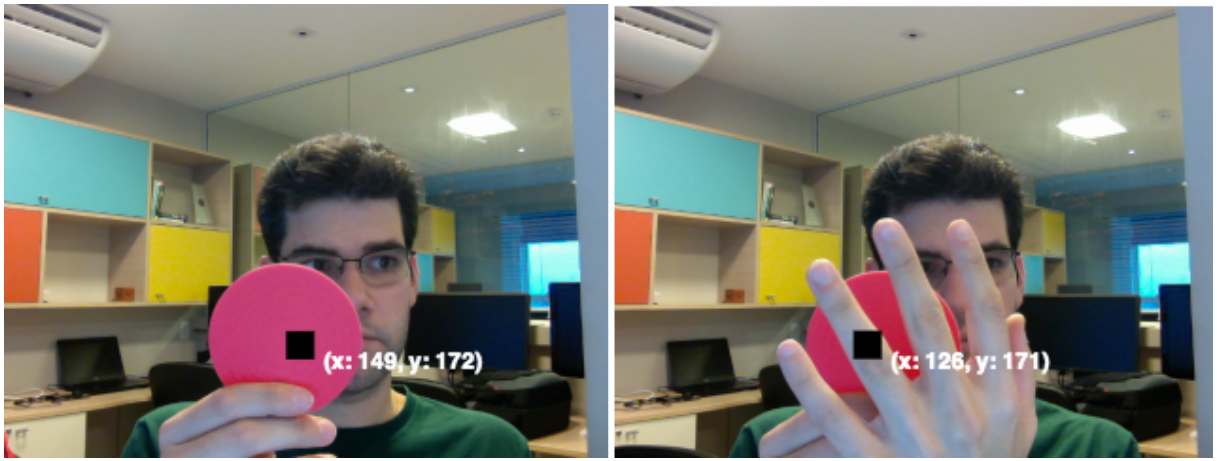


Examples

Performance

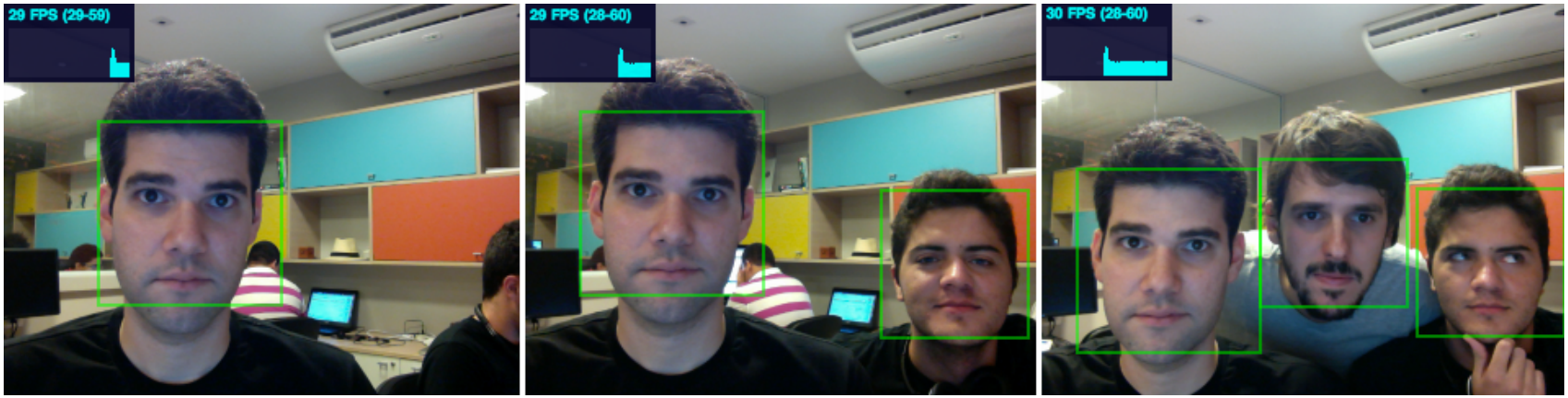


Oclusion robustness

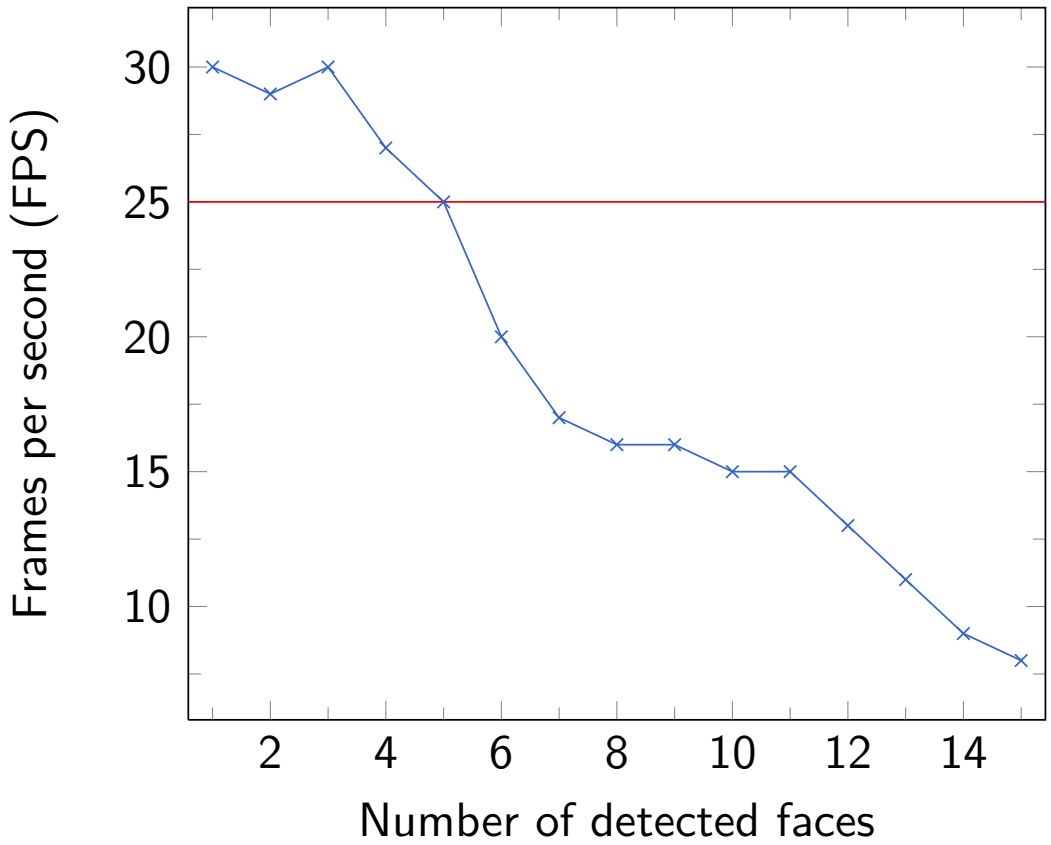


Examples

Examples

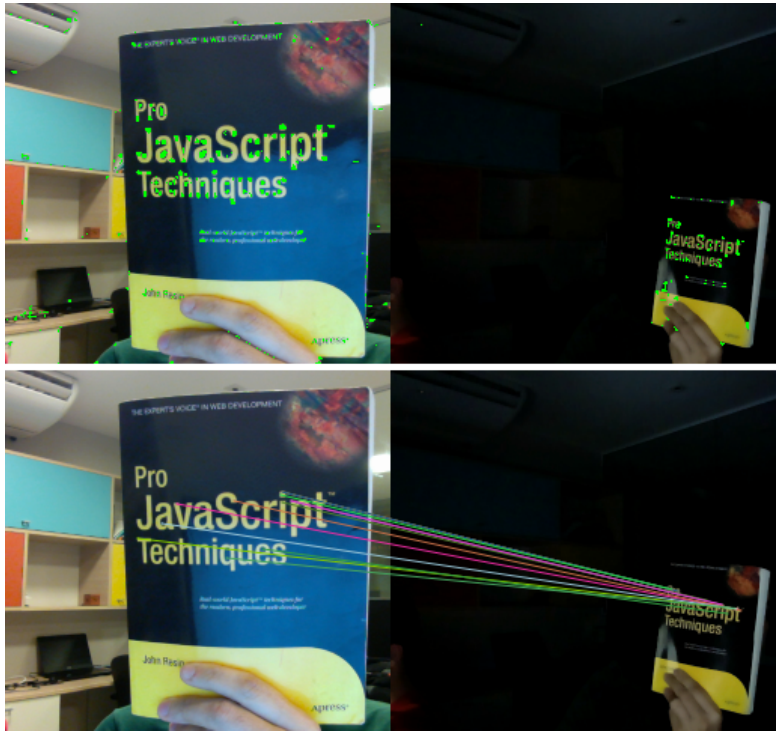


Performance



Oclusion robustness

Examples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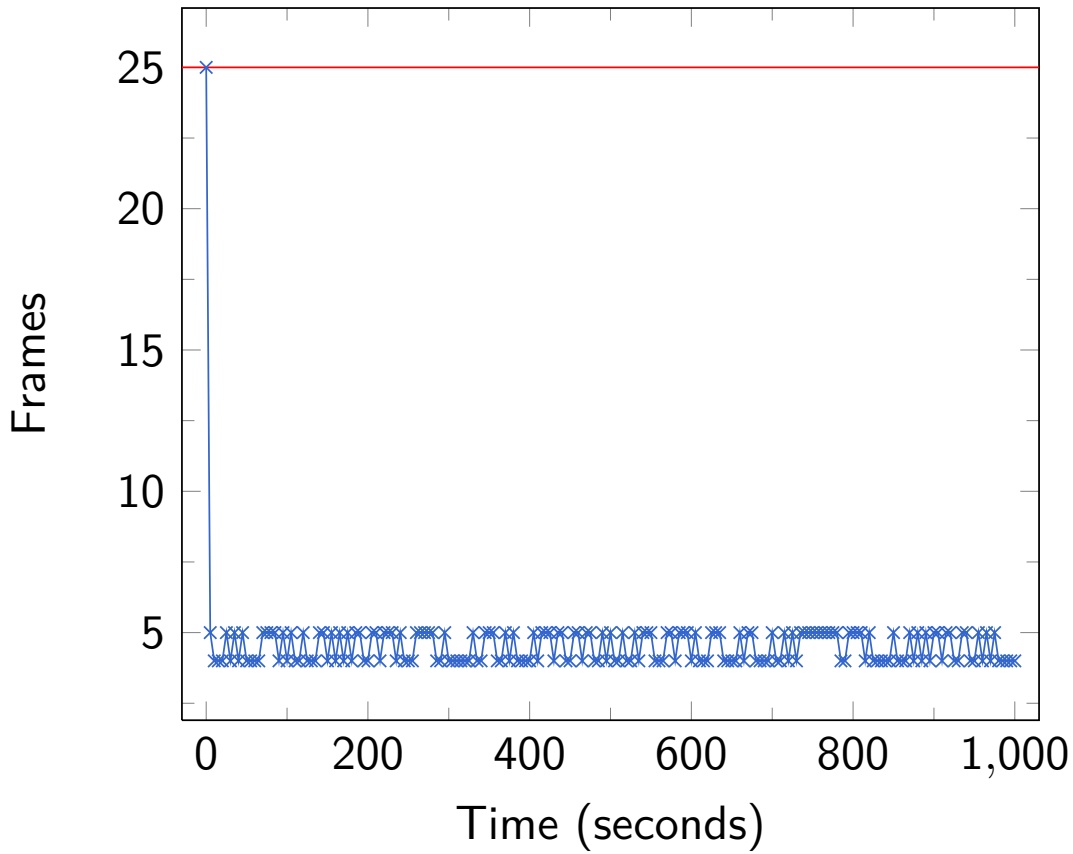


Oclusion robustness

Outline

Benefits of a JavaScript tracking solution

	OSAKit	*tracking.js* + color	*tracking.js* + face
Avg frame rate	25 FPS	30 FPS	25 FPS
Avg file size	22 MB	8 KB	187 KB
Avg load time (256 Kbps)	11 min	0.25 seconds	5 seconds

Contributions

- Academic material about web
- Pioneered a tracking library for the web called *tracking.js*
- Optimizations for existing techniques

Future work

- Publication about web browser concepts
- Publication comparing JavaScript tracking solutions with plugin-based and server-side solutions
- Double Exponential Smoothing technique
- Perspective-*n*-Point problem (P*n*P) calculation
- Image processing layer capable of transformations and filters

Website

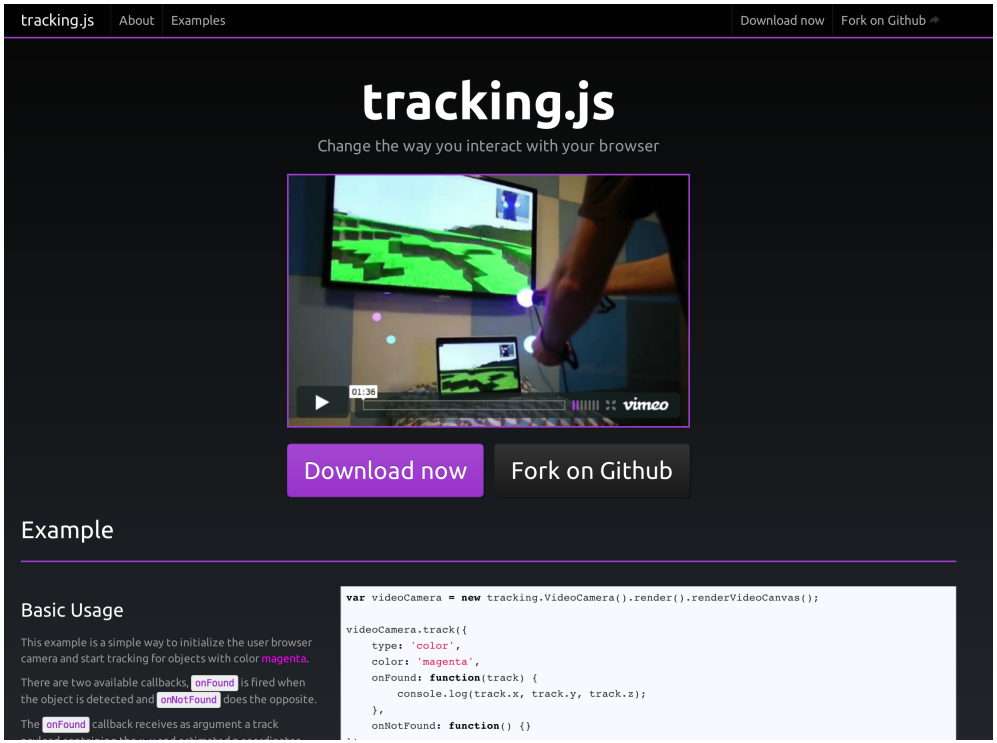
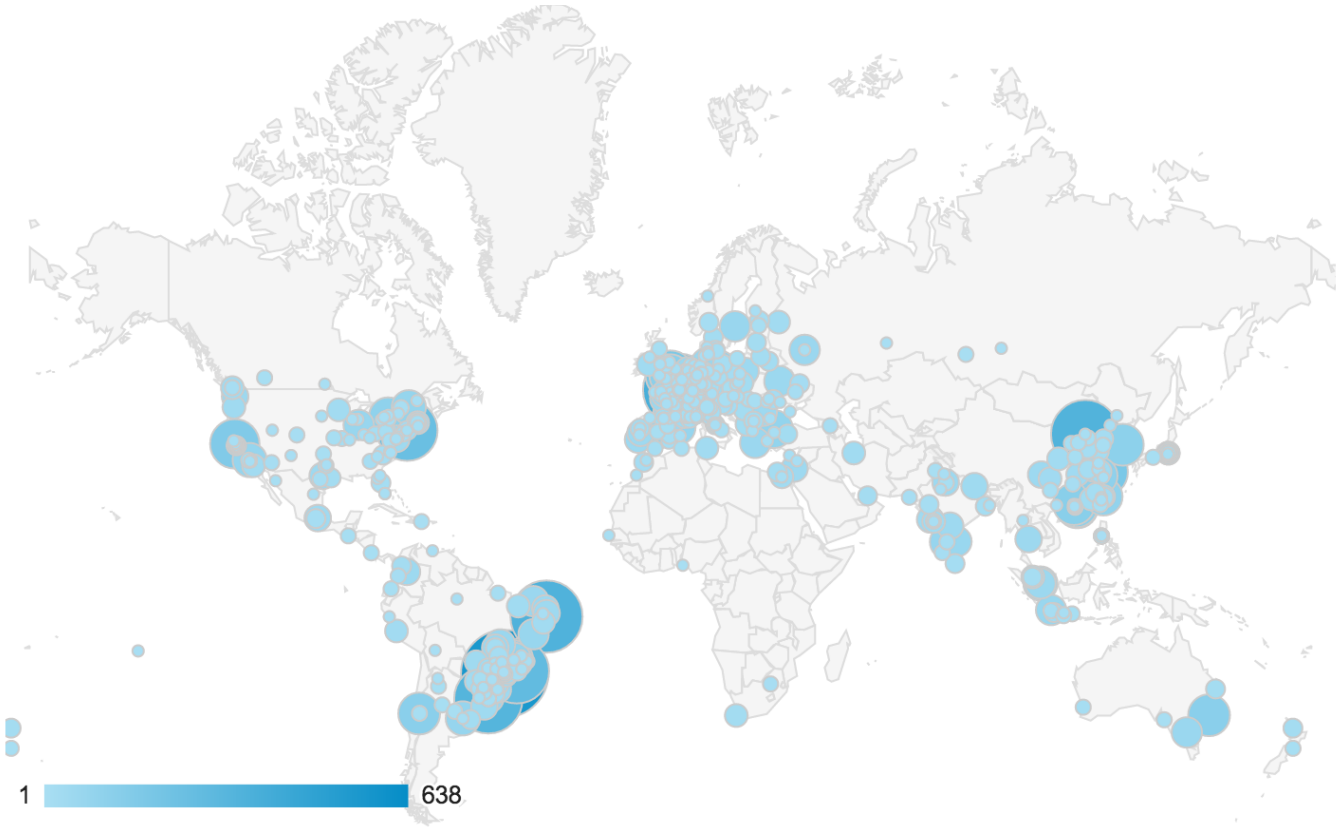


Figure : http://trackingjs.com

Popularity



Popularity

David Herman
@littlecalculist
Following

Spontaneous applause for Eduardo Lundgren's incredible demos of trackingjs.com #braziljs

Lisa Larson-Kelley
@lisamarienyc
Following

A library I wish I had back in the day with Flash -- #javascript #webcam gestures, tracking tracking.js buff.ly/1cmlNp2

HTML5 Weekly
@HTML5Weekly
Follow

Tracking.js: Webcam/Camera Based Interaction for Web Page Elements - trackingjs.com

Popularity

- 445 tweets mentioning *tracking.js*
- 31,258 website page views
- Project hosted on Mozilla Developer Network
- Talk presented on DevFest Brazil - Brazil, 2012
- Talk presented on W3C Conference - Brazil, 2012
- Talk presented on HTML5 Dev Conf - USA, 2013
- Talk accepted on JS.everywhere - USA, 2013

Thank you!