Tracking Library for the Web

Eduardo A. Lundgren Melo

UNIVERSIDADE FEDERAL DE PERNAMBUCO

Centro de Informática U·F·P·E

Master of Science in Computer Science

Silvio de Barros Melo (*Advisor*)

Veronica Teichrieb (*Co-Advisor*)

Outline

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Motivation

- The web browser environment is evolving fast

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- 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

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- Interpreted languages have limited computational power
- Modern web browsers can natively capture the user media
- Capturing and processing user media are required steps for visual tracking

Objectives

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- Accelerate the use of visual tracking in commercial products
- Provide a cross-platform tracking library
- Design and implement a tracking library for the web

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World Wide Web

The World Wide Web is a shared information system operating on top of the Internet

The beggining of the web

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- 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

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- Without requiring any third-party plugins installation

Browser technologies

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- Web can be augmented with other technologies
- JavaScript is the main programming language
- Layout and style information uses Cascading Style Sheets

Browser architecture

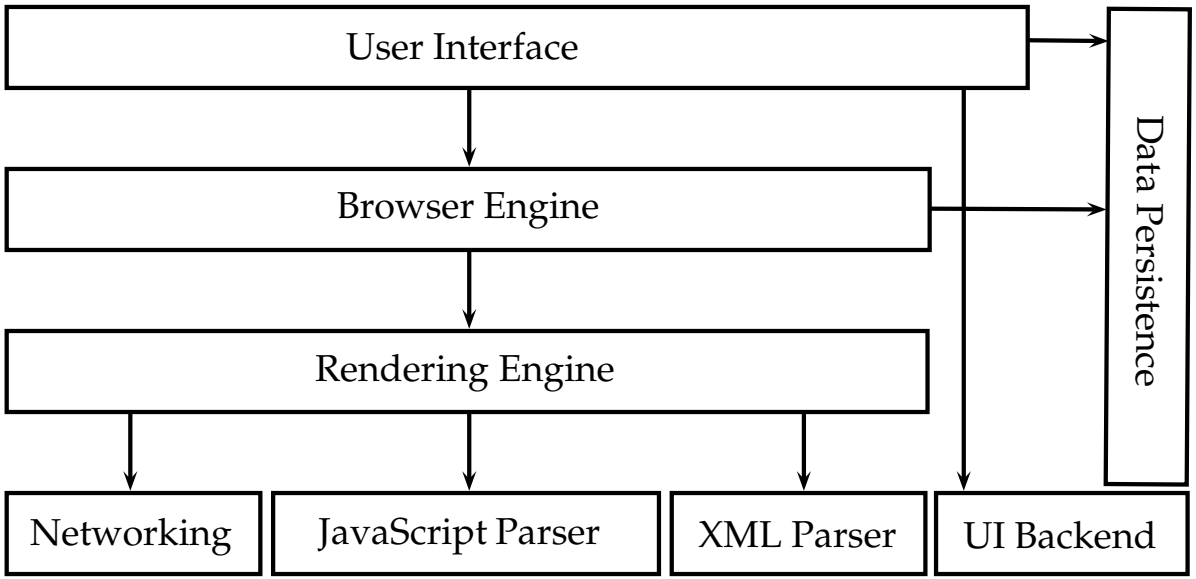

Figure : Reference architecture for web browsers

Audio and video

Figure : Video and audio HTML5 elements

Audio and video

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

Listing 1: Capturing browser microphone and camera

Canvas element

- HTML5 element

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- Resolution-dependent bitmap canvas

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- Two-dimensional grid, computer graphics coordinate system

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- HTML5 element
- Resolution-dependent bitmap canvas
- Two-dimensional grid, computer graphics coordinate system
- Can render graphs, game graphics, art, or other visual images

Canvas element

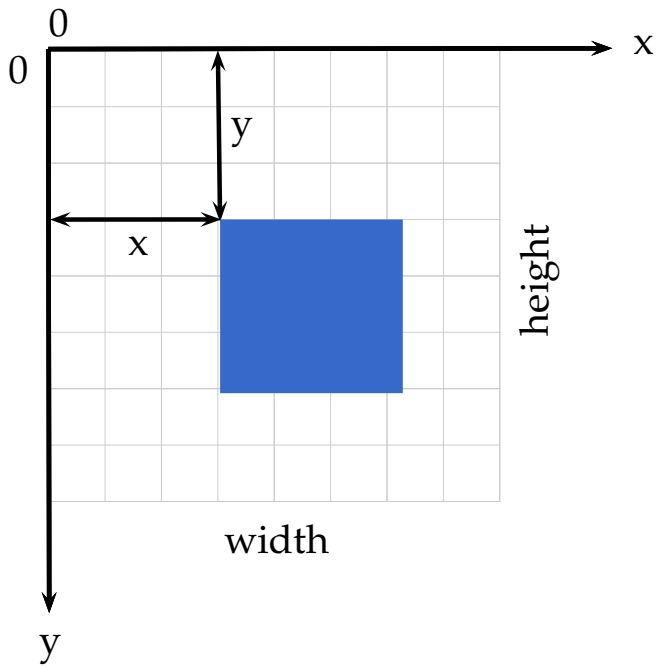

Figure : The canvas coordinate space

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- Typed data structures were added to JavaScript
- JavaScript-typed arrays access raw binary more efficiently

Typed arrays performance benchmark

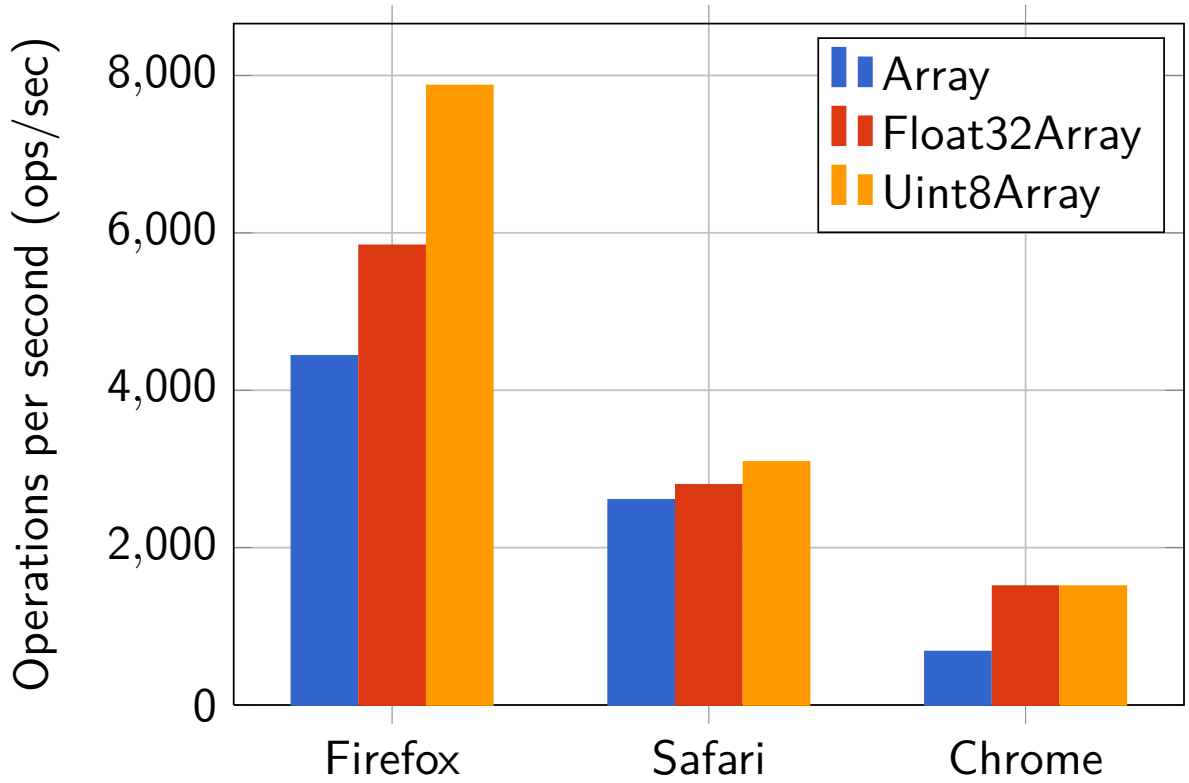

Figure : Regular *vs* typed arrays performance benchmark

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- Consider the 2×3 array $\begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \end{bmatrix}$, in row-major order it is laid out contiguously in linear memory as $\begin{bmatrix} 1 & 2 & 3 & 4 & 5 & 6 \end{bmatrix}$.

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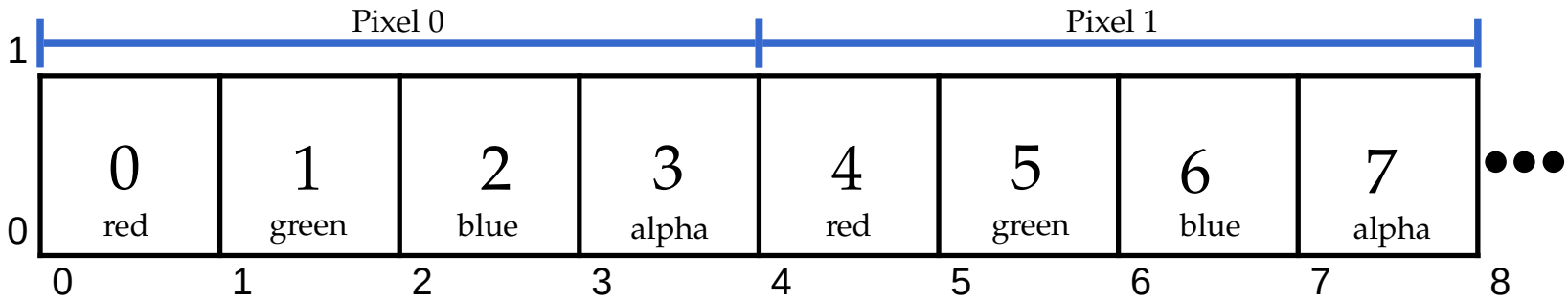

Figure : The canvas image data array of pixels

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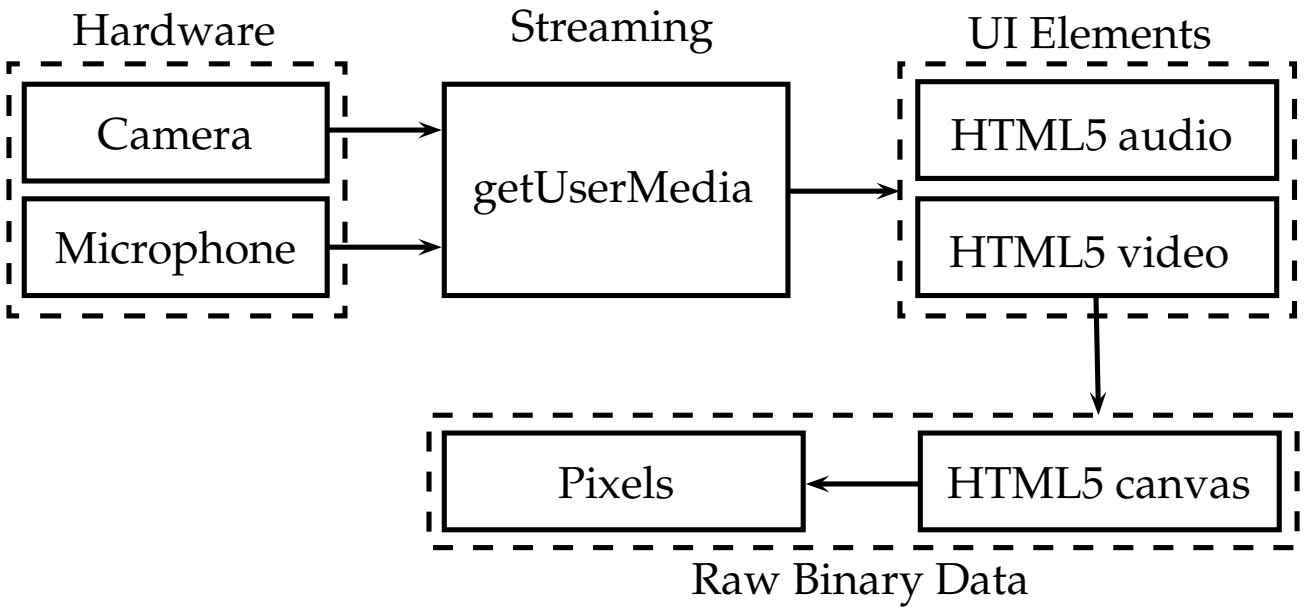

Figure : Access flow of raw binary data captured from videos on modern browsers

Visual tracking

Tracking an object in a video sequence means continuously identifying its location when either the object or the camera are moving

Figure : Example of an accurate object tracking robust to occlusion

Visual tracking

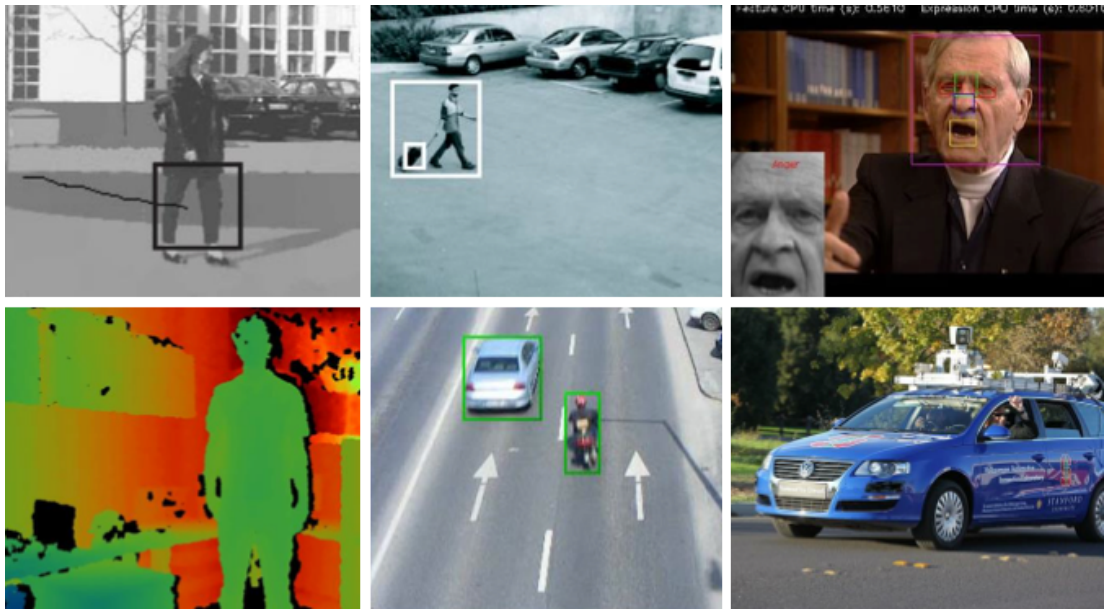

Figure : Computer vision applications: motion-based recognition (top left); automated surveillance (top center); video indexing (top right); human-computer interaction (bottom left); traffic monitoring (bottom center); vehicle navigation (bottom right).

Which devices could use tracking.js?

Different devices such as mobile phones, notebooks, and even head-worn (Google Project Glass), provide an embedded web browser capable to run JavaScript and HTML5.

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tracking.js

Tracking library for the web aiming to provide a common infrastructure to develop applications and to accelerate the use of those techniques on the web in commercial products

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It runs on native web browsers without requiring third-party plugins installation

Related work

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

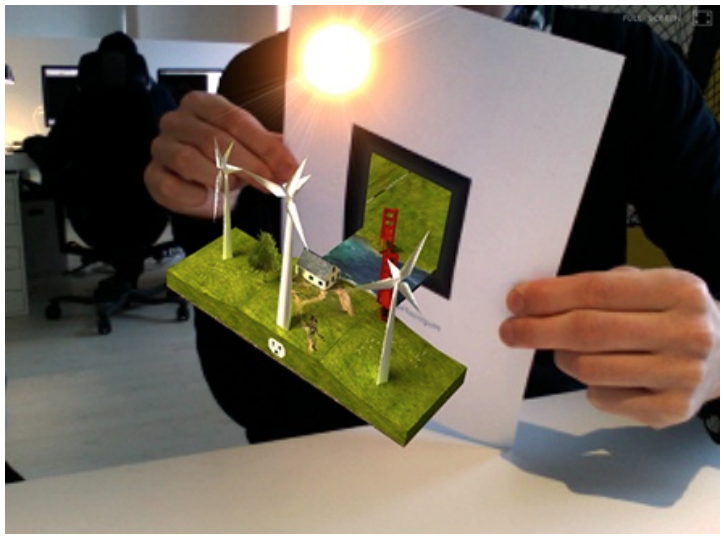

Figure : Marker based AR for the web using FLARToolKit

Related work

- JSARToolkit: is a JavaScript port of FLARToolKit

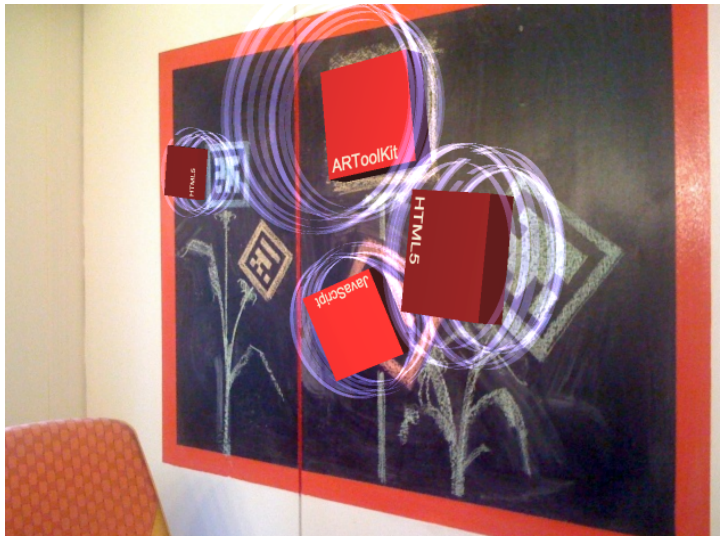

Figure : Marker-based AR for the web using JSARToolKit

Related work

- Unifeye Viewer: from Metaio company, it offers a robust markerless tracking solution for the web to ActionScript

Figure : Markerless example of image projected over a magazine cover using Unifeye Viewer solution

Library modules

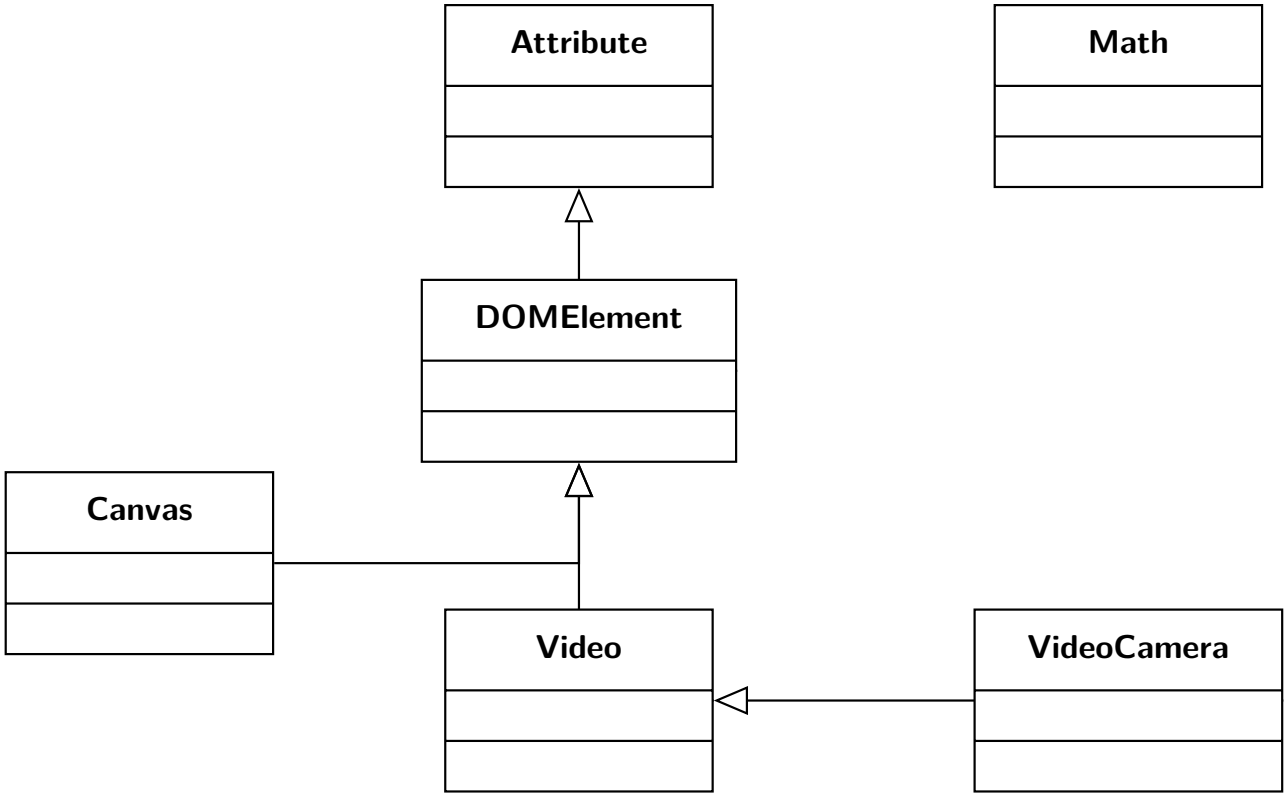

Figure : Base classes of tracking.js library

Library modules

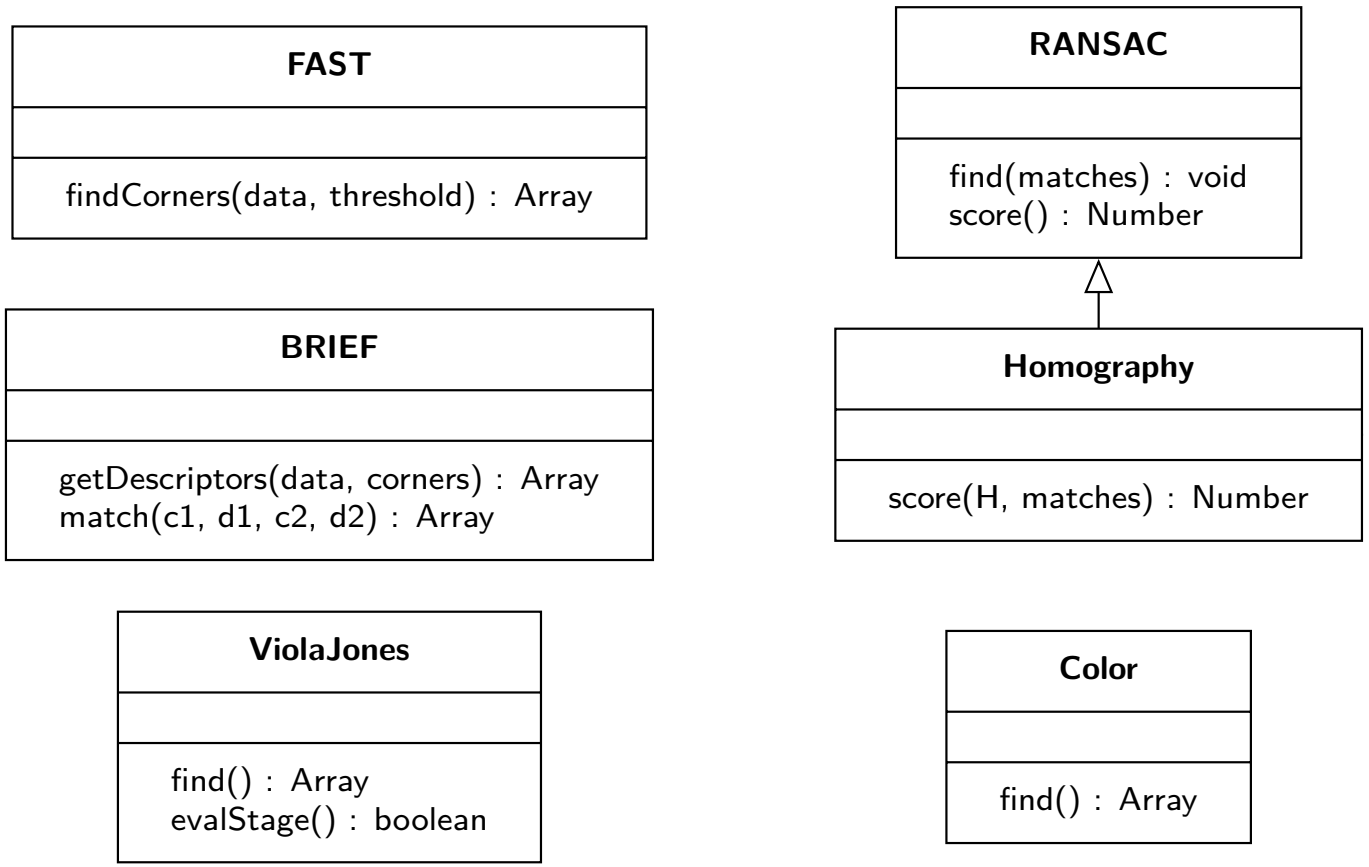

Figure : Visual tracking classes of tracking.js library

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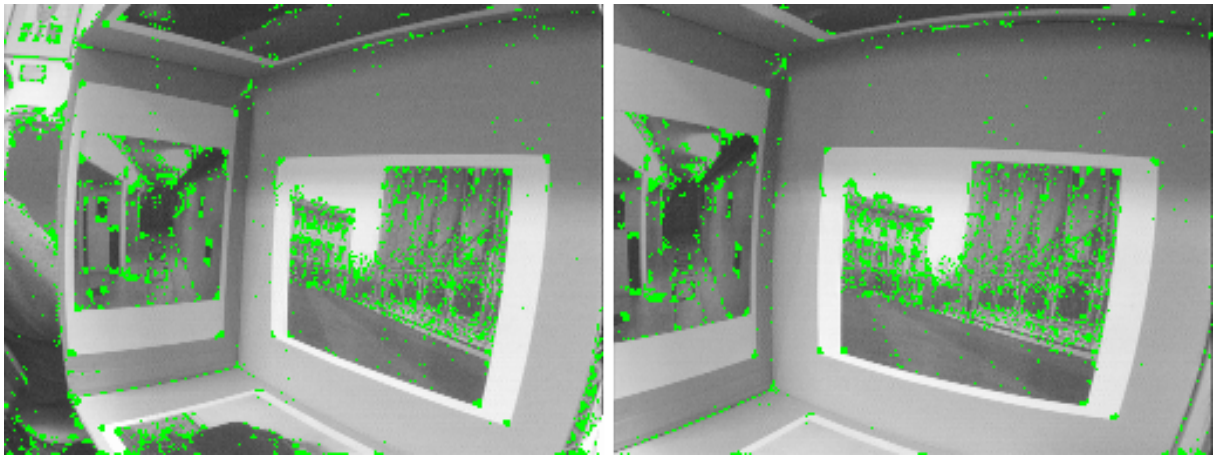

Figure : Image features detected on two different frames, green pixels represents found keypoints

Feature detector

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The test is based on whether the concentric contiguous arcs around the pixel are significantly different from the central pixel p

Feature detector

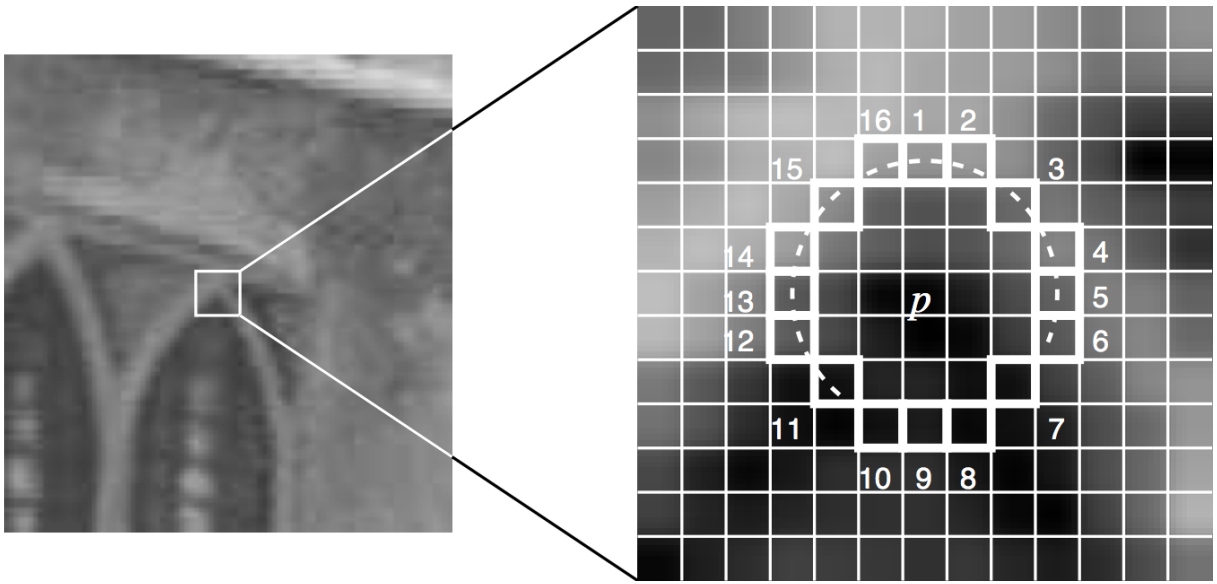

Figure : FAST: point segment test corner detection in an image patch

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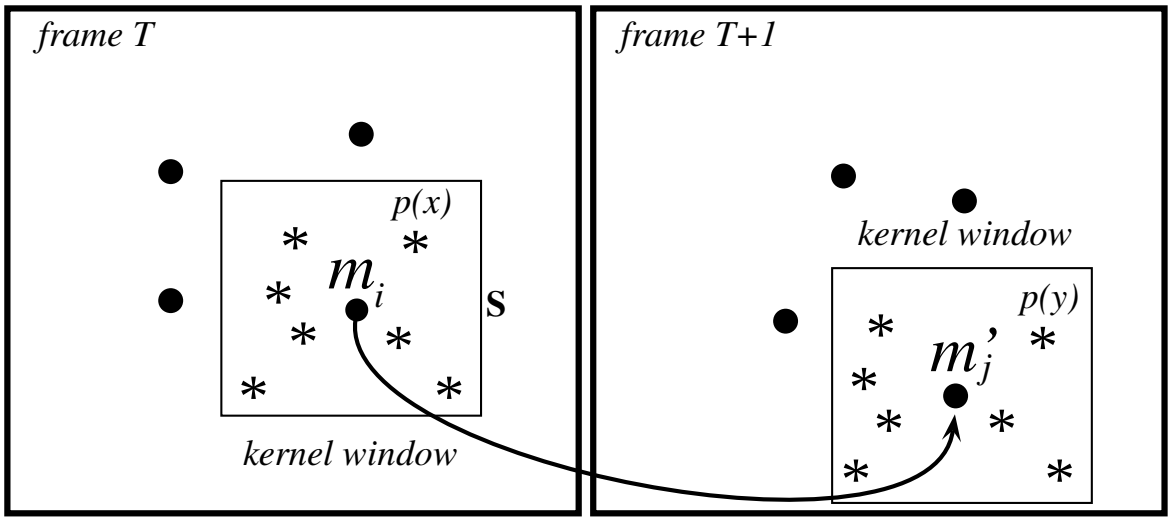

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BRIEF uses a binary string to describe the keypoints and having local descriptors that are fast to compute, to match and being memory efficient are important aspects

Feature extractor

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

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

where $\mathbf{p(x)}$ is the pixel intensity. The set of binary tests is defined by the n_d ($\mathbf{x}$, $\mathbf{y}$)-location pairs uniquely chosen during the initialization

Feature extractor

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, since it presented good matching results and performance. The number of bytes required to store the descriptor can be calculated by $k = n_d/8$

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- Distance metric is critical to the performance
- Using binary strings reduces the size of the descriptor

Feature extractor

Given two image patches x and y, denote their binary descriptors as $b(x) \in \{0,1\}^n$ and $b(y) \in \{0,1\}^n$ respectively, the Hamming distance is computed by

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

From the hamming distance, the Hamming weight can be calculated

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

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Homography estimation

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A 2D point (x, y) in an image can be represented as a 3D vector $\mathbf{x} = (x_1, x_2, x_3)$ where $x = \frac{x_1}{x_3}$ and $y = \frac{x_2}{x_3}$

Homography estimation

Homography is a mapping from $P^2 \rightarrow P^2$ which is a projectivity if and only if there exists a non-singular 3×3 matrix H such that for any point in P^2 represented by vector $\mathbf{x}$ it is true that its mapped point equals $H\mathbf{x}$

$$c \begin{pmatrix} u \\ v \\ 1 \end{pmatrix} = H \begin{pmatrix} x \\ y \\ 1 \end{pmatrix}, \quad H = \begin{pmatrix} h1 & h2 & h3 \\ h4 & h5 & h6 \\ h7 & h8 & h9 \end{pmatrix},$$

where c is any non-zero constant, $(u\ v\ 1)^T$ represents **x'**, $(x\ y\ 1)^T$ represents **x**

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- The iteration containing more inliers is selected
- The matrix H is recomputed from all inliers in that iteration

Rapid object detection (Viola Jones)

- TODO