Augmented reality on mobile devices

A comparison of technologies to build augmented reality apps under iOS platform

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What is augmented reality?

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Mix real world data with virtual elements.

— Myself

Can be brought to mobile devices?

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Can be brought to mobile devices?

Yes

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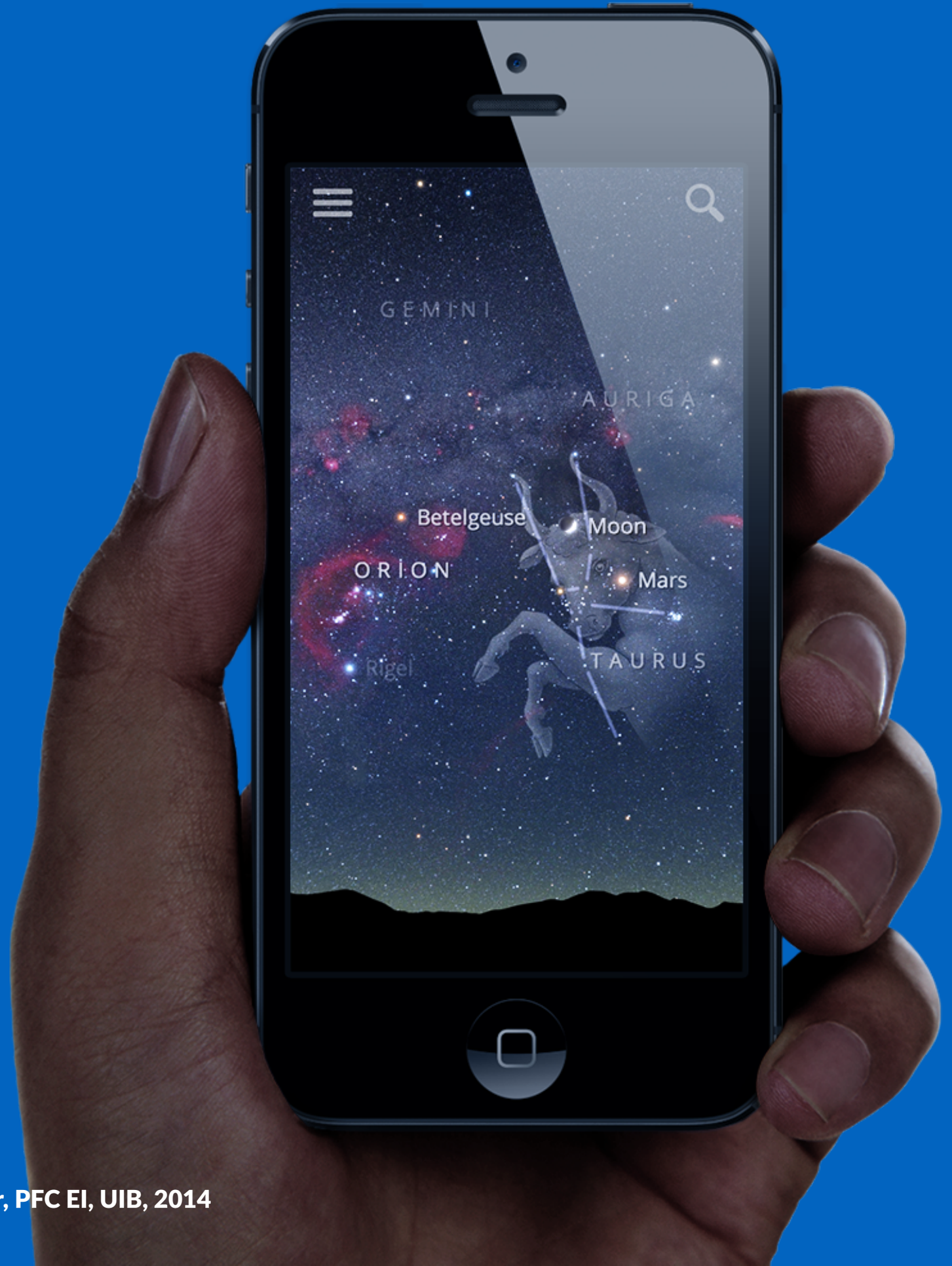

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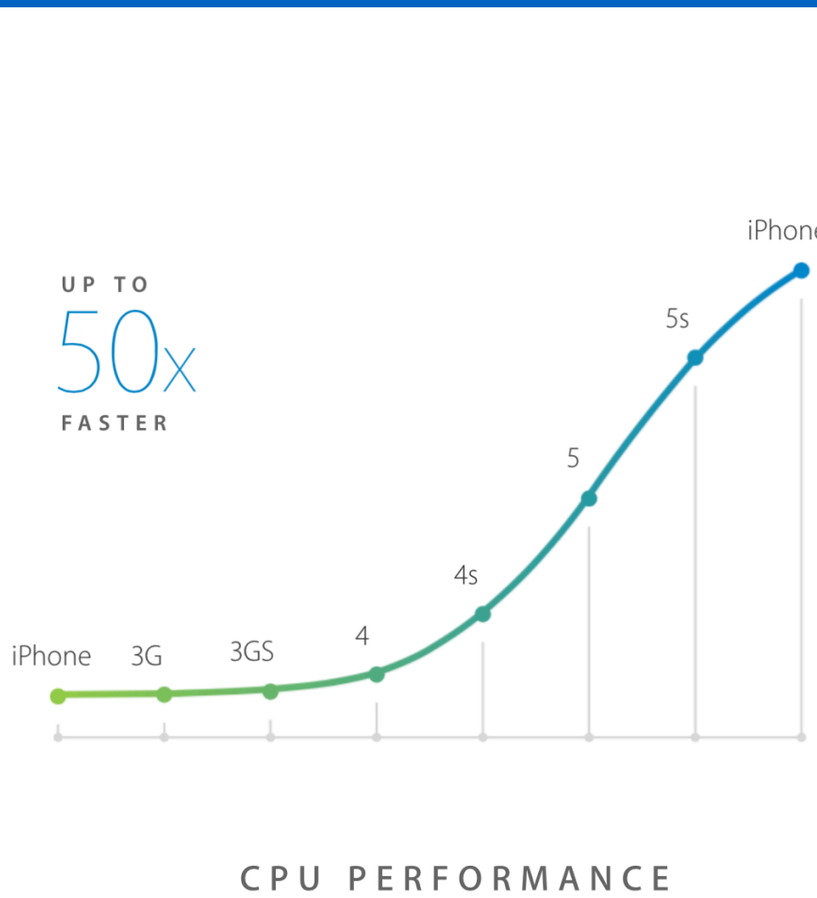
Augmented reality on mobile devices

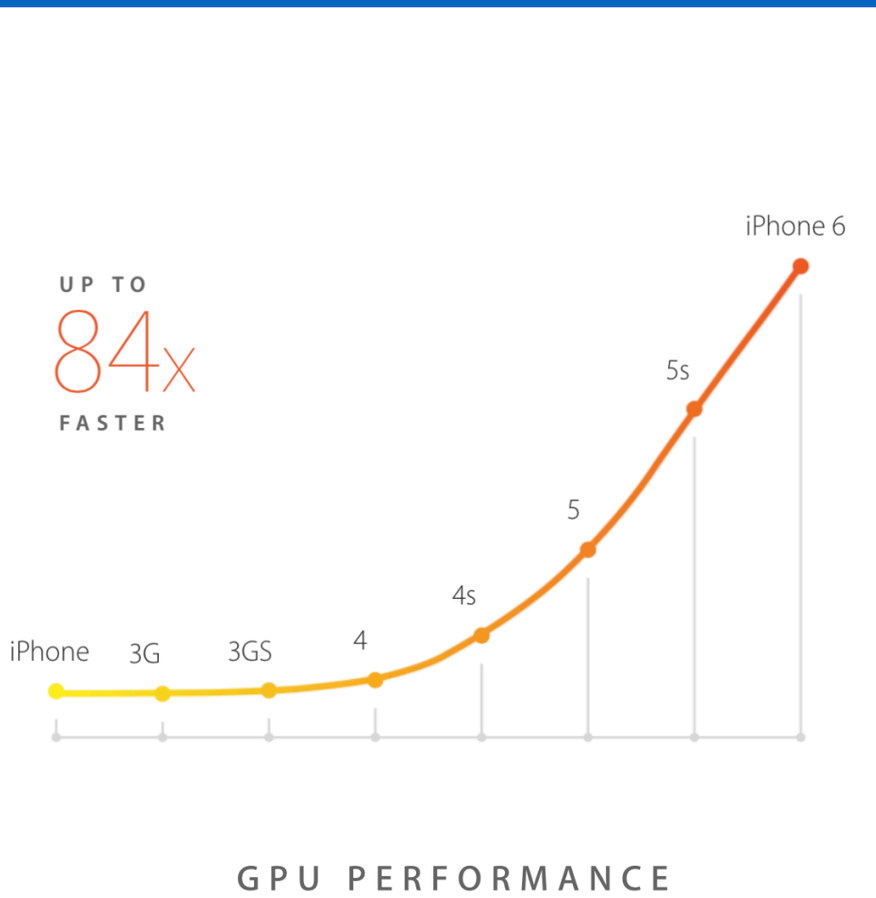
- Different ways to bring it to mobile
- Faster, more robust CV algorithms introduced recently
- Powerful mobile devices

AR on mobile

- Can use complex image processing
- Faster GPUs make possible to use real-time CV algorithms
- OpenGL ES
- Can take advantage of another built-in sensors

A8 chip performance





- Source: Apple, Geekbench performance test

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Ponster

Augmented reality app to draw posters on flat surfaces such as walls or doors

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Inspiration

IKEA catalog

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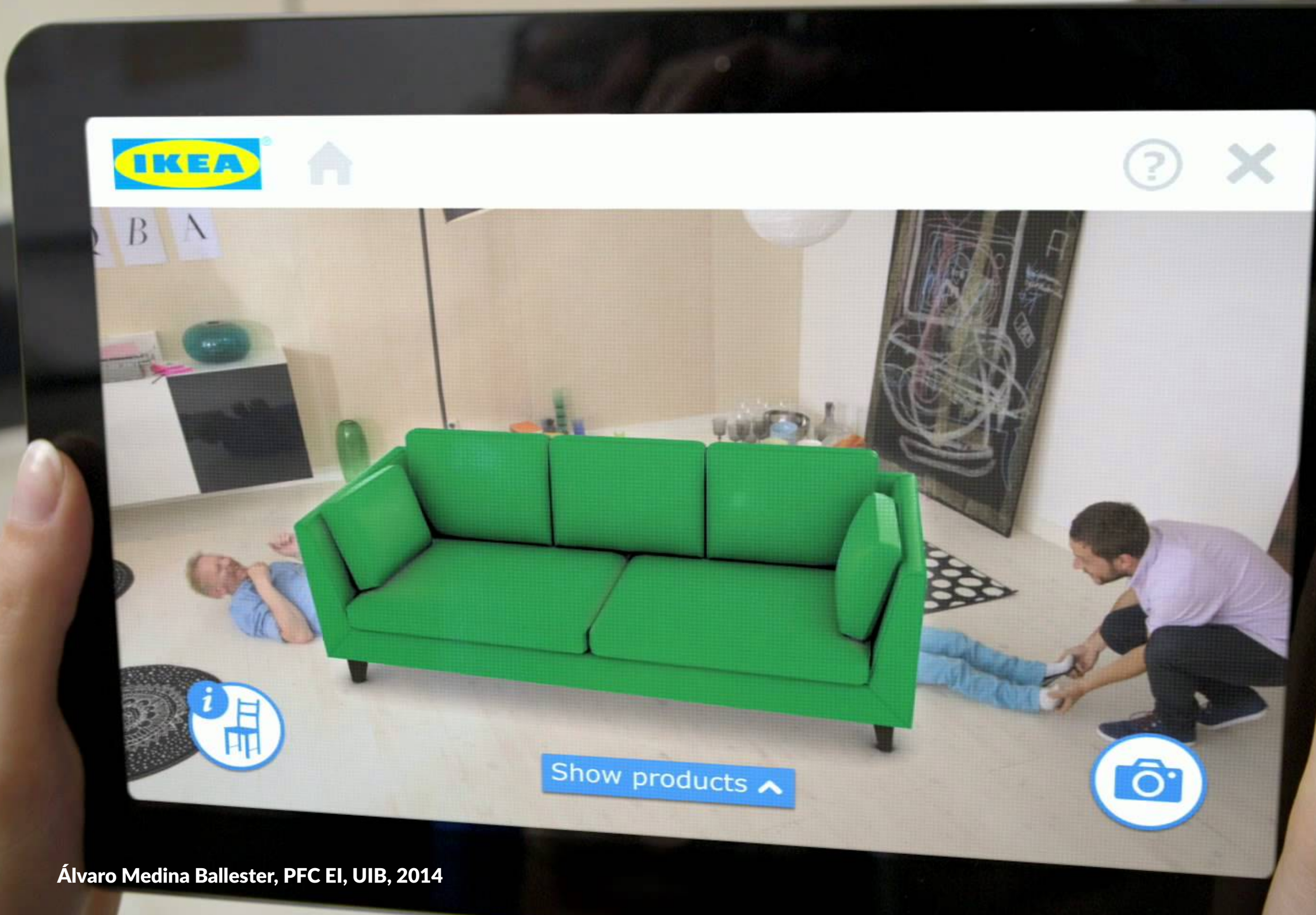

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Different ways to bring AR

- Image processing-only
- Sensors
- Combination

First hypothesis

Image processing-only

First hypothesis

Use video feed from the camera to process each frame with computer-vision algorithms

Key concepts

- **Robustness**: quality of the tracking algorithm when the scene changes and the object to track is hard to determine.
- **Invariance**: capacity of algorithms to be tolerant to rotation, scale and perspective changes.
- **Performance**:
  - 20 FPS minimum acceptable
  - 60 FPS goal, 30 FPS enough

Image processing-only approximation

Template matching & feature detection

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Template matching

Find areas of an image that are similar to the *template image* provided

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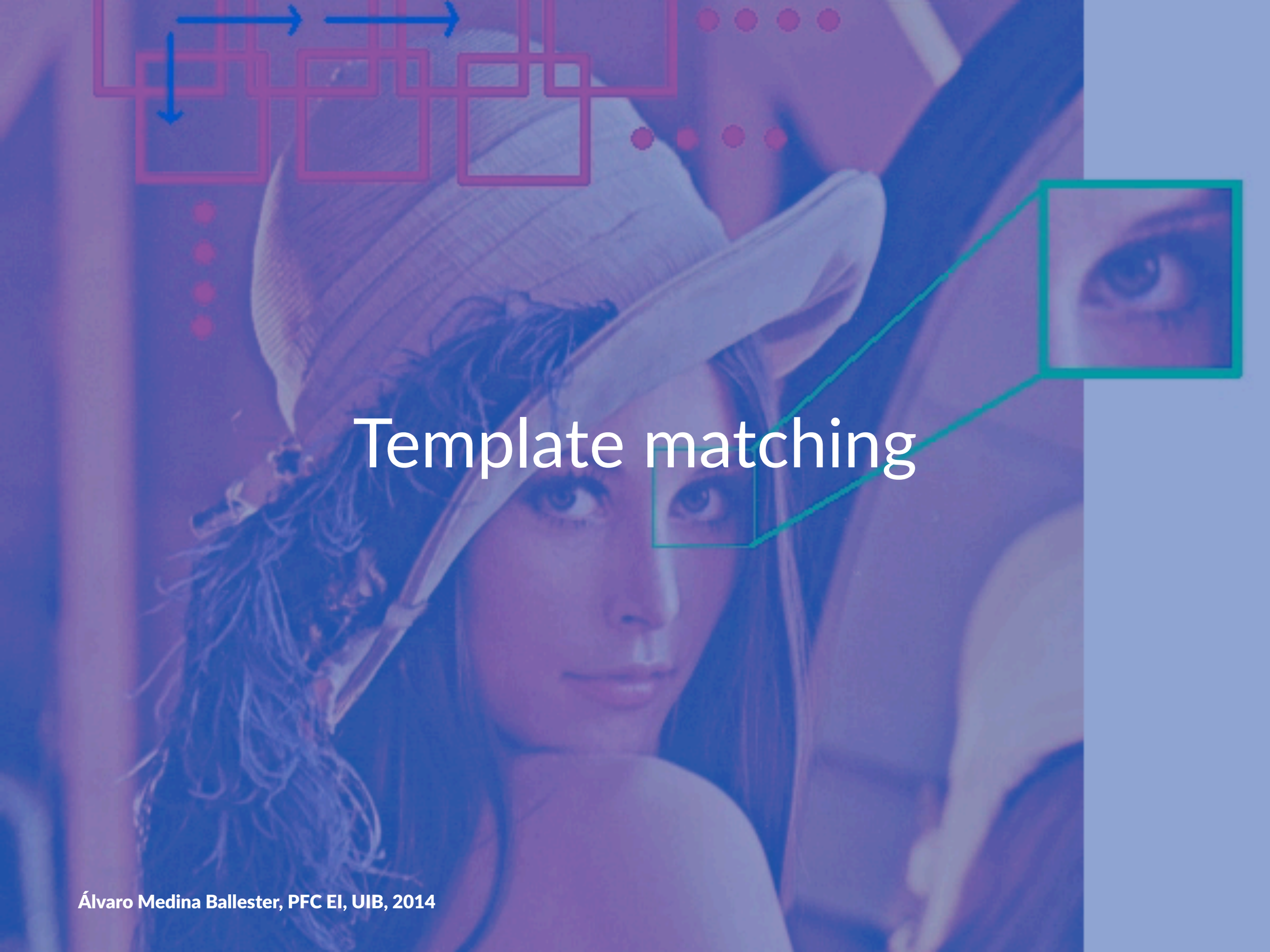

Template matching

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Template matching

Several methods of template matching: `CCOR`, `SQDIFF`

25~30 FPS on A6 chip

Not invariant to rotation, scale, perspective warp

Easy to implement

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Code example

```
// Perform Match Template
cv::matchTemplate(videoFrame, pattern, resultImage, matchMethod);

// If pattern has been found, draw poster
if (PatternDetector::isTracking()) {
  roiRect = cv::Rect(x, y, poster.size().width, poster.size().height);
  poster.copyTo(outputImage(roiRect));
}
```

Fast to compute

Easy to develop

Not rotation, scale and perspective invariant

Not very robust

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How to bring scale invariance to match template?

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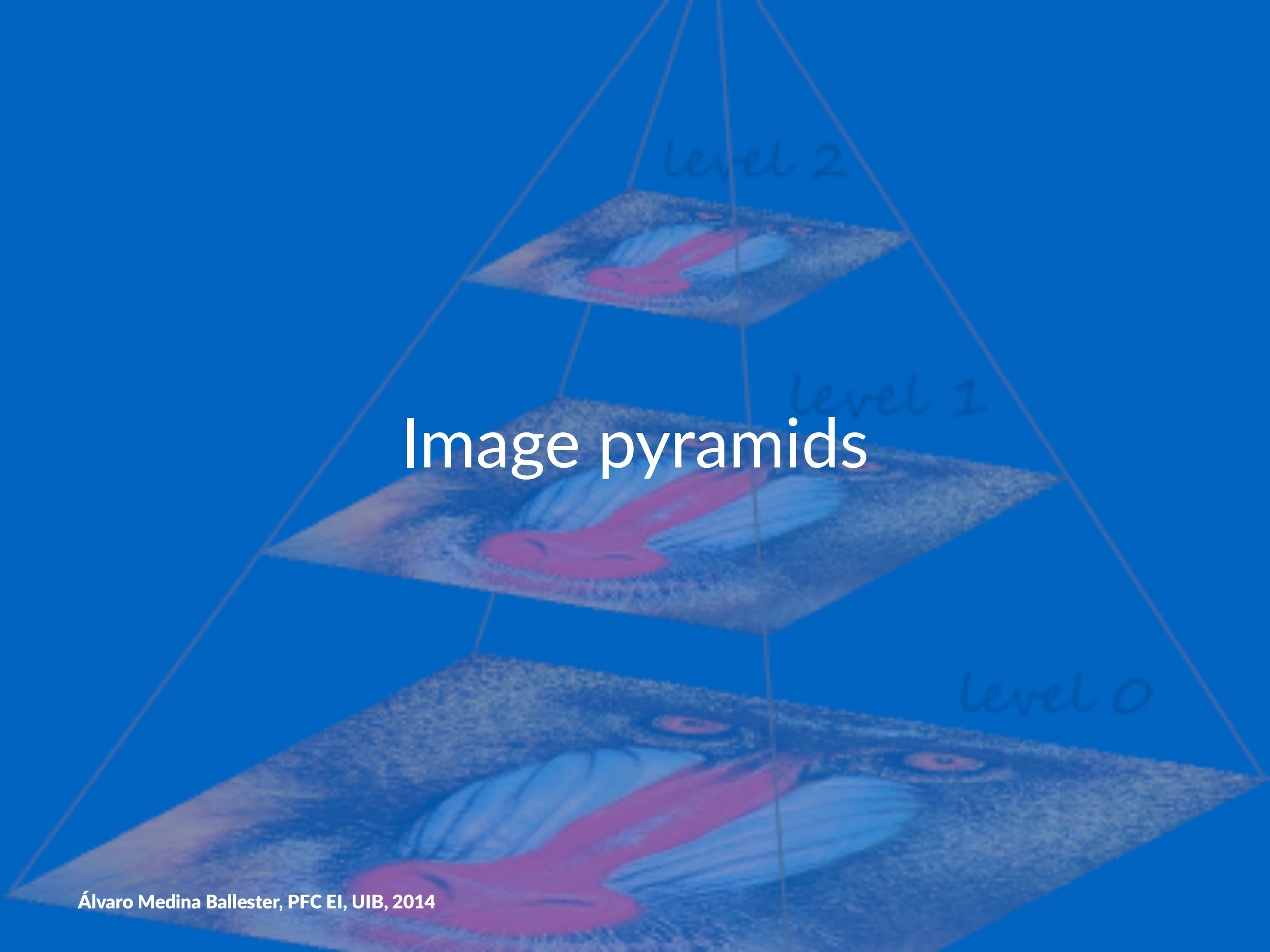

Image pyramids

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Image pyramids

A basic image pyramid system has been developed for template matching.

Creating several source images at different sizes.

Easy to implement.

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Template matching

Fast, easy to implement. More features needed (invariance).

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Feature detection

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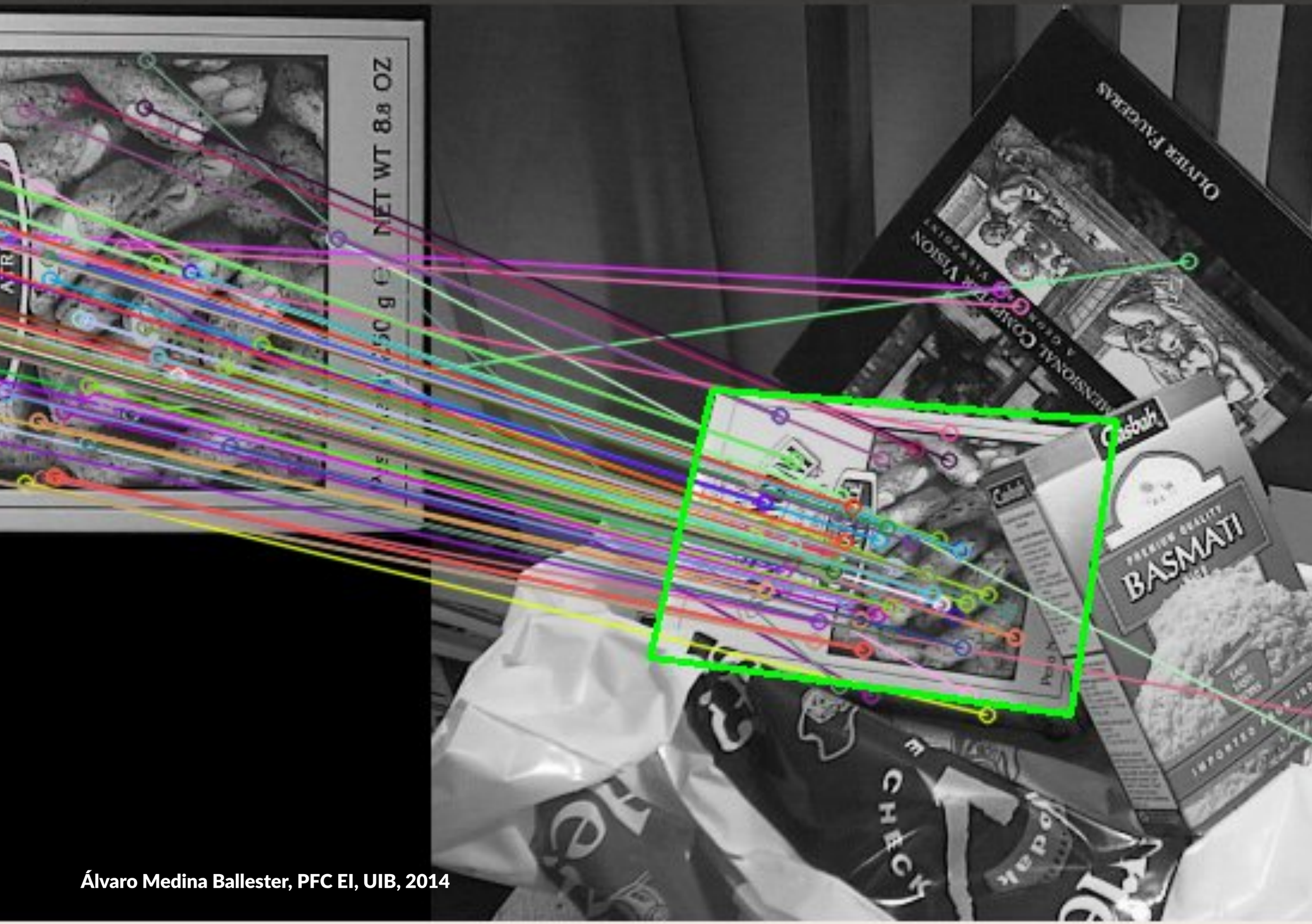
Feature detection

- SIFT introduced in 1999 by David Lowe
- Many techniques available
- Three approximations tested: SURF, FREAK, ORB
- Most are invariant to scale, rotation and perspective

s & Object detection



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Feature detection

Three steps

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Keypoint detection

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Keypoint detection

Corners, points, blobs, junctions

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Keypoint detection

Must be easy to find, repeatable, robust to image changes to get good results

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Descriptors

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Descriptors

Neighbourhood of keypoints

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Matching

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Matching

Between the feature vectors computed from both images

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SURF

Speeded-Up Robust Features

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SURF keypoint detector and descriptor extractor

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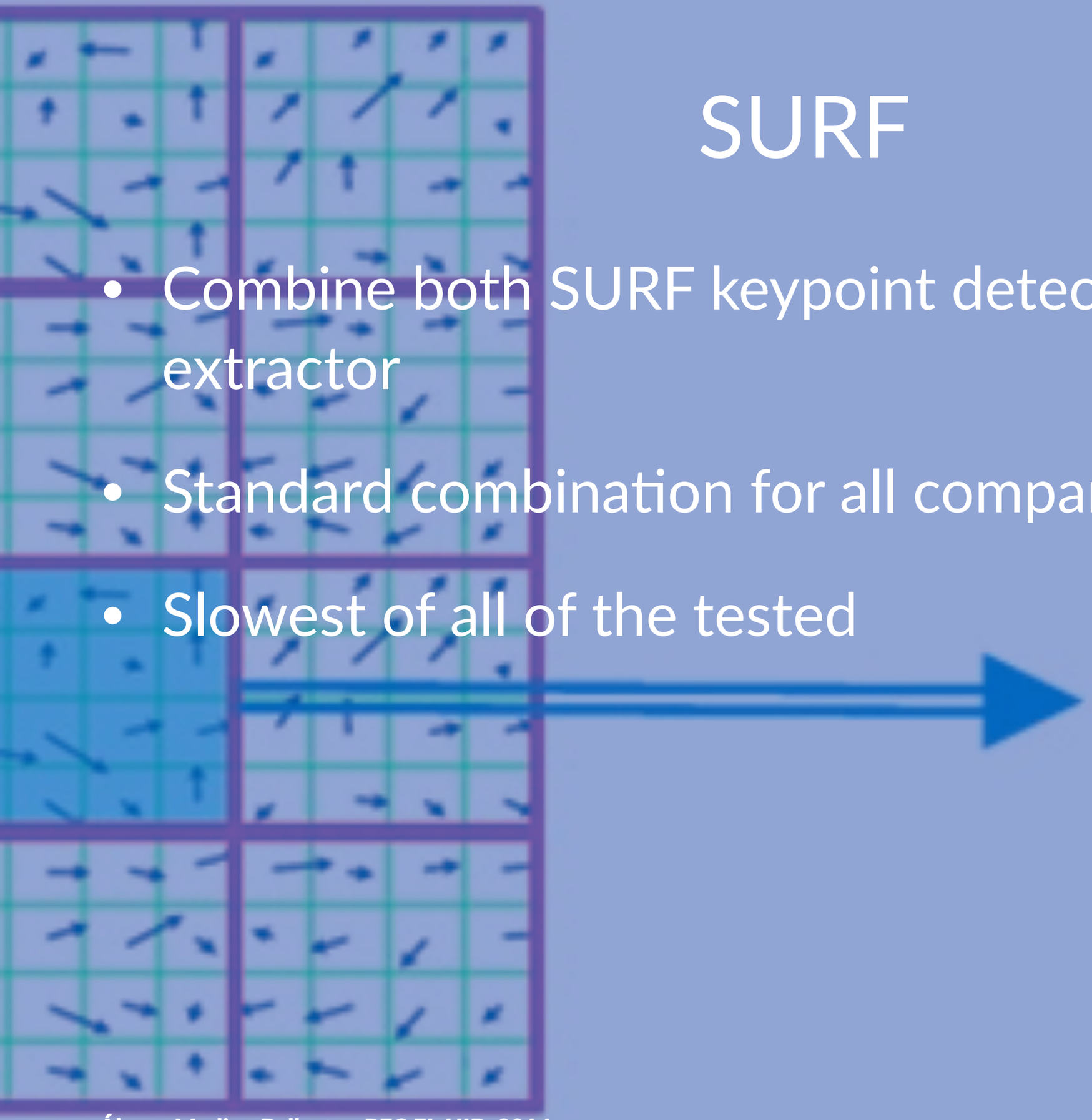
SURF

- Combine both SURF keypoint detector and extractor
- Standard combination for all comparisons
- Slowest of all of the tested



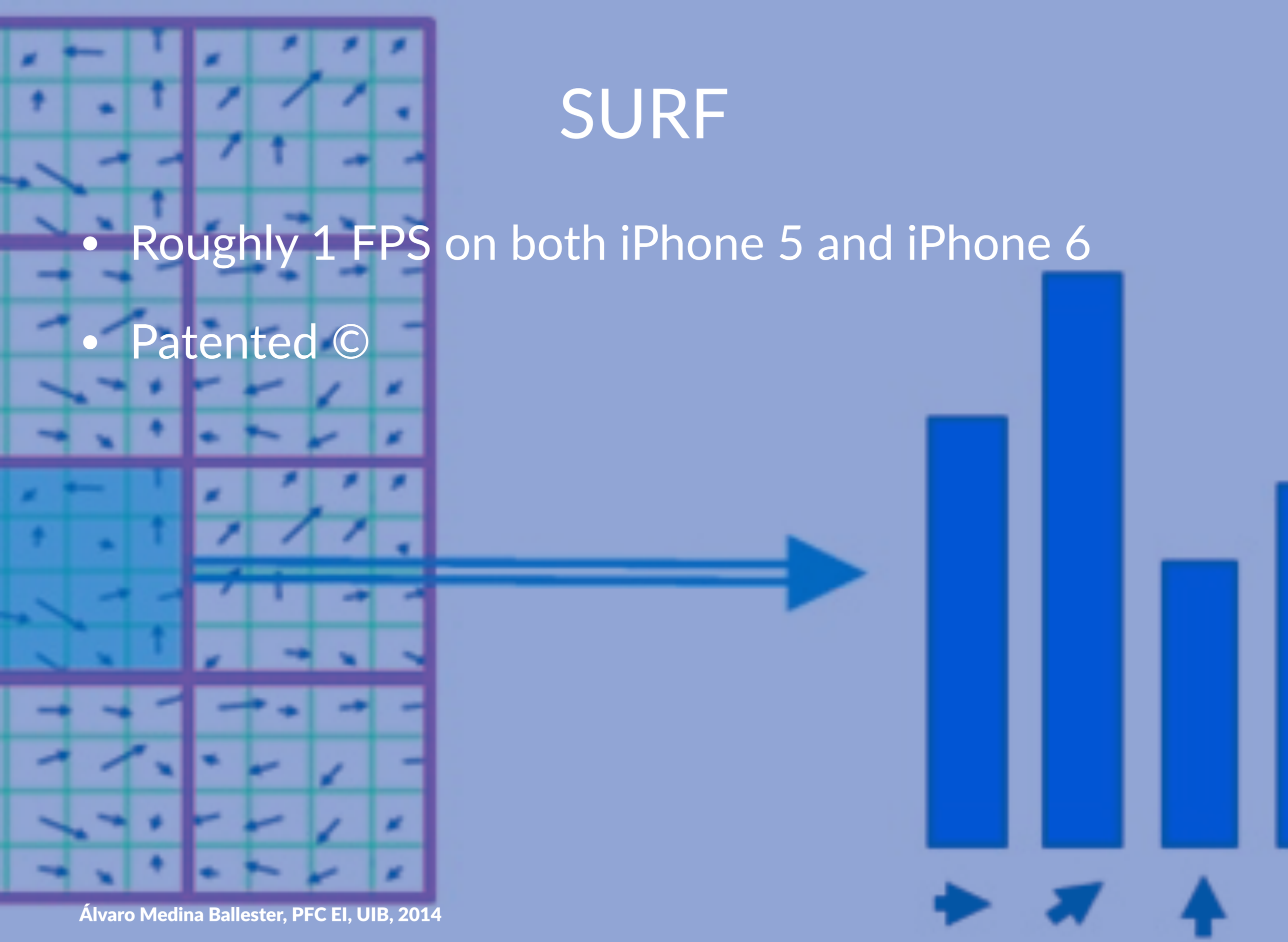
SURF

- Hessian matrix approximation for keypoints
- Descriptors based on histogram oriented gradients (HOG)[1]
- Scale and rotational invariant

[1] Levi Gil, (2013, August 18). A Short introduction to descriptors [blog post], http://gilscvblog.wordpress.com/2013/08/18/a-short-introduction-to-descriptors/

SURF

- Roughly 1 FPS on both iPhone 5 and iPhone 6
- Patented ©



FREAK

Fast Retina Keypoint

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FREAK

SURF keypoint detector and FREAK descriptor extractor

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FREAK

- SURF as keypoint detector
- FREAK as descriptor extractor becomes a huge performance improvement
- Uses a retina-like pattern for computing descriptors

FREAK

- Generates binary descriptors
- Scale and rotation invariant

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ORB

Oriented Fast & Rotated Brief

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ORB

ORB feature detector and descriptor extractor

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ORB

- rBRIEF (Rotated BRIEF) for keypoint detection
- oFAST (Oriented FAST) for descriptor extractor
- Better performance than the other approximations
- Almost the same tracking quality

Matching

Different matching for the selected descriptors

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Matching

Binary and not binary descriptors

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Brute force

Can be used in binary **Hamming distance**...

and non binary descriptors **L1/L2**

Has good performance with binary descriptors

FLANN

Fast library for approximate nearest neighbours

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FLANN

Many matching algorithms

Randomized-KD tree for SURF

Locality-Sensitive Hashing (LSH) for ORB

Performance comparison

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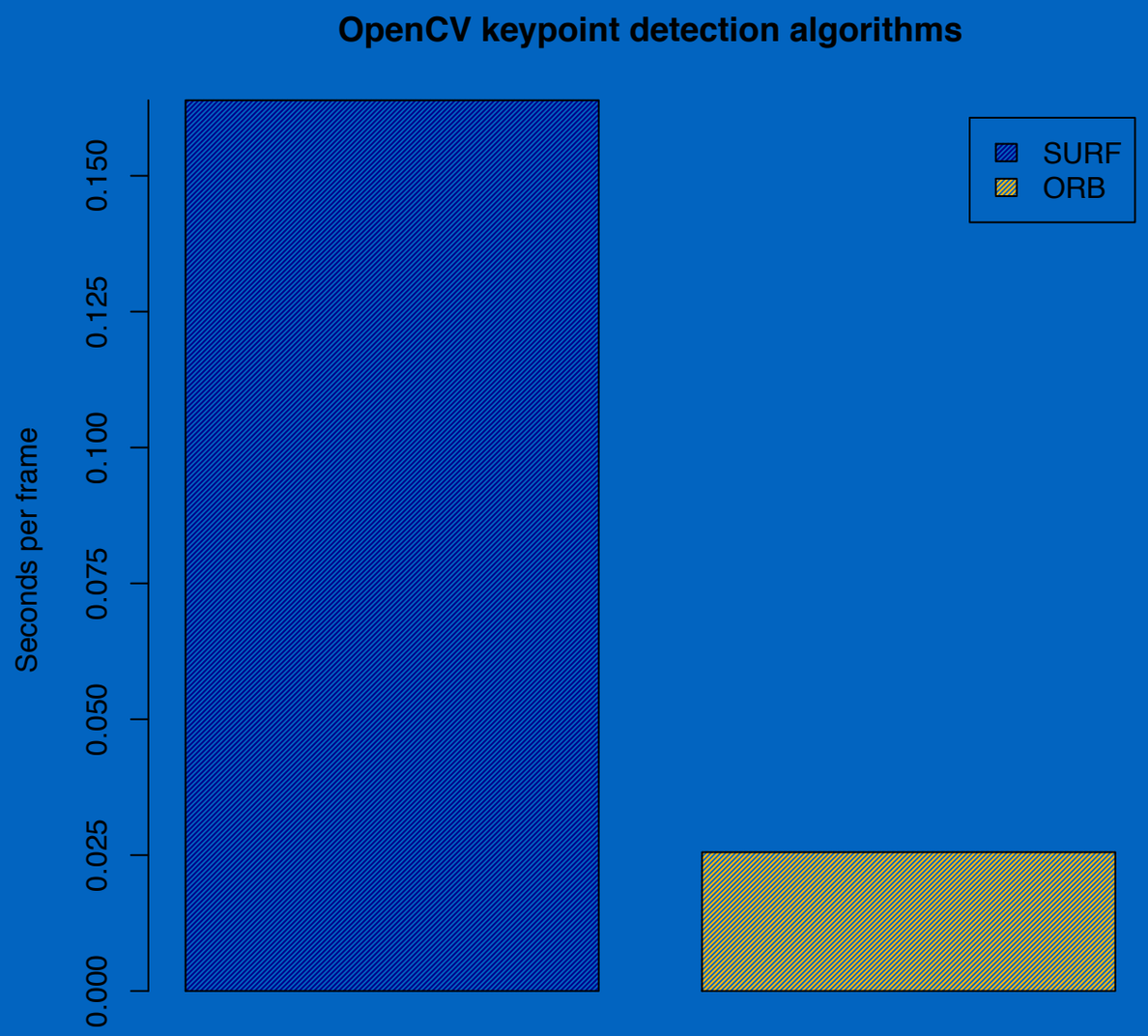
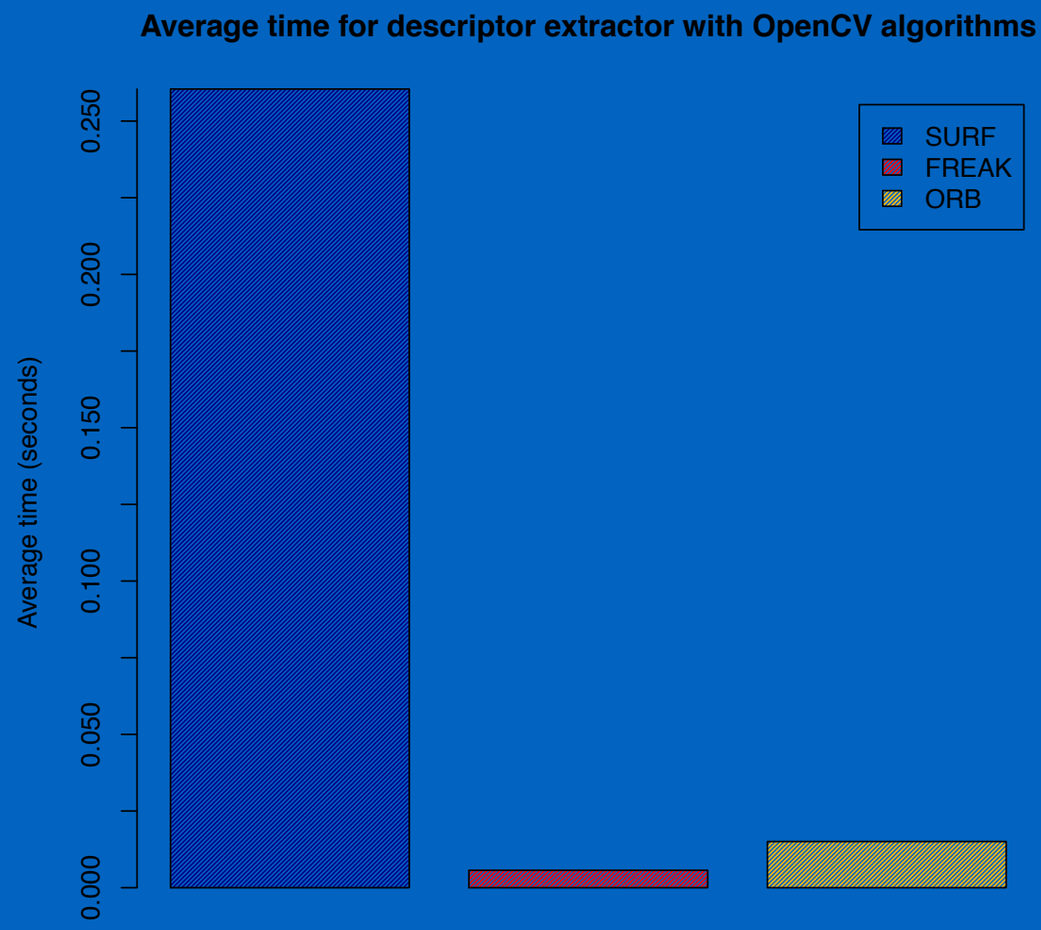
Average time for detecting keypoints



FREAK vs SURF vs ORB descriptor performance



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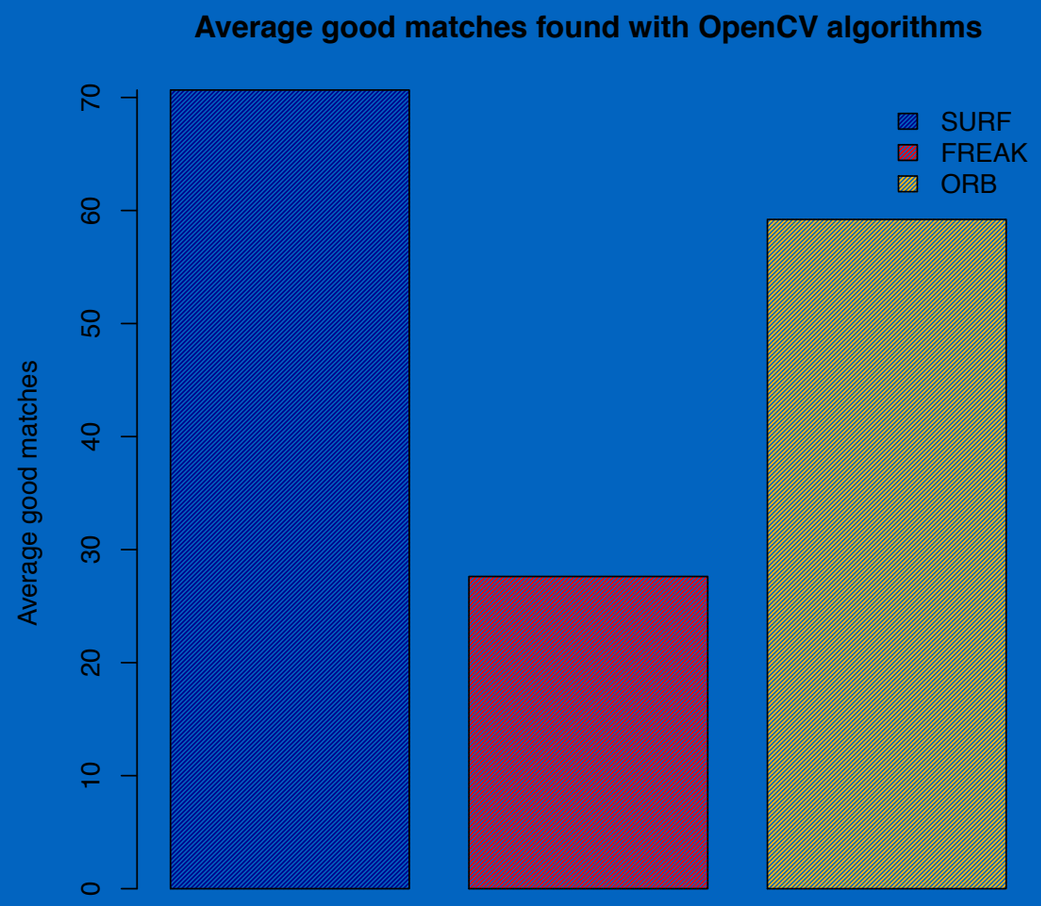
FREAK vs SURF vs ORB number of good matches



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Feature detection

Not enough for AR apps on mobile devices

Heavy algorithms

Not so invariant to rotation, perspective

Natural feature tracking

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Natural feature tracking

Fast, robust and high-quality tracking on mobile devices

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Natural feature tracking

Detect interest regions

Compute the movement

Evaluate feedback

Not image processing-only technique

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Natural feature tracking

Thanks to mobile sensors, we can track the object even if all the interest points are not present in the scene.

Calculate the movement of the interest regions is faster than detecting features in each frame.

Natural feature tracking

The chosen technique for bringing AR to Ponster app (and many others)

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Technologies

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App built for iOS

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App built for iOS

Objective-C, Objective-C++, C++

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App built for iOS

UIKit, CoreData, CocoaPods

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App built for iOS

AVFoundation, CoreVideo

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OpenCV SDK for AR

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OpenCV

Version 2.4.8 and 2.4.9

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OpenCV

Used to implement template matching & feature detection algorithms

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OpenCV

Does not bring Natural Feature Tracking by default. It has to be implemented by developer. Not yet optimised for ARM architectures.

The solution was to change to a mobile AR SDK that takes natural feature detection approach

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Vuforia

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Vuforia

High quality AR SDK

Based on natural feature detection

Uses mobile sensors to compute the pattern movement

Closed source, free to use

Optimised for ARM architecture

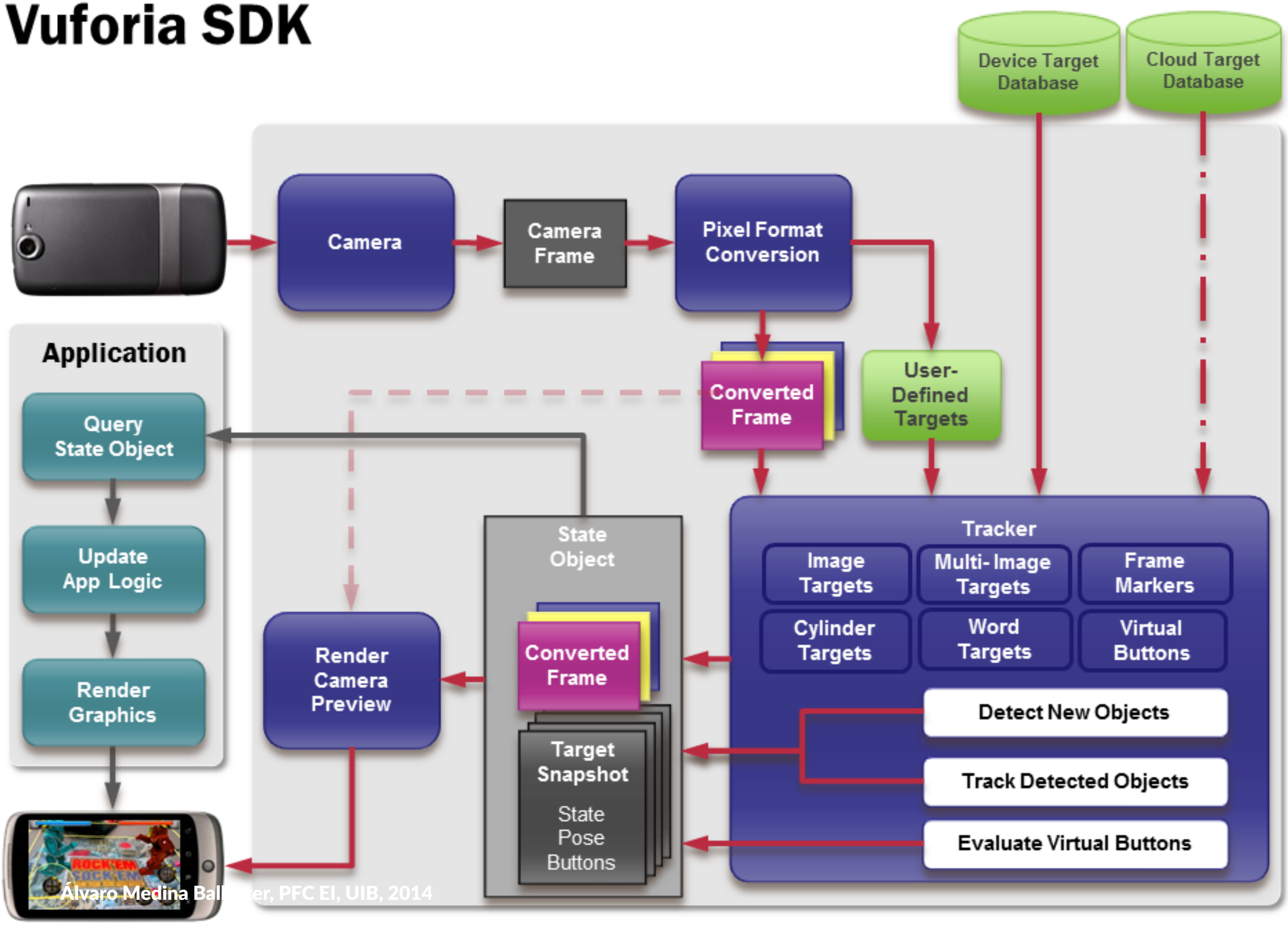
Vuforia

Constant 30 FPS performance

Able to keep tracking even in the pattern is not entirely visible

Uses OpenGL ES for rendering

Vuforia SDK



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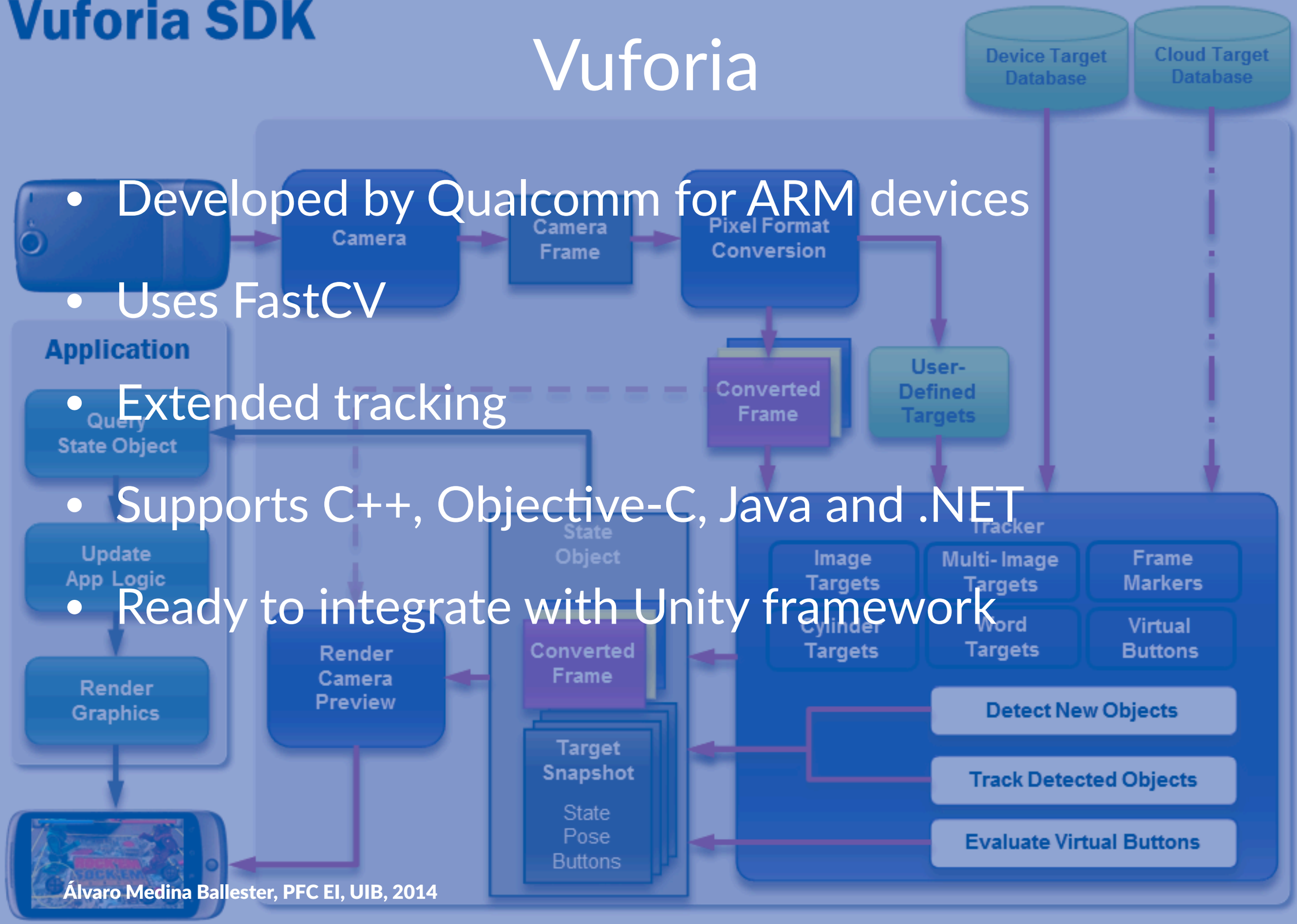
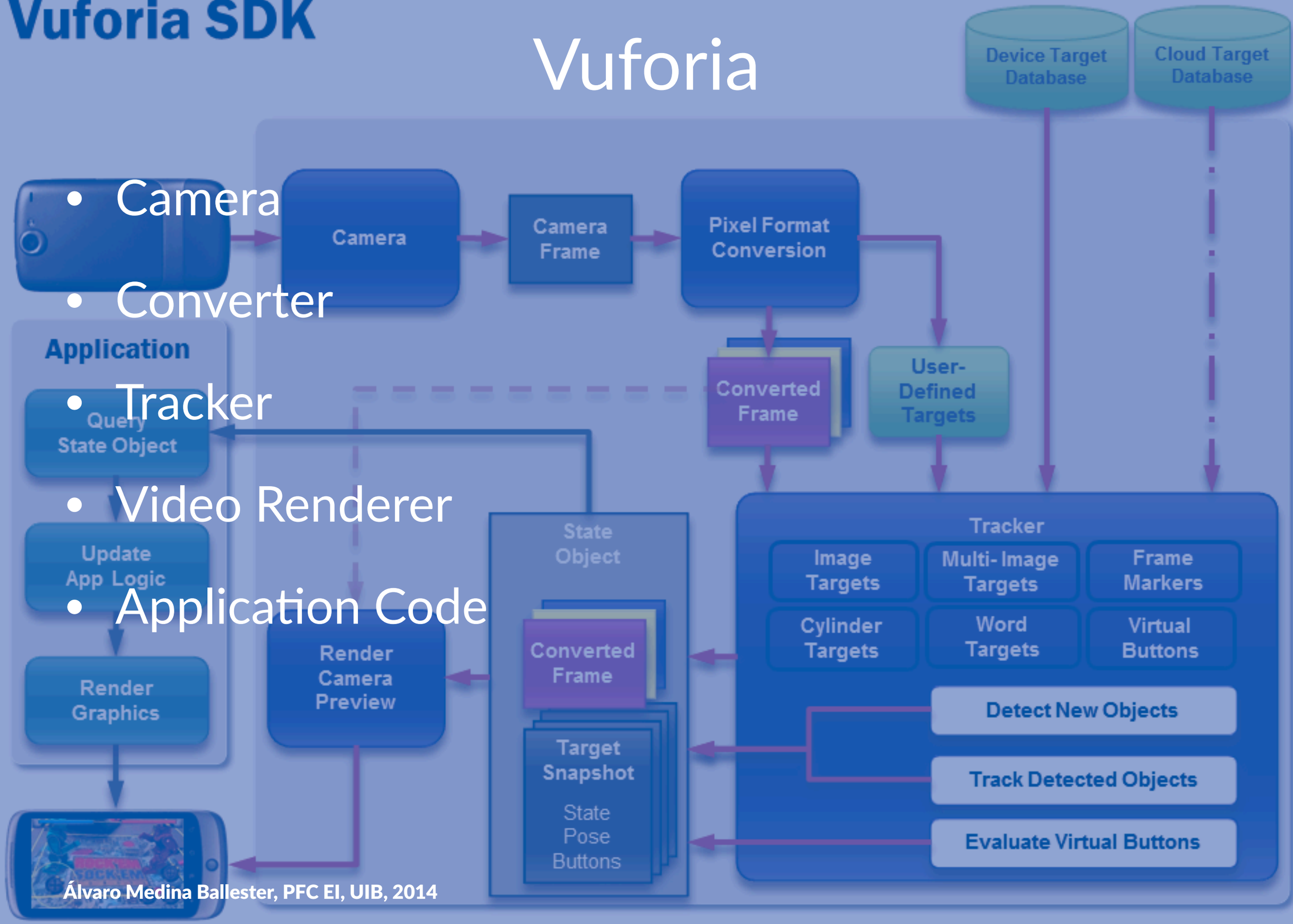
Vuforia

- Developed by Qualcomm for ARM devices
- Uses FastCV
- Extended tracking
- Supports C++, Objective-C, Java and .NET
- Ready to integrate with Unity framework



Vuforia

- Camera
- Converter
- Tracker
- Video Renderer
- Application Code



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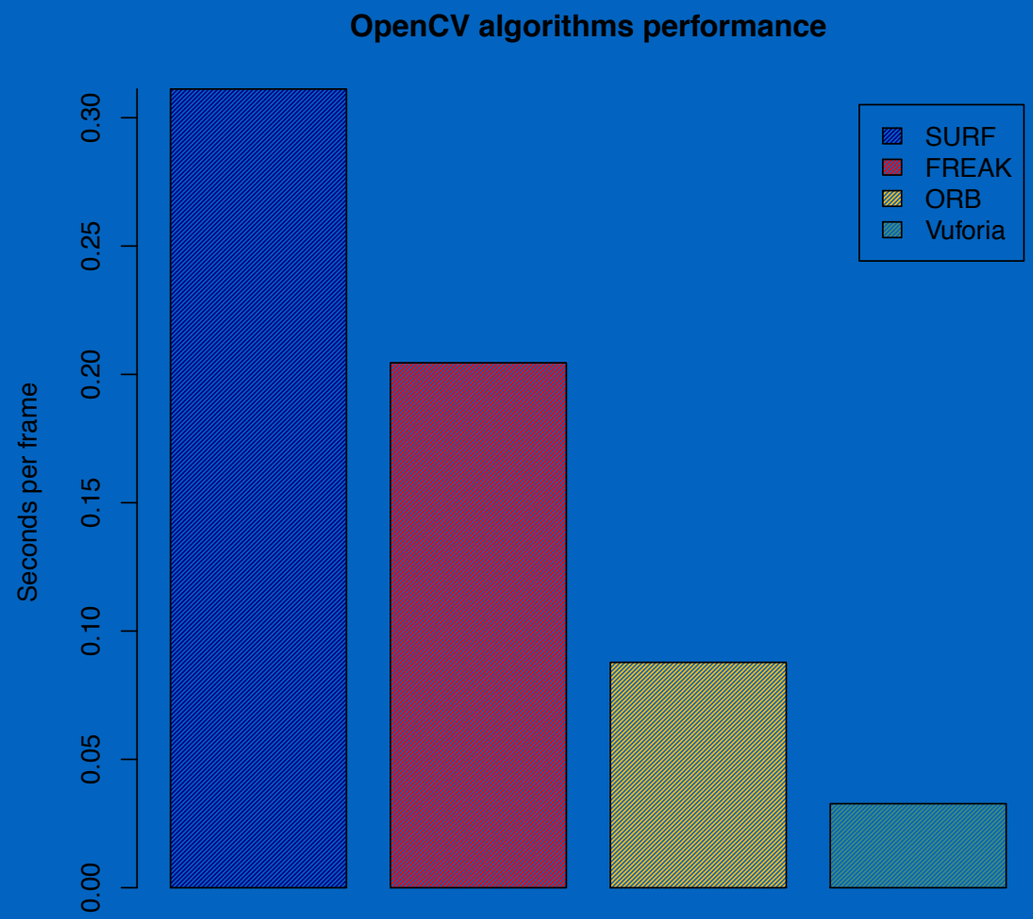
Performance comparison with OpenCV approximations



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Vuforia

We have been able to efficiently detect the pattern and track it with maximum robustness, invariance and speed.

✌🏼

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Super fast

Mobile

Multiplatform

Free to use

Used by Lego and IKEA examples

👎🏼

Propietary technology

Unknown tracking algorithm

Harder to integrate than OpenCV

Necessary to learn a bit of OpenGL ES

Demo

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Questions?

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