



JeVois Smart Machine Vision Camera

Open-source quad-core camera effortlessly adds powerful machine vision to all your PC, Arduino, and Raspberry Pi projects.



Welcome to JeVois!

Please visit <http://jevois.org/start> for information about:

- Connecting JeVois to your computer
- Video capture software and setting different video resolutions
- Connecting to the command-line interface of JeVois
- Updating microSD card to latest JeVois software
- This guide was written for JeVois software **1.5.2**
- Note: pre-loaded microSD cards of Turnkey kits use software 1.0.0; some modules described here will be missing, just skip over these pages.
- Guide revision **1.0**



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How to use this guide:

JeVois machine vision
module name

Link to
documentation page

Introduction

Explanation of the
display organization

Video resolutions which
will launch this module

Saliency + gist + faces + objects

<http://jevois.org/moddoc/DemoSalGistFaceObj/modinfo.html>

640x360 @ 50fps
640x312 @ 50fps

- A visual attention algorithm finds the most interesting location in the field of view.
- On alternating frames, either
 - attempt to detect a face in the attended region,
 - or attempt to recognize a handwritten digit, using a deep neural network.

Saliency map: brighter locations are more attention-grabbing

Pink square: Attended location

Green circle: smoothed attended locations over time

Feature maps that contribute to the saliency map

Recognition scores for digits 0 to 9

Gist of the scene (statistical summary, can be used for scene classification)

Last recognized face

Last recognized handwritten digit

JeVois Guided Tour

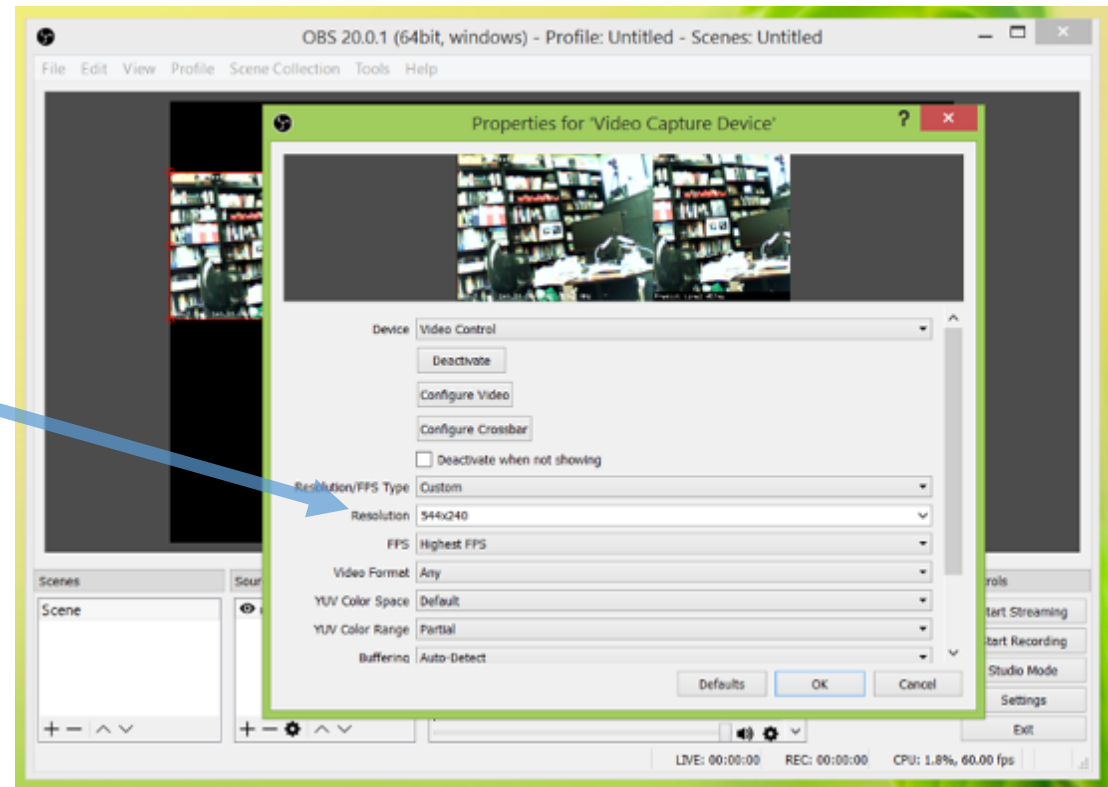


JeVois Smart Machine Vision Camera

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To launch a module, select its video resolution (shown at top right of each page) in your video capture software.



Example: setting resolution in Open Broadcaster Studio

See <http://jevois.org/start> for more detailed instructions.



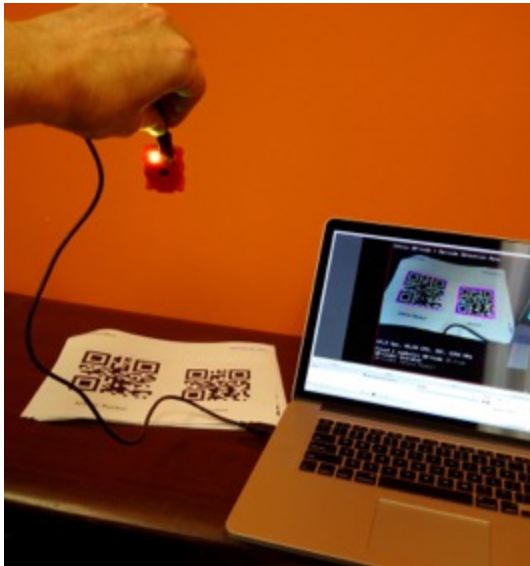
JeVois Smart Machine Vision Camera

Open-source quad-core camera effortlessly adds powerful machine vision to all your PC, Arduino, and Raspberry Pi projects.



For some modules, this guide provides sample images: point JeVois towards them while running that module. You may want to either:

- print this guide (color required for some examples to work well)
- display it on a tablet or computer screen (beware of reflections of lights in your room onto those screens, as they could interfere with JeVois processing; also some older screens may have too much flicker and may not work well)





JeVois Smart Machine Vision Camera

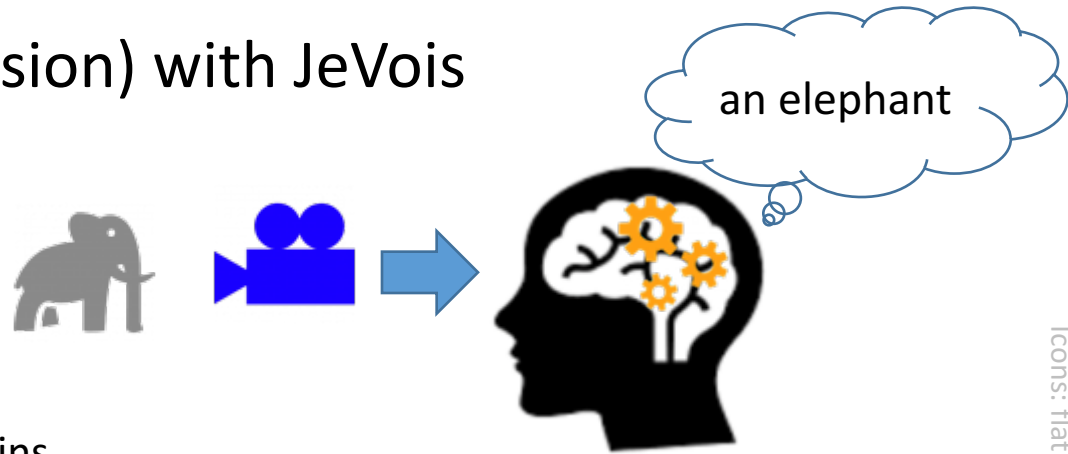
Open-source quad-core camera effortlessly adds powerful machine vision to all your PC, Arduino, and Raspberry Pi projects.



Computer vision (machine vision) with JeVois

Standard camera:

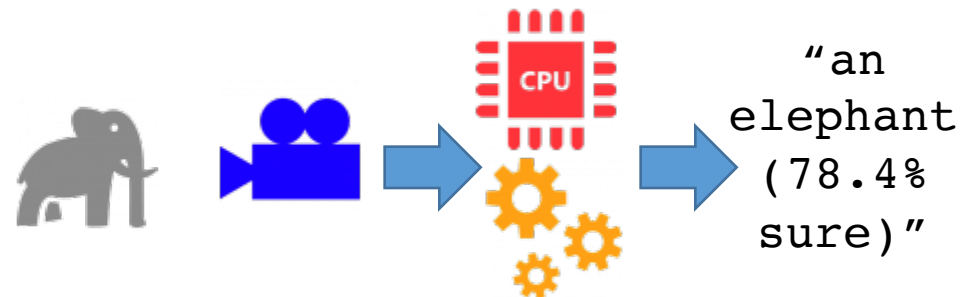
- captures video
- sends video to human user
- human brain interprets what video contains



Icons: flaticon

JeVois smart camera:

- captures video
- processes video to interpret what it contains
- sends interpretation to user, robot, or another computer





JeVois Smart Machine Vision Camera

Open-source quad-core camera effortlessly adds powerful machine vision to all your PC, Arduino, and Raspberry Pi projects.



Now get ready to be amazed and try these out:

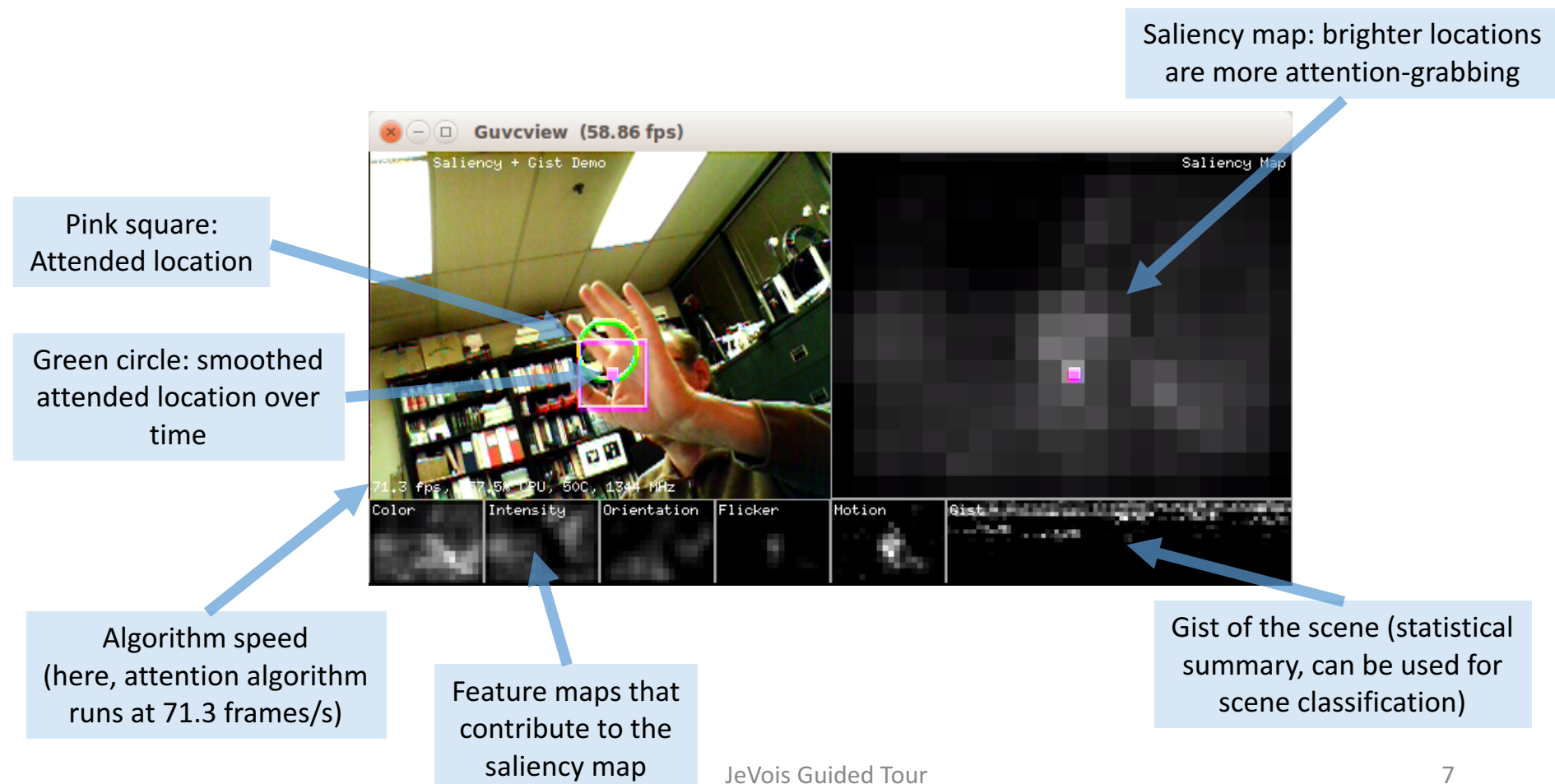
1. Visual attention – finding interesting things
2. Face and handwritten digit recognition
3. QR-codes and other tags
4. Road detection
5. Object matching
6. Object recognition with deep neural networks
7. Color-based object tracking
8. Moving object detection
9. Record video to the microSD card inside JeVois
10. Motion flow detection
11. Eye tracking
12. and more!

Visual attention: Saliency

640x300 @ 60fps

<http://jevois.org/moddoc/DemoSaliency/modinfo.html>

- Finds the location in the camera's view that is the most attention-grabbing, conspicuous, or so-called **salient**. Based on a neuroscience model that mimics attention processing in the human brain.
- This module only finds interesting things. It does not recognize what they are.



Visual attention: Saliency

640x300 @ 60fps

<http://jevois.org/moddoc/DemoSaliency/modinfo.html>

- Try it: wave at JeVois, point JeVois towards complex scenes and see what it finds most interesting.



Visual attention: Saliency

640x300 @ 60fps

<http://jevois.org/moddoc/DemoSaliency/modinfo.html>

- Search the web for images where something “catches your eye”, and show them to JeVois.



Image credit:  Chris Fort / flickr

JeVois Guided Tour

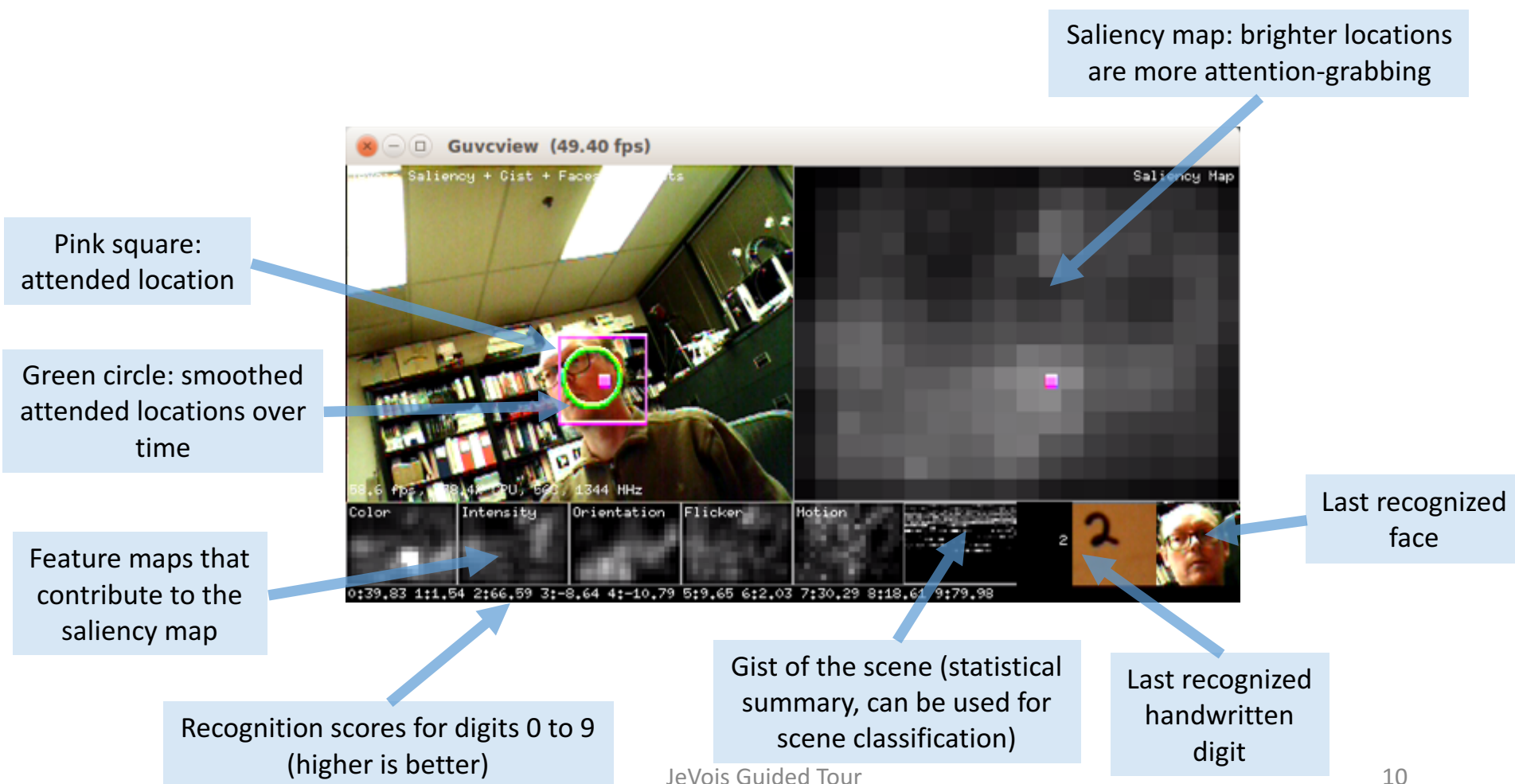
Saliency + gist + faces + objects

640x360 @ 50fps

640x312 @ 50fps

<http://jevois.org/moddoc/DemoSalGistFaceObj/modinfo.html>

- A visual attention algorithm finds the most interesting location in the field of view.
- Then, interpret what is in the attended region, in two ways:
 - attempt to detect a face, and,
 - attempt to recognize a handwritten digit, using a deep neural network.



Saliency + gist + faces + objects

640x360 @ 50fps

640x312 @ 50fps

<http://jevois.org/moddoc/DemoSalGistFaceObj/modinfo.html>

- Point JeVois to a digit, check bottom-right corner of video.
- Adjust distance so digit fits inside pink box (this algorithm is not very invariant to size).
- Hold JeVois straight (this algorithm does not handle rotation very well).

6

8

4

- Sometimes this algorithm makes mistakes.
- It was trained on 60,000 images. It was 99.2% correct on an independent set of 10,000 test images. But live video is always much harder.

Saliency + gist + faces + objects

640x360 @ 50fps

640x312 @ 50fps

<http://jevois.org/moddoc/DemoSalGistFaceObj/modinfo.html>

- Point JeVois to a face, check bottom-right corner of JeVois video.
- Adjust distance so face fits inside pink box (this algorithm is not very invariant to size).
- Hold JeVois straight (this algorithm does not handle rotation very well).



Saliency + gist + faces + objects

640x360 @ 50fps

640x312 @ 50fps

<http://jevois.org/moddoc/DemoSalGistFaceObj/modinfo.html>

- Try with your own face too! You may need to move it and shake it to make it attention-grabbing!
- Adjust distance from camera to make sure your face fits in the pink square.



JeVois Guided Tour

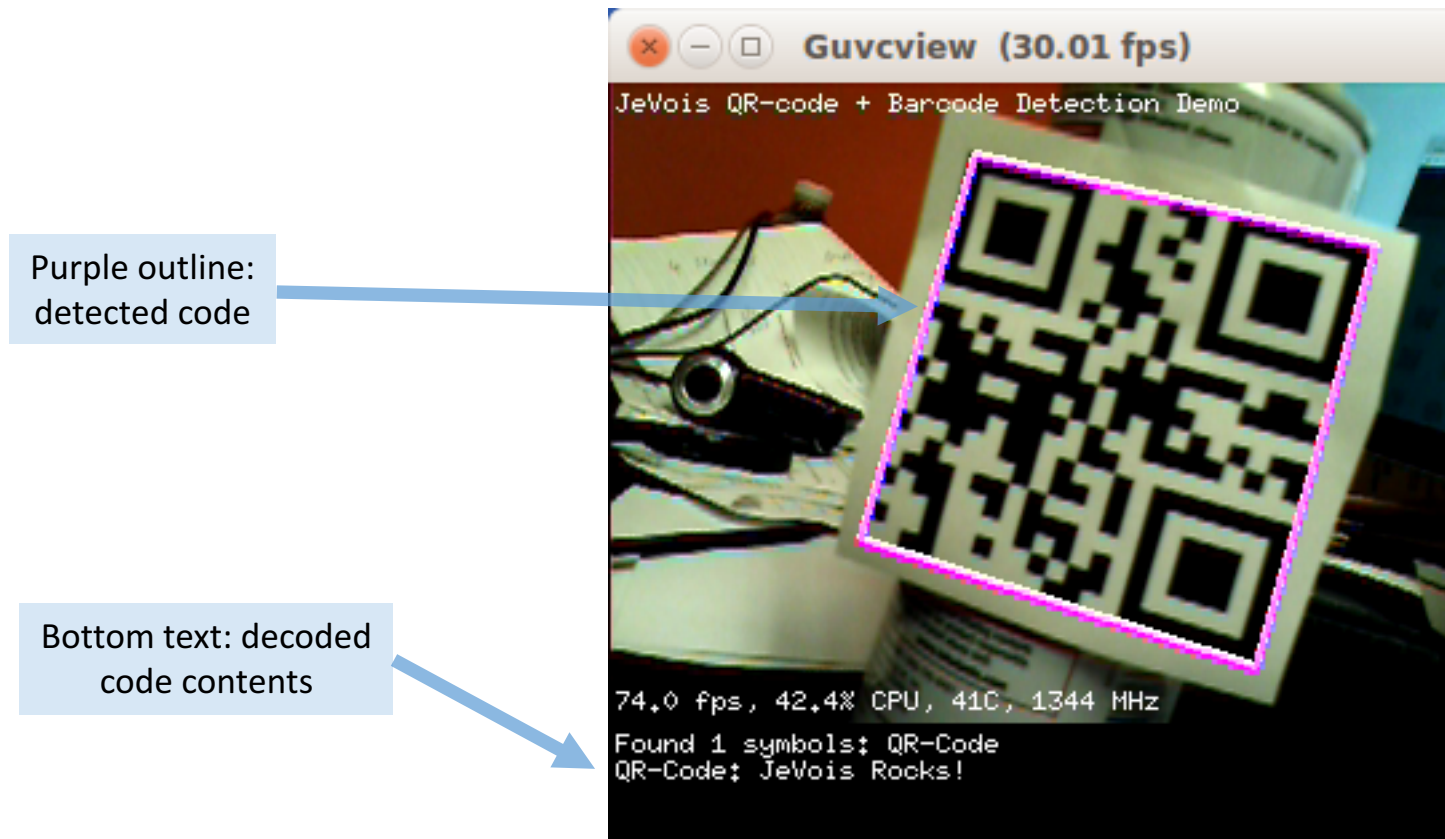


QR-codes and barcodes

320x286 @ 30fps

<http://jevois.org/moddoc/DemoQRcode/modinfo.html>

- Detect and decode QR-codes (2D barcodes) and standard barcodes.
- Useful for robots, visual aids for the blind, automated processing of packaged goods, etc.
- Note: only QR-codes enabled by default (no barcodes); see documentation for how to enable barcodes.



QR-codes and barcodes

320x286 @ 30fps

<http://jevois.org/moddoc/DemoQRcode/modinfo.html>



hello JeVois



JeVois Rocks!

QR-codes and barcodes

320x286 @ 30fps

<http://jevois.org/moddoc/DemoQRcode/modinfo.html>

- Try it by searching for QR-codes on the web.
- Make your own QR-codes, for example at <http://www.qr-code-generator.com>



elevator



kitchen

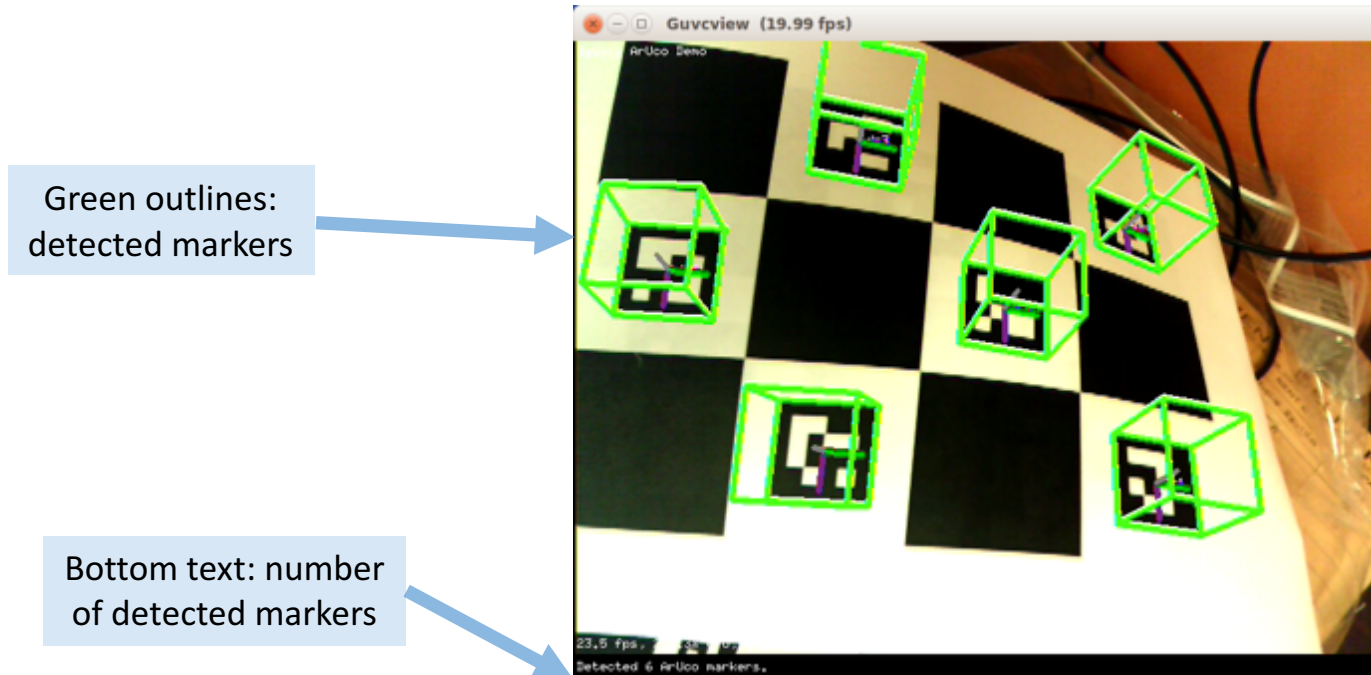
ArUco markers

320x260 @ 30fps

640x500 @ 20fps

<http://jevois.org/moddoc/DemoArUco/modinfo.html>

- ArUco markers are small 2D barcodes often used in augmented reality and robotics.
- JeVois can find them, decode their identity, and recover their full 6D pose (3D location + 3D orientation).



- Note: default behavior is to only show 2D outlines of markers.
- To enable 6D pose computation and cube displays, connect to JeVois serial port and issue:
`setpar dpose true`
`setpar showcube true`

ArUco markers

320x260 @ 30fps

640x500 @ 20fps

<http://jevois.org/moddoc/DemoArUco/modinfo.html>



ArUco 42



ArUco 18



ArUco 12



ArUco 27



ArUco 43



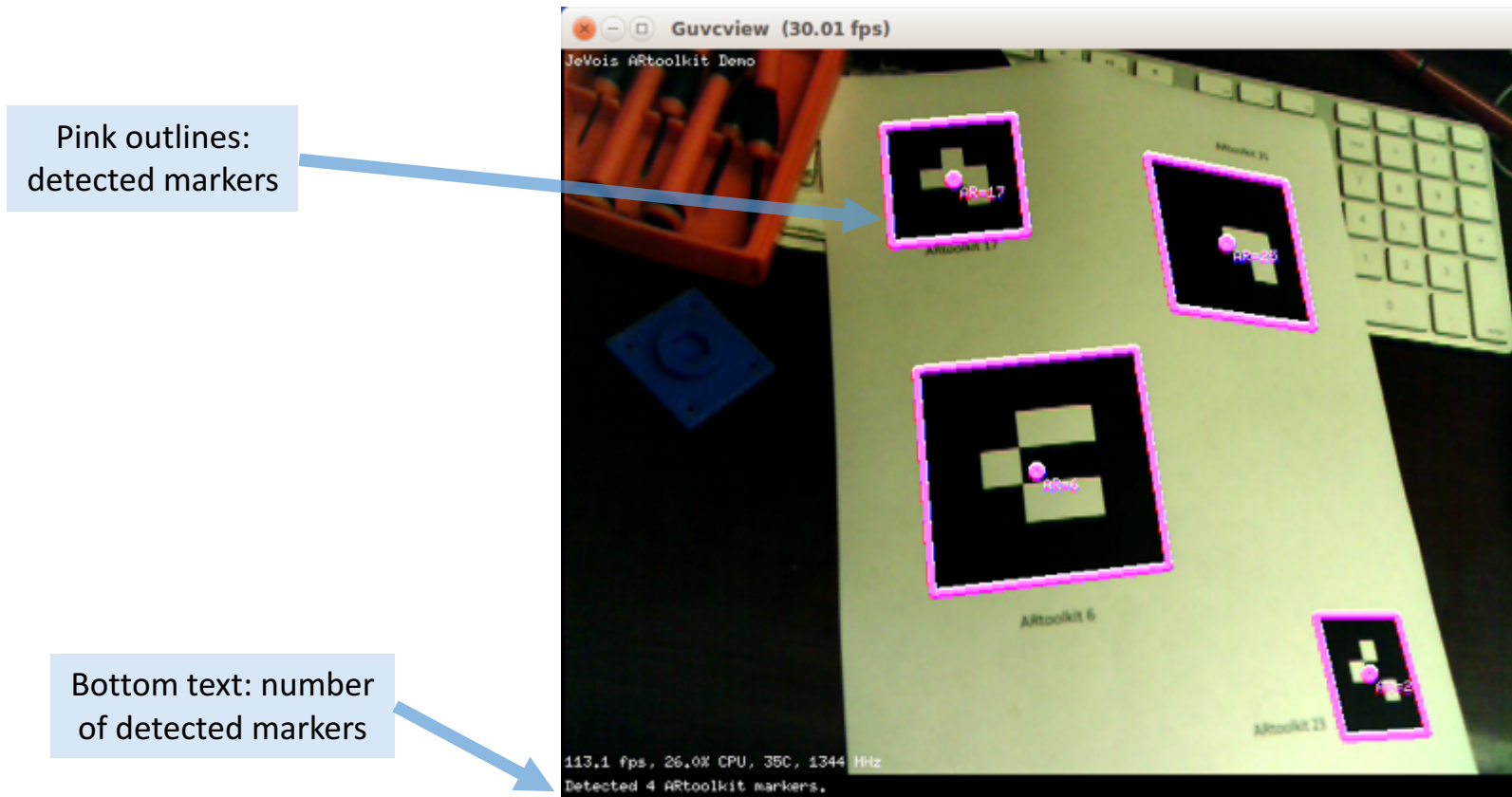
ArUco 5

ARtoolkit markers

320x258 @ 60fps

<http://jevois.org/moddoc/DemoARtoolkit/modinfo.html>

- ARtoolkit markers are small 2D barcodes often used in augmented reality and robotics.
- JeVois can find them, decode their identity, and recover their full 6D pose (3D location + 3D orientation).
- This algorithm is ultra fast: 400+ fps @ at 320x240, 100+ fps @ 640x480, 20+ fps @ 1280x1024.



ARtoolkit markers

320x258 @ 60fps

<http://jevois.org/moddoc/DemoARtoolkit/modinfo.html>

- You can assign roles to markers to help a robot find its way. For example: you can decide that marker 25 means “turn right”, marker 23 means “charging station”, etc.

ARtoolkit 25



ARtoolkit 23



ARtoolkit 17



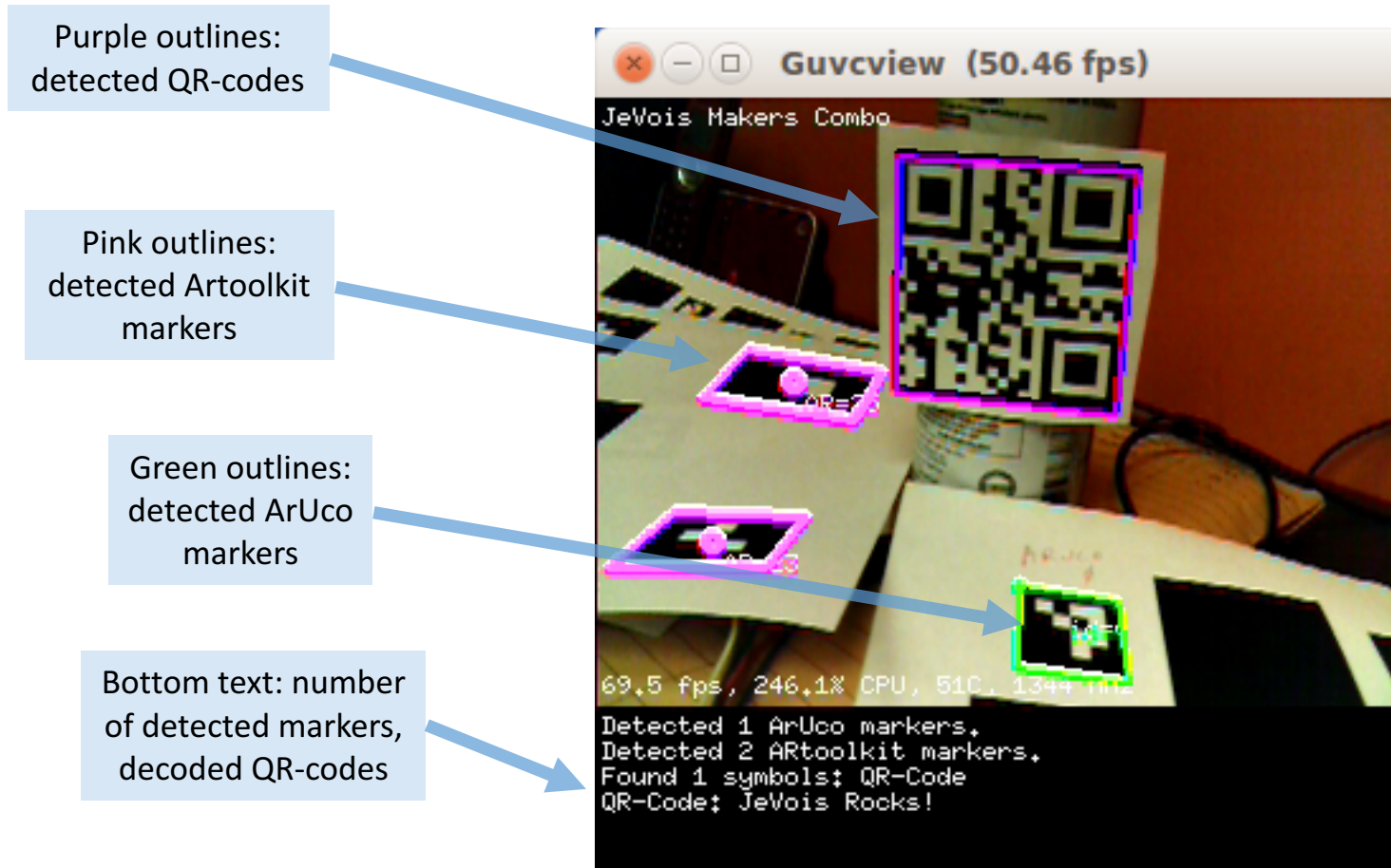
ARtoolkit 6



Markers Combination

<http://jevois.org/moddoc/MarkersCombo/modinfo.html>

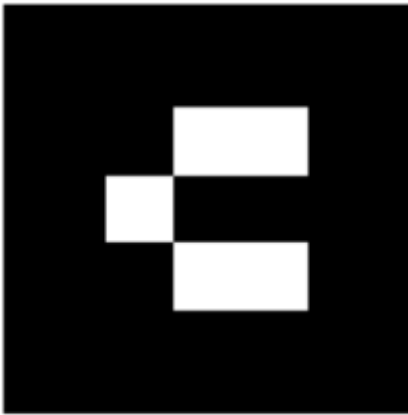
- Detect QR-codes, ArUco markers, and Artoolkit markers at the same time!
- The 3 algorithms run in parallel on the quad-core processor of JeVois



Markers Combination

640x546 @ 20fps

<http://jevois.org/moddoc/MarkersCombo/modinfo.html>



ARtoolkit 6



ArUco 18

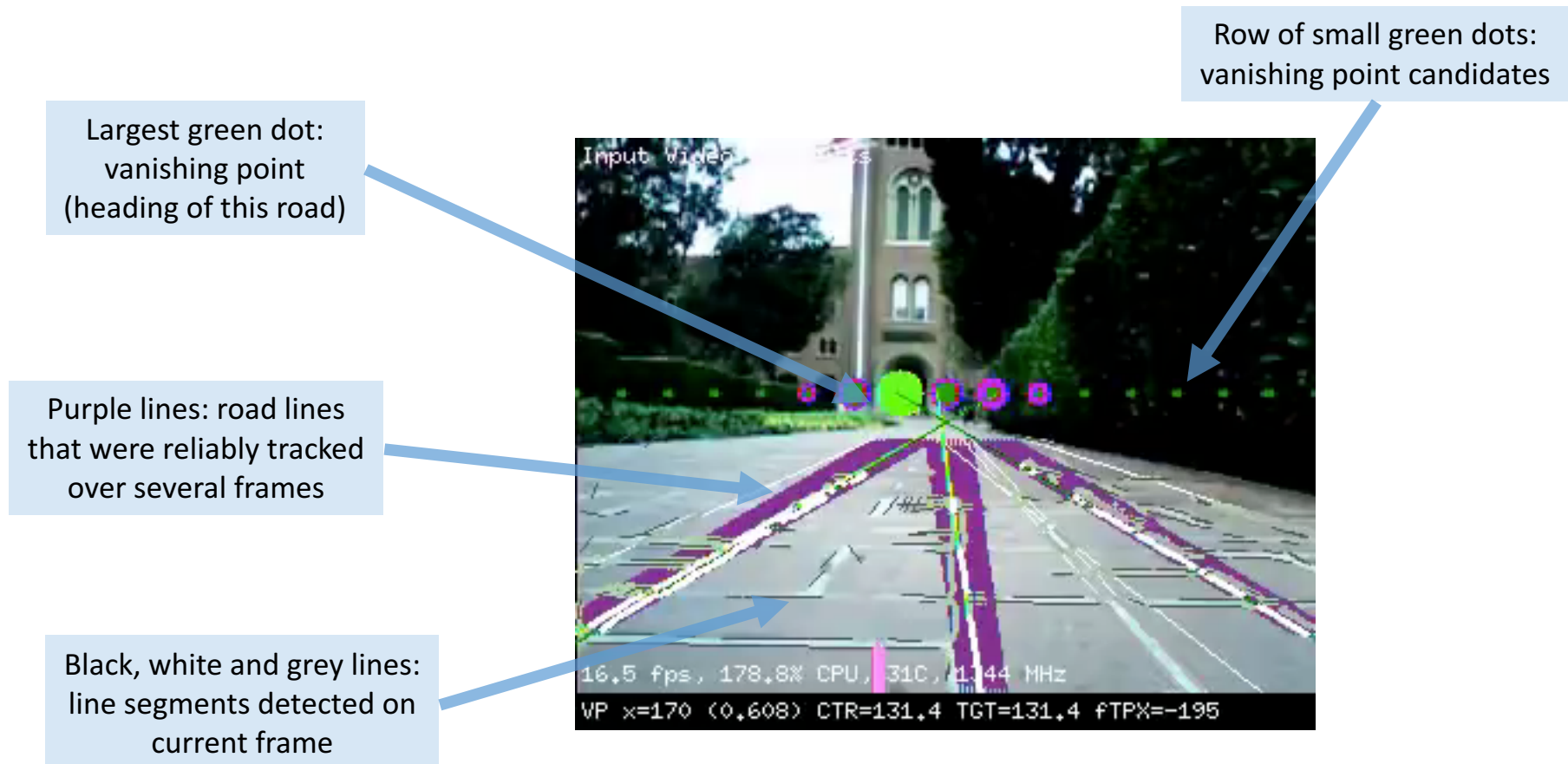


office

Road detection

<http://jevois.org/moddoc/RoadNavigation/modinfo.html>

- Combines detection and tracking of line segments at the edges of the road or on the road (e.g., lane dividers), and texture analysis to distinguish the road region from its surroundings.
- Be sure to position JeVois so that the row of green dots is on the horizon line of your scene.
- Note: this algorithm runs much faster when there is no display (drawing all these lines slows it down).



Road detection

320x256 @ 30fps

<http://jevois.org/moddoc/RoadNavigation/modinfo.html>

- Be sure to position JeVois so that the row of green dots is on the horizon line of your scene.
- Move JeVois left and right: large green dot should move too, as it tracks the road's vanishing point.



Road detection

320x256 @ 30fps

<http://jevois.org/moddoc/RoadNavigation/modinfo.html>

- Be sure to position JeVois so that the row of green dots is on the horizon line of your scene.
- Move JeVois left and right: large green dot should move too, as it tracks the road's vanishing point.



Road detection

320x256 @ 30fps

<http://jevois.org/moddoc/RoadNavigation/modinfo.html>

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Road detection

320x256 @ 30fps

<http://jevois.org/moddoc/RoadNavigation/modinfo.html>

- Be sure to position JeVois so that the row of green dots is on the horizon line of your scene.
- Move JeVois left and right: large green dot should move too, as it tracks the road's vanishing point.



Object detection and matching

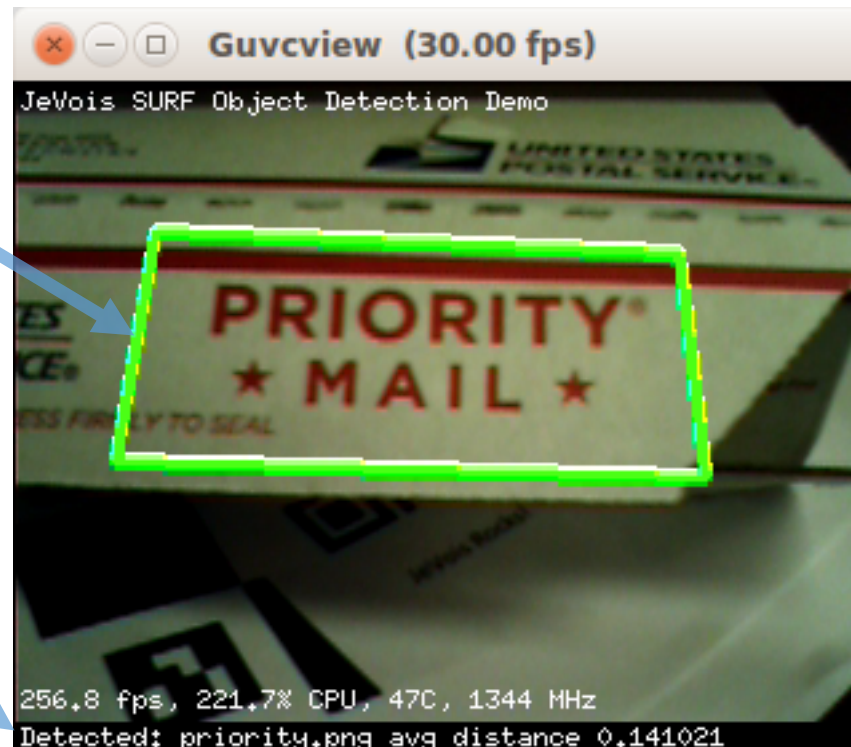
320x252 @ 30fps

<http://jevois.org/moddoc/ObjectDetect/modinfo.html>

- Finds objects by matching keypoint descriptors between the current image and a set of training images.
- 4 phases:
 - detect keypoint locations, typically corners or other distinctive texture elements or markings;
 - compute keypoint descriptors: summary representations of image patch around each keypoint;
 - match descriptors from current image to descriptors previously extracted from training images;
 - if enough matches found between current image and a given training image, draw green box.

Green box:
identified object

Text at bottom:
name of identified object



<http://jevois.org/moddoc/ObjectDetect/modinfo.html>

- By default, this module is only trained for one object: Priority Mail logo (only the red part).
- See above documentation page and JeVois tutorials for how to train new objects live.

PRIORITY[®]
★ MAIL ★

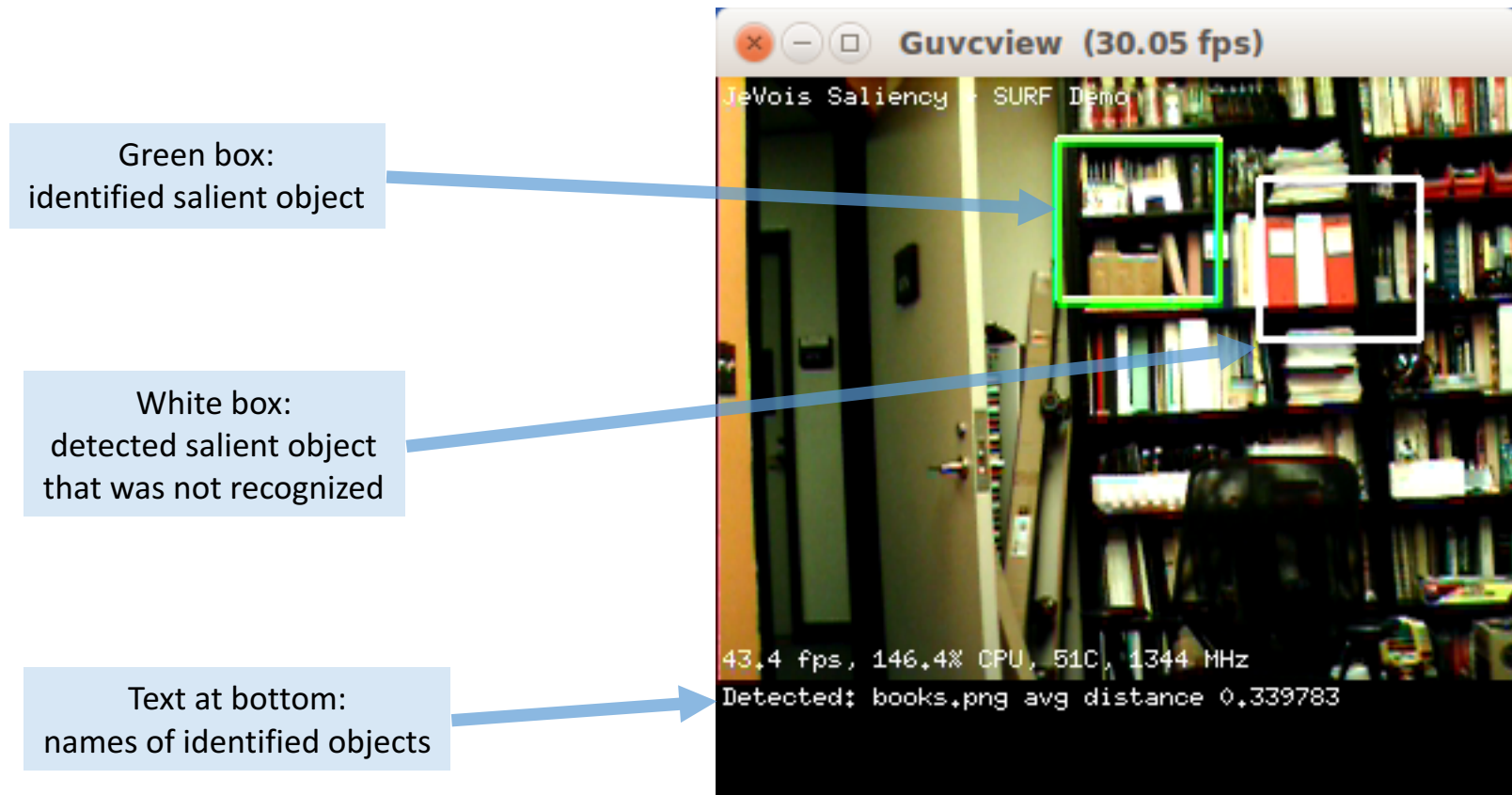


Salient object detection and matching

320x288 @ 30fps

<http://jevois.org/moddoc/SaliencySURF/modinfo.html>

- Combines saliency detection to locate objects, and keypoint matching.
- Recognizes salient objects by matching keypoint descriptors between a current set of salient regions and a set of training images.

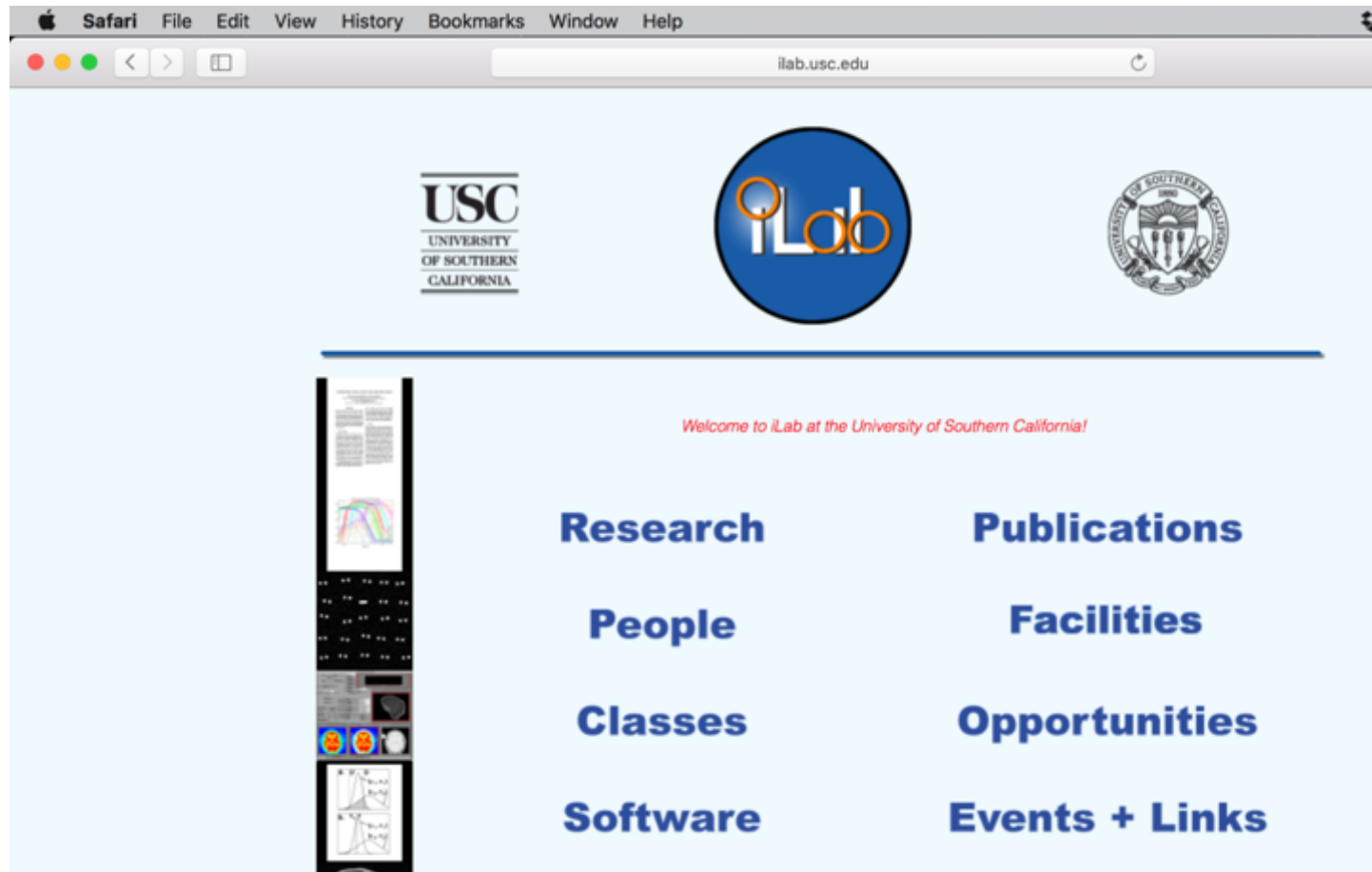


Salient object detection and matching

320x288 @ 30fps

<http://jevois.org/moddoc/SaliencySURF/modinfo.html>

- Trained by default on blue iLab logo, point JeVois to it and adjust distance so it fits in an attention box.
- Can easily add training images by just copying them to microSD card.
- Can tune number and size of salient regions, can save regions to microSD to create a training set.

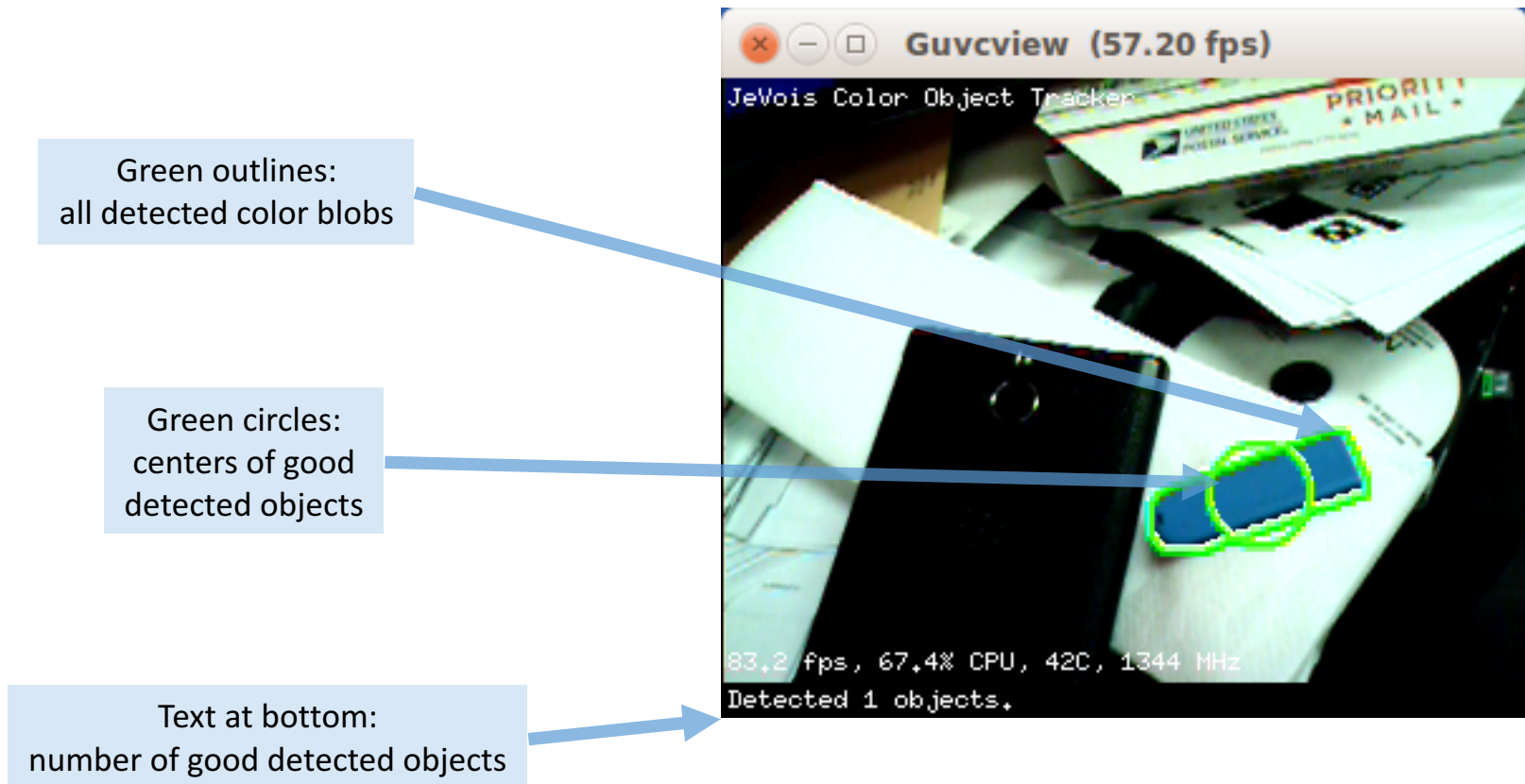


Color-based object tracking

320x254 @ 60fps

<http://jevois.org/moddoc/ObjectTracker/modinfo.html>

- Isolates pixels with a given hue, saturation, and brightness of color pixels, and extracts object contours.
- When image is clean (not too many blobs), identifies large enough blobs and mark them with a circle.

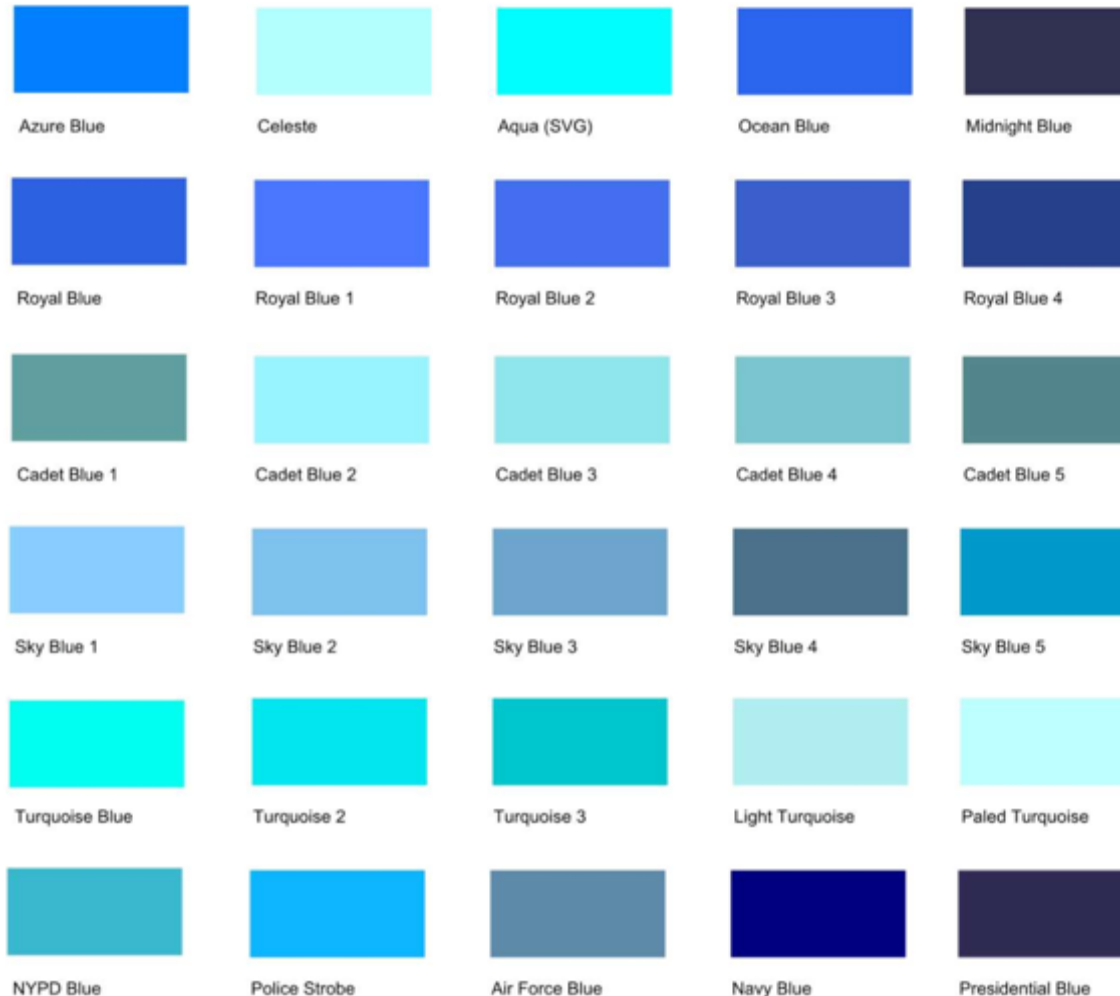


Color-based object tracking

320x254 @ 60fps

<http://jevois.org/moddoc/ObjectTracker/modinfo.html>

- Tuned by default for light blue objects. Can easily be changed using runtime parameters.
- Depending on your printer or screen, hopefully some of these objects should be detected.
- Try it with real blue objects!



source: drawingblog.mycoloringland.com

Object recognition with deep learning

544x240 @ 15fps

864x480 @ 15fps

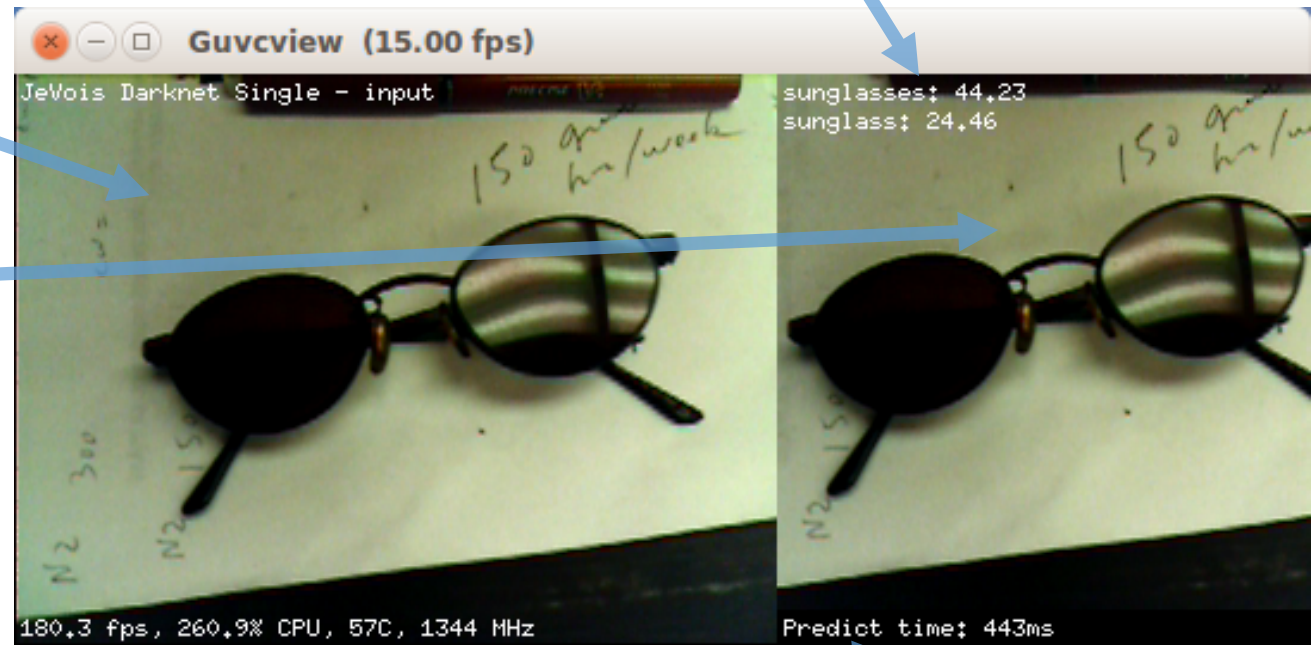
<http://jevois.org/moddoc/DarknetSingle/modinfo.html>

- Identifies the object in a square region in the center of the camera field of view using a deep convolutional neural network, trained to recognize 1000 different object types (object classes).
- Network size can be adjusted by changing video size. It directly affects both speed and accuracy. Larger networks run slower but are more accurate. See module documentation.

Top scoring object classes recognized
by the deep network, and confidence scores (0 .. 100)

Live video at
15 frames/s

Central region that was last
sent to the deep network



Time taken for neural network
predictions on this image

Object recognition with deep learning

544x240 @ 15fps

864x480 @ 15fps

<http://jevois.org/moddoc/DarknetSingle/modinfo.html>

- Try it with these objects or any other object you like.
- Sometimes this module will make mistakes! This module was trained using 1.2 million images. Performance was 58.7% correct (mean average precision) on a test set of 50,000 images.























Attention + deep object recognition

460x240 @ 15fps

880x480 @ 15fps

<http://jevois.org/moddoc/DarknetSaliency/modinfo.html>

- Find the most interesting object using visual attention algorithm, then identify it using a deep convolutional neural network, trained to recognize 1000 different object types (object classes).
- Network size can be adjusted by changing video size. It directly affects both speed and accuracy. Larger networks run slower but are more accurate. See module documentation.

The screenshot shows a window titled "Gvvcview (15.01 fps)" displaying a live video feed. A pink rectangular box highlights a red toy car on a dark surface. A small pink square is visible on the car. To the right of the main video, a smaller inset shows a zoomed-in view of the car. Below the inset, a black box displays the following text:

```
sports car: 61.08  
racer: 22.84  
  
Predict time: 203ms
```

Annotations with arrows point to various parts of the interface:

- Live video at 15 frames/s**: Points to the main video feed.
- Pink box: attended (most salient) region**: Points to the pink bounding box around the car.
- Attended region that was last sent to the deep network**: Points to the small pink square on the car.
- Top scoring object classes recognized by the deep network, and confidence scores (0 .. 100)**: Points to the text "sports car: 61.08" and "racer: 22.84".
- Time taken for neural network predictions on this image**: Points to the text "Predict time: 203ms".

At the bottom of the window, status information is visible: "fps, 197.0% CPU, 49C, 1344".

Attention + deep object recognition

460x240 @ 15fps

880x480 @ 15fps

<http://jevois.org/moddoc/DarknetSaliency/modinfo.html>

- Try it with the same images as the previous module!

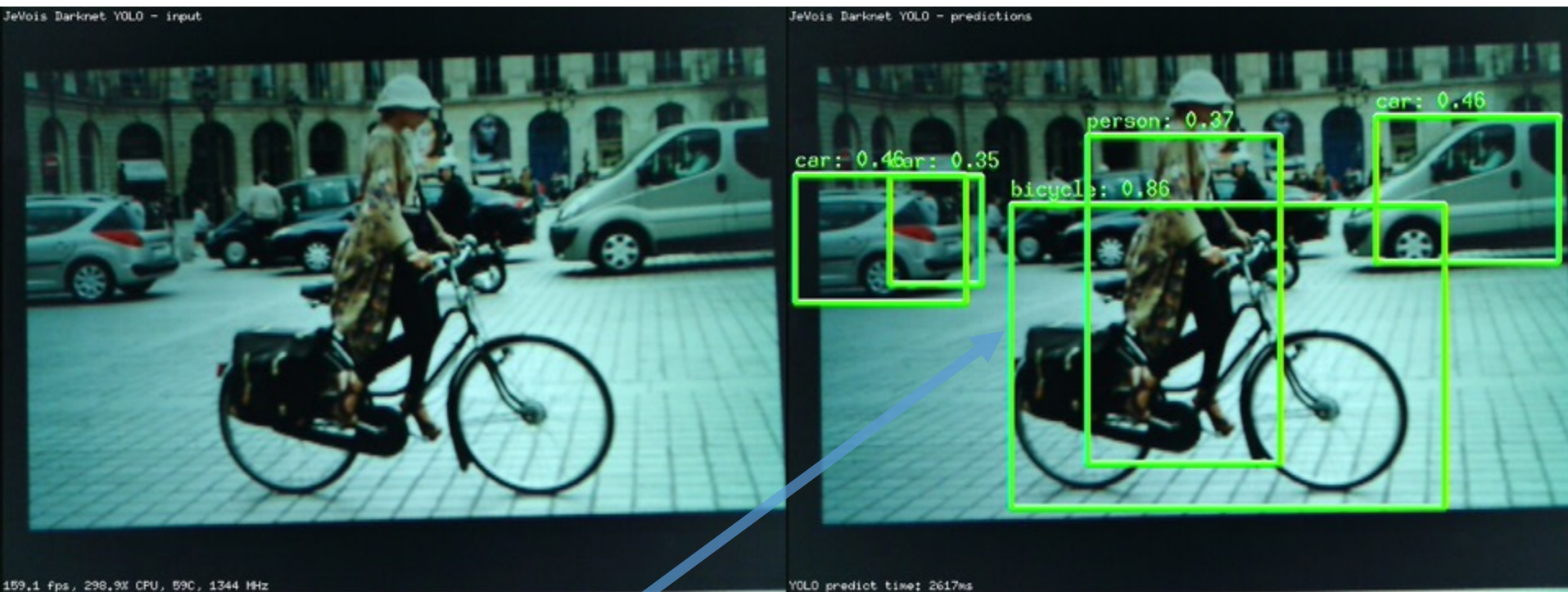


Deep neural scene analysis

1280x480 @ 15fps

<http://jevois.org/moddoc/DarknetYOLO/modinfo.html>

- Detect and recognize all objects in the camera's view, using a state-of-the-art deep neural network for combined object localization and recognition.
- Quite slow but very powerful. Trained to recognize 20 object types: Aeroplanes, Bicycles, Birds, Boats, Bottles, Buses, Cars, Cats, Chairs, Cows, Dining tables, Dogs, Horses, Motorbikes, People, Potted plants, Sheep, Sofas, Trains, and TV/Monitors.



Live video at
15 frames/s

All objects detected and recognized,
and confidence scores (0 .. 100)

Time taken for neural network
predictions on this image

Deep neural scene analysis

1280x480 @ 15fps

<http://jevois.org/moddoc/DarknetYOLO/modinfo.html>



Deep neural scene analysis

1280x480 @ 15fps

<http://jevois.org/moddoc/DarknetYOLO/modinfo.html>



Deep neural scene analysis

1280x480 @ 15fps

<http://jevois.org/moddoc/DarknetYOLO/modinfo.html>



Deep neural scene analysis

1280x480 @ 15fps

<http://jevois.org/moddoc/DarknetYOLO/modinfo.html>



Deep neural scene analysis

1280x480 @ 15fps

<http://jevois.org/moddoc/DarknetYOLO/modinfo.html>



Deep neural scene analysis

1280x480 @ 15fps

<http://jevois.org/moddoc/DarknetYOLO/modinfo.html>



Deep neural scene analysis

1280x480 @ 15fps

<http://jevois.org/moddoc/DarknetYOLO/modinfo.html>



Deep neural scene analysis

1280x480 @ 15fps

<http://jevois.org/moddoc/DarknetYOLO/modinfo.html>



Deep neural scene analysis

1280x480 @ 15fps

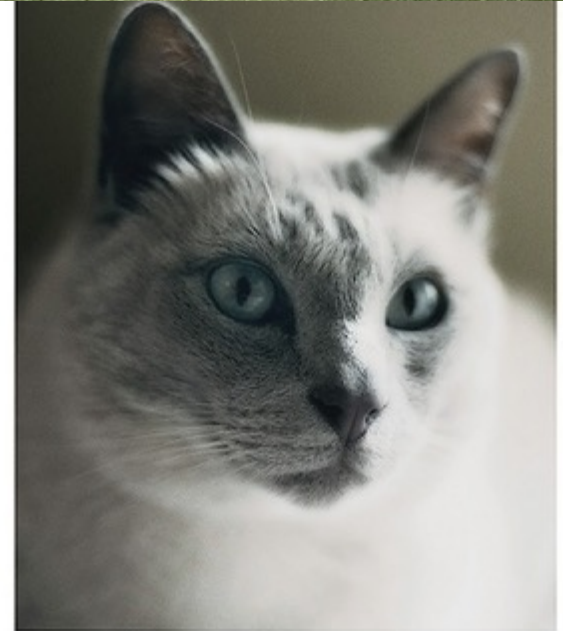
<http://jevois.org/moddoc/DarknetYOLO/modinfo.html>



Deep neural scene analysis

1280x480 @ 15fps

<http://jevois.org/moddoc/DarknetYOLO/modinfo.html>

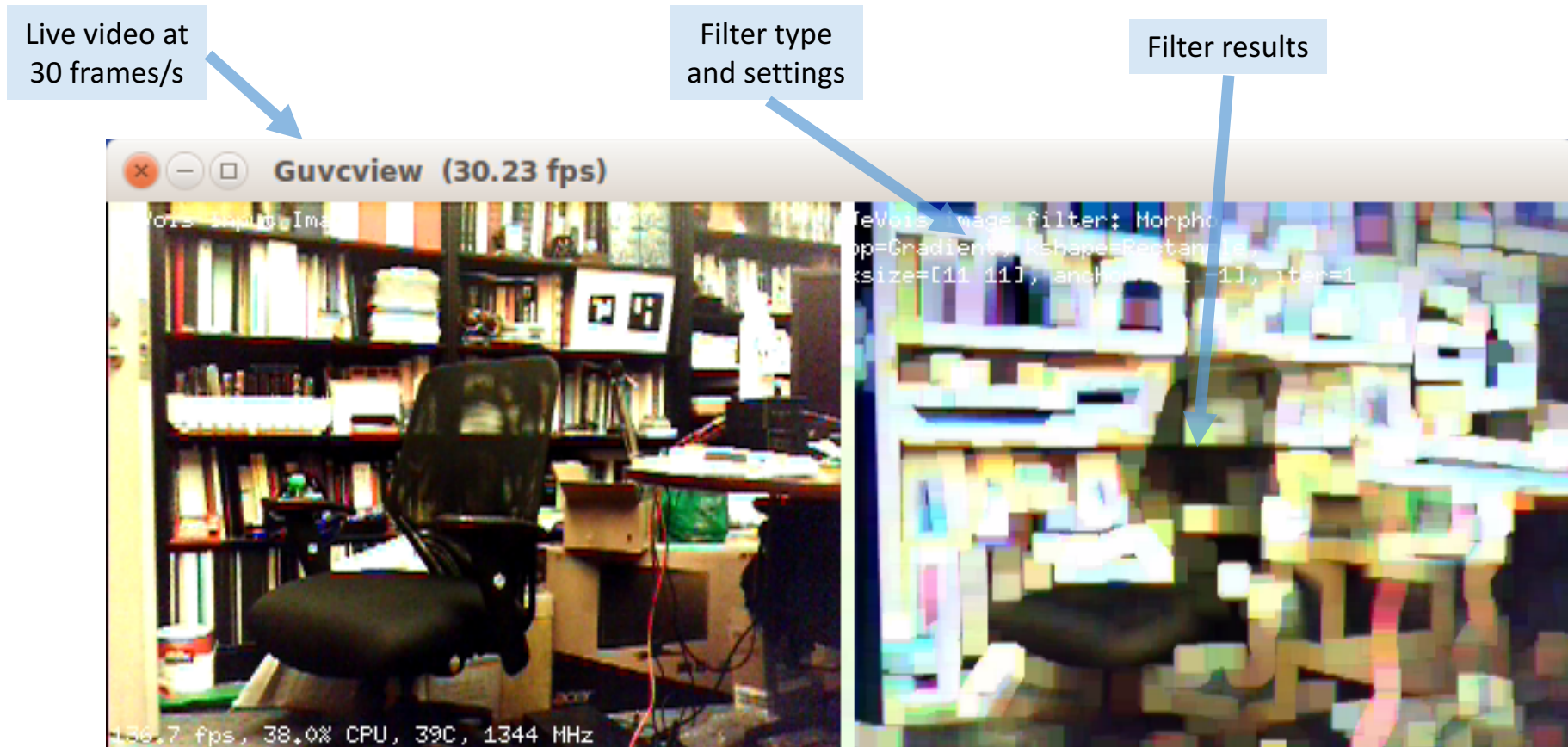


Color filtering

640x240 @ 30fps

<http://jevois.org/moddoc/ColorFiltering/modinfo.html>

- This module is to learn about basic image filtering. It was developed to allow students to instantly observe the effects of different filters and their parameters on live video. The module implements a variety of filters using OpenCV. Each filter exposes some parameters (e.g., kernel size) that can be set interactively to understand their effects onto the filter behavior.
- To trigger different filters, you need to send commands to JeVois. See module documentation.



Save video to microSD

320x240 @ 60fps

176x144 @ 120fps

<http://jevois.org/moddoc/SaveVideo/modinfo.html>

- Records video and saves it to the MicroSD card inside the JeVois smart camera.
- Useful, for example, to record footage that will be used to train some machine vision algorithm.
- To start saving: connect to JeVois and send "start" command; to stop, send "stop" command.
- Successive start/stop cycles save to different video files.
- Access the files either live by exporting microSD as virtual flash drive, or offline by taking microSD out of JeVois and inserting it into your desktop or laptop.
- Supports high frame rates, e.g., 120fps at 176x144 or 88x72.

Recording indicator.
Turns to RECORDING after start
Turns to NOT RECORDING after stop

Recorded file name and
directory on microSD card



Moving object detection

<http://jevois.org/moddoc/DemoBackgroundSubtract/modinfo.html>

- Learns a statistical model of the scene over time, that is, learns the color and brightness of each pixel, including small variations due to noise, small changes in lighting, etc.
- When an image region becomes very different than the learned model, show it in the right panel as detected foreground region.
- Keep JeVois stable and wait for a few seconds. Right panel should turn mostly black. Now move your hand or some object in front of JeVois. It should appear as a white region in the right panel.



Live video

Moving objects appear as white blobs here

- Note: sometimes, moving a large object in front of JeVois will trigger a change in auto exposure setting, which may make the whole scene brighter, and hence the whole scene will be detected as changing on the right side. This module is hence best used with manual exposure and gain settings (see module documentation for details).



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JeVois vision modes with greyscale outputs

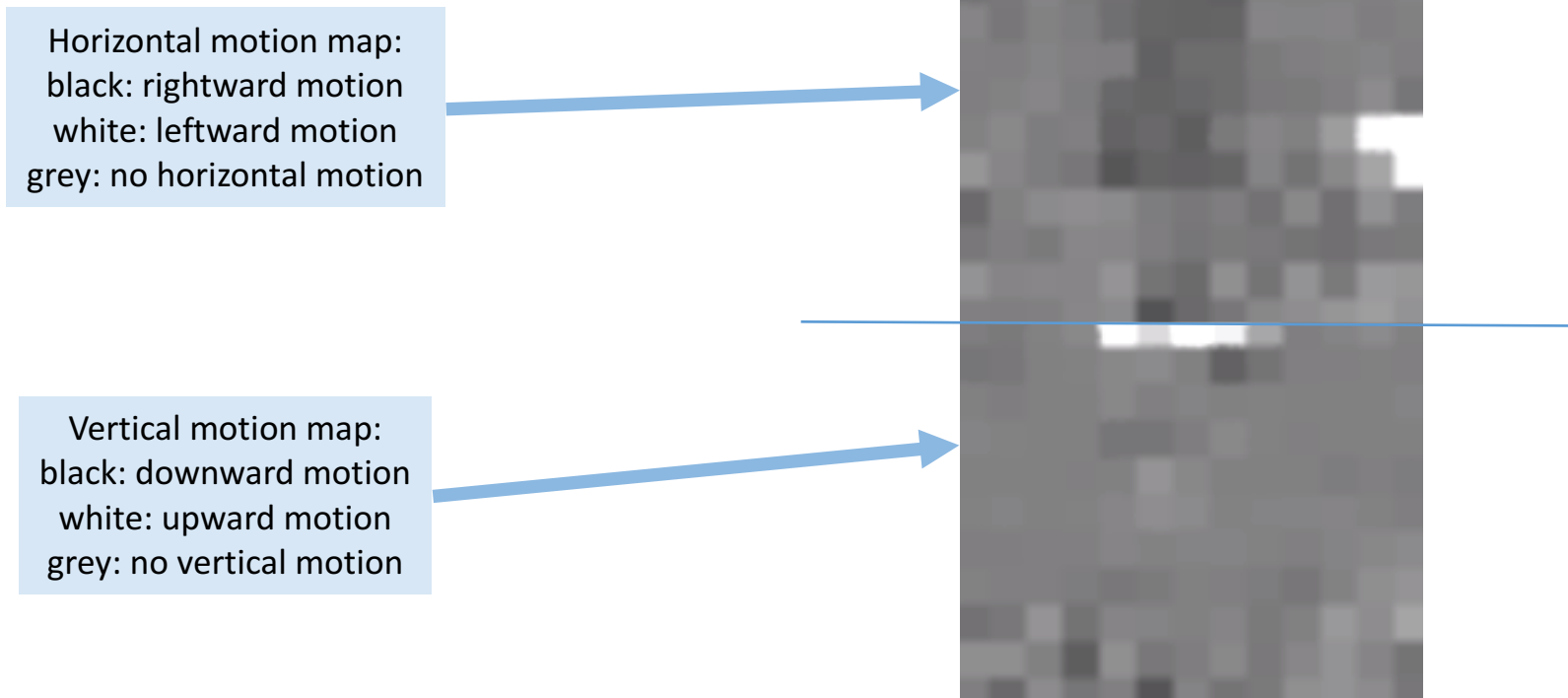
- These may not work with all video capture software.
- Known issues with Windows and AMCap when trying to capture greyscale video (not only from JeVois).
- See <http://jevois.org/start> for more information.

Optical flow

GRAY 176x288 @ 100fps

<http://jevois.org/moddoc/OpticalFlow/modinfo.html>

- Computes horizontal and vertical optical flow into two separate optical flow maps.
- Very fast: 100 frames/s with 176x144 input video.
- Intended for use as a pre-processor: images sent out may be further processed by the host computer.
- Try it: move your hand or other objects in front of JeVois.



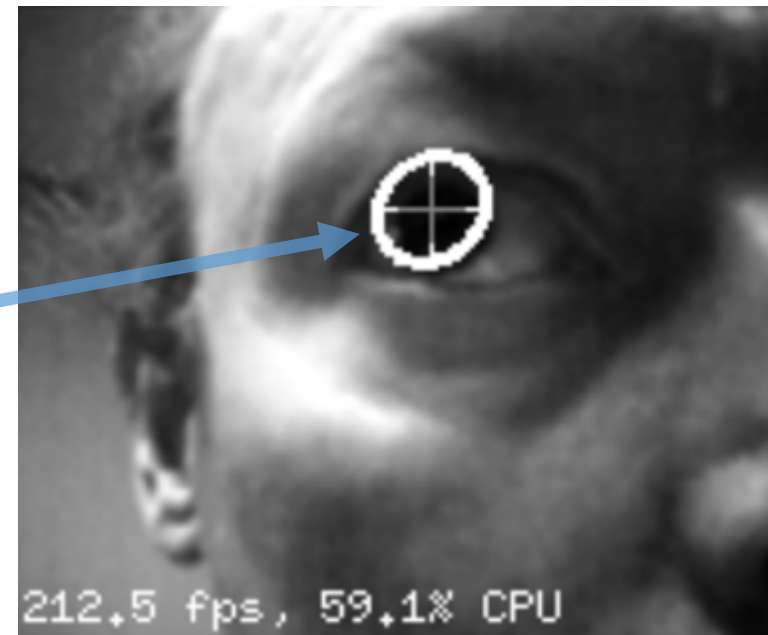
Eye tracking

GRAY 176x144 @ 120fps

<http://jevois.org/moddoc/DemoEyeTracker/modinfo.html>

- Implements an eye tracker, which is based on detecting the outline of the pupil.
- Used in research on attention, eye movements, psychophysics, human-computer interfaces, user interface design, gaming, advertising, driving safety, and neurology.
- Note: need to switch video capture software to grayscale mode (not supported by all software).
- Supports high frame rates, e.g., 30fps at 640x480, 60fps at 320x240, 120fps at 176x144.
- Note that the camera has to be very close to the eye for this to work well with stock optics. To be useful in practice, some prism or tele-lens should be used so that the camera can be out of the field of view of the human participant.

Crosshair: center of the pupil
Ellipse: edges of pupil



Eye tracking

GRAY 176x144 @ 120fps

<http://jevois.org/moddoc/DemoEyeTracker/modinfo.html>

- Try it: can it detect these pupils?

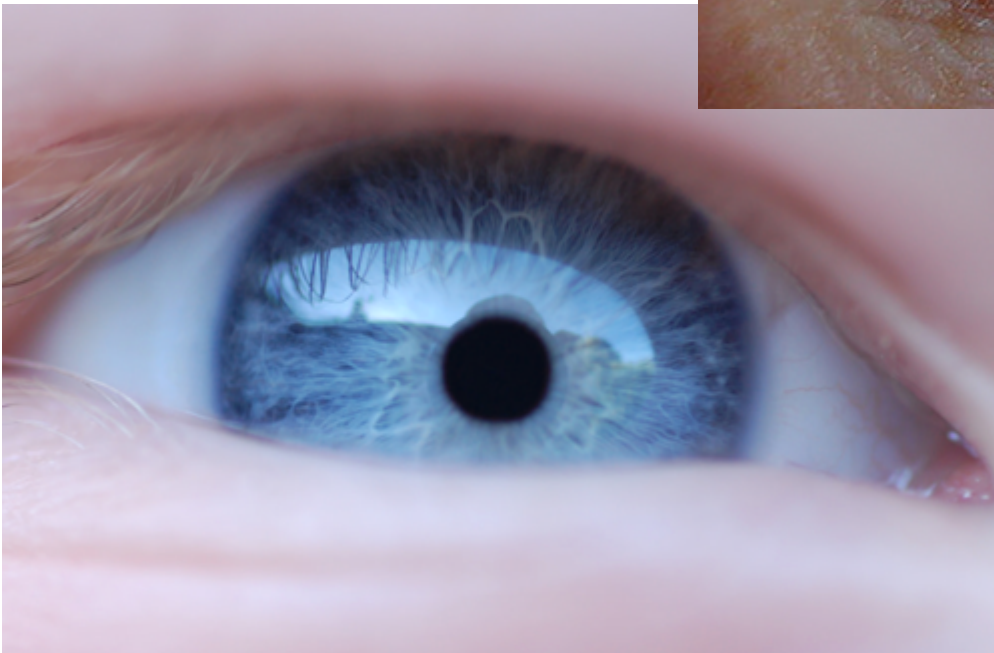
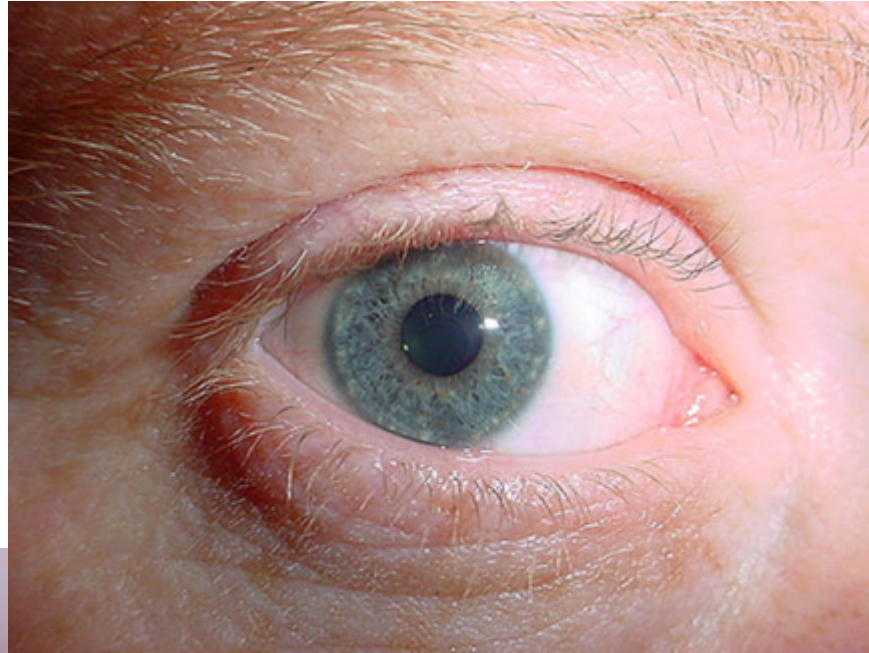
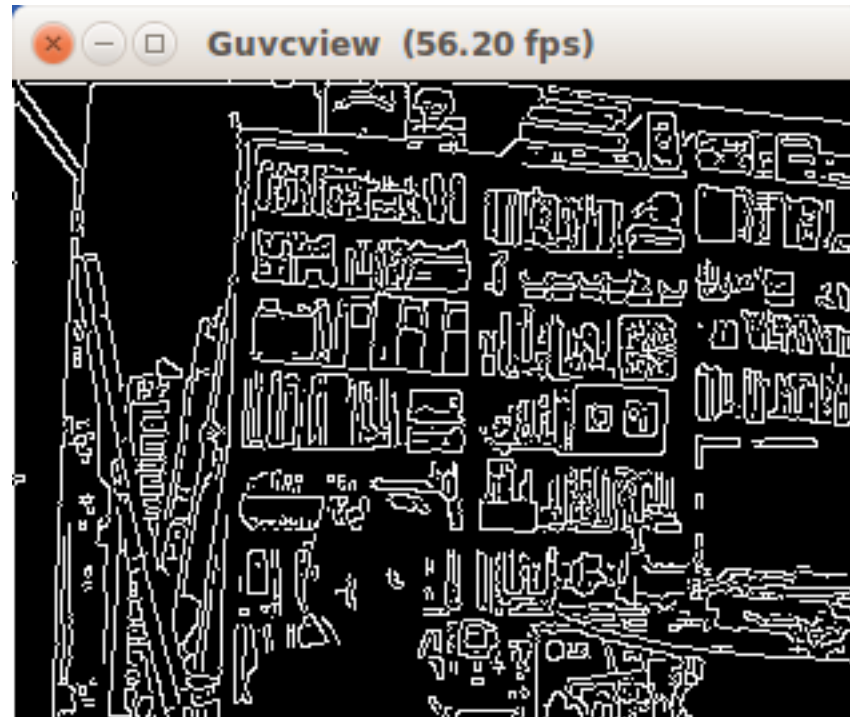


Image credit:  steve lodefink, Glenn Reilly, Paul Scott / flickr

Edge detection

<http://jevois.org/moddoc/EdgeDetection/modinfo.html>

- Compute edges in an image using the Canny edge detection algorithm.
- Intended as a pre-processor, delivering edge maps to a host computer, which may then be in charge of further processing them, for example to detect objects of various shapes.
- Runs at 60+ frames/s with resolution 320x240 on the JeVois camera.
- Try it: point JeVois to anything!



Edge detection X4

GRAY 320x960 @ 45fps

<http://jevois.org/moddoc/EdgeDetectionX4/modinfo.html>

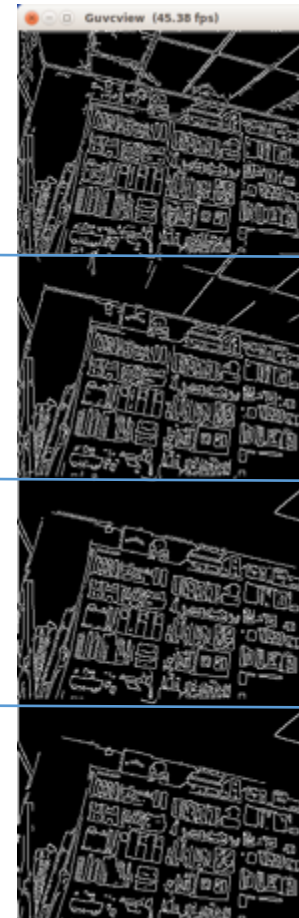
- Compute 4 Canny edge detection filters with 4 different settings, in parallel.
- Intended as a pre-processor, delivering edge maps to a host computer, which may then be in charge of further processing them, for example to detect objects of various shapes and sizes.
- Runs at 45+ frames/s with resolution 320x240 on the JeVois camera.
- Try it: point JeVois to anything!

Finest settings (most details)

Fine

Coarse

Coarsest settings (least details)



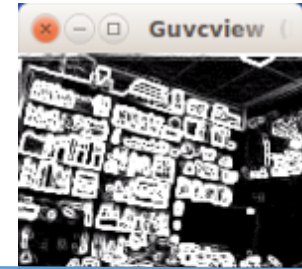
GPU image processing

GRAY 160x495 @ 60fps

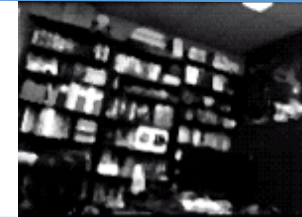
<http://jevois.org/moddoc/DemoCPUGPU/modinfo.html>

- GPU (graphics processing unit) is a second processor element inside JeVois. Normally it is used to create smooth 3D displays. But, since JeVois has no screen, we can use it instead for machine vision!
- This module computes saliency and gist over our 4 CPU cores while also computing 4 different image filters over the dual-core GPU, finally combining all results into a single grayscale image:
 - saliency: multicore CPU-based detection of the most attention-grabbing location.
 - GPU filter 1: Sobel edge detector.
 - GPU filter 2: Median filter.
 - GPU filter 3: Morphological erosion filter.
 - GPU filter 4: Morphological dilation filter.

Sobel edge detector



Median filter
(removes noise)



Erosion filter
(widens holes)



Dilation filter
(fills holes)



Saliency map, feature maps,
and gist (tiny scale)





JeVois Smart Machine Vision Camera

Open-source quad-core camera effortlessly adds powerful machine vision to all your PC, Arduino, and Raspberry Pi projects.



There is more!

- Please visit <http://jevois.org> for more information.
- All available machine vision modules are listed at: <http://jevois.org/doc/UserDemos.html>
- You can program your own modules using Python + OpenCV 3.3
- You can also program your own modules in C++
- With JeVois, the future of machine vision is in your hands!