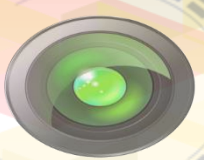


embedded VISION ALLIANCE

Creating Smarter, More Interactive Apps and Systems with Computer Vision

Jeff Bier, Founder, Embedded Vision Alliance / President, BDTI

Augmented World Expo – June 8, 2015

“Half of the human brain is devoted directly or indirectly to vision.”

– Paraphrased from Prof. Mriganka Sur, MIT

Computer Vision and Augmented Reality

- **Computer vision**: automatically extracting meaning from images

- For augmented reality, computer vision:
  - Identifies objects
  - Estimates and tracks objects' position and orientation
  - Locates the device in the environment
  - Locates the viewer's eyes

circuitstoday.com

laptopmag.com

The Evolution of Vision Technology

***Computer vision*:** research and fundamental technology for extracting meaning from images

***Machine vision*:** factory applications

***Embedded vision*:** thousands of applications

- Consumer, automotive, medical, defense, retail, gaming, security, education, transportation, …
- Embedded systems, mobile devices, PCs and the cloud

The Highest Bandwidth Input Channel

Machines are useful mainly to the extent that they **interact with the physical world**

Visual information is the richest source of information about the real world: People, places, and things

Vision is the highest-bandwidth mode for machines to obtain real-world info

Embedded vision enables our things to be:

- **More responsive**: Knowing what's around and what's going on
- **More personal and secure:** Knowing who is around them
- **Safer, more autonomous**: Knowing location relative to objects, people
- **Easier to use**: Enabling natural user interfaces

Embedded Vision in Mobile

Photography

Vision enables capturing better photos and improving captured shots

- High dynamic range
- Automatic panorama
- Face and smile detection
- Object removal
- Trick shots

SnapPhun by MacHeal LLC

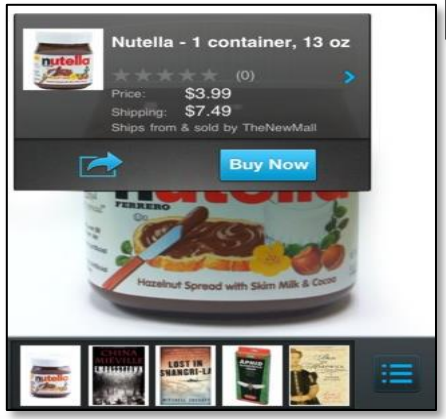
Almalence

Visual Search

Visual search turns mobile phones into a powerful tools for learning about physical objects

- What is it?
  Do users like it?
- Where can I buy it?
  Is this price good?
- What else is like it?

engadget.com



Interactive Visual Search: Amazon Flow

www.youtube.com/watch?v=etusHx633fU

Innovating with Embedded Vision: MotionSavvy Empowers the Deaf

www.youtube.com/watch?v=sqAbOZMZp_E

Libraries and SDKs: Human Interaction

- Skeletal tracking
  - Detect humans and track joints, limbs, head, etc. (may not include fingers)
  - Typically requires 3D sensor
- Hand/finger tracking
  - Detect human hands and track hand and finger joints
- Some companies provide hardware + software combinations
- Examples: SoftKinetic, Kinect SDK, Leap Motion, Nible UX, Intel RealSense


skelTrackK2.mp4

Libraries and SDKs: Human Interaction

- Gesture
  - Identify human gestures for user interaction
  - May or may not rely on skeletal/hand/finger tracking
  - Examples: PointGrab, eyeSight

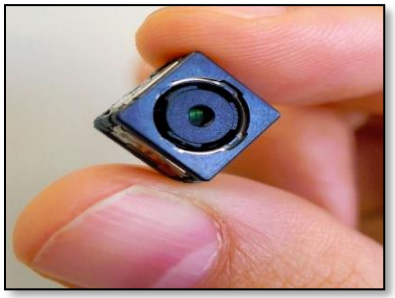
Libraries and SDKs: Human Interaction

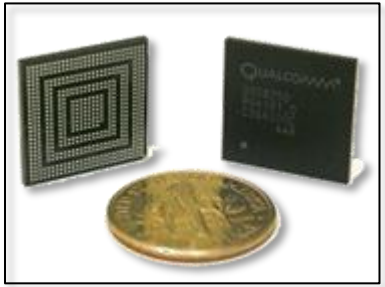
- Face analysis
  - Face detection: find faces in image
  - Face recognition: identify an individual person by matching facial features against a database
  - Emotion recognition: identify emotions based on facial expressions
  - Other: head pose, gender, age, track lips, track gaze, etc.
  - Examples: OpenCV, Lambda Labs, Animetrics, Libface, Eyeris, Visage

VisageFaceTrack_short.mp4

One Sensor, Many Uses

Software-Defined Sensor





?

```
// convert cpu Mat to gpu array
void mat_to_array(cv::Mat& input, array& output) {
    input.convertTo(input, CV_32FC3); // floating point
    const unsigned size = input.rows * input.cols;
    const unsigned w = input.cols;
    const unsigned h = input.rows;
    float r[size];
    float g[size];
    float b[size];
    int tmp = 0;
    for (unsigned i = 0; i < h; i++) {
        for (unsigned j = 0; j < w; j++) {
            Vec3f ip = input.at<Vec3f>(i, j);
            tmp = j * h + i; // convert to column major
            r[tmp] = ip[2];
            g[tmp] = ip[1];
            b[tmp] = ip[0];
        }
    }
    output = join(2,
                  array(h, w, r),
                  array(h, w, g),
                  array(h, w, b))/255.f; // merge, set range [0-1]
}
```

What Do You Want to Sense?

- People
  - Presence
  - Number
  - Location, trajectory
  - Pose, head pose, gaze, gestures
  - Age, gender, grouping
  - Identity
  - Emotional state, drowsiness
  - Heart rate, intoxication
  - …
- Places
  - What's around?
  - Boundaries (map)
  - Location in space
- Things
  - Type
  - Number
  - Size, orientation
  - 3D location, trajectory
- Situations
  - Potential collision
  - Unexpected changes

Embedded Vision in Wearables

Augmented Reality for Industry

www.youtube.com/watch?v=9Wv9k_ssLcI

Interpreter for the Visually Impaired

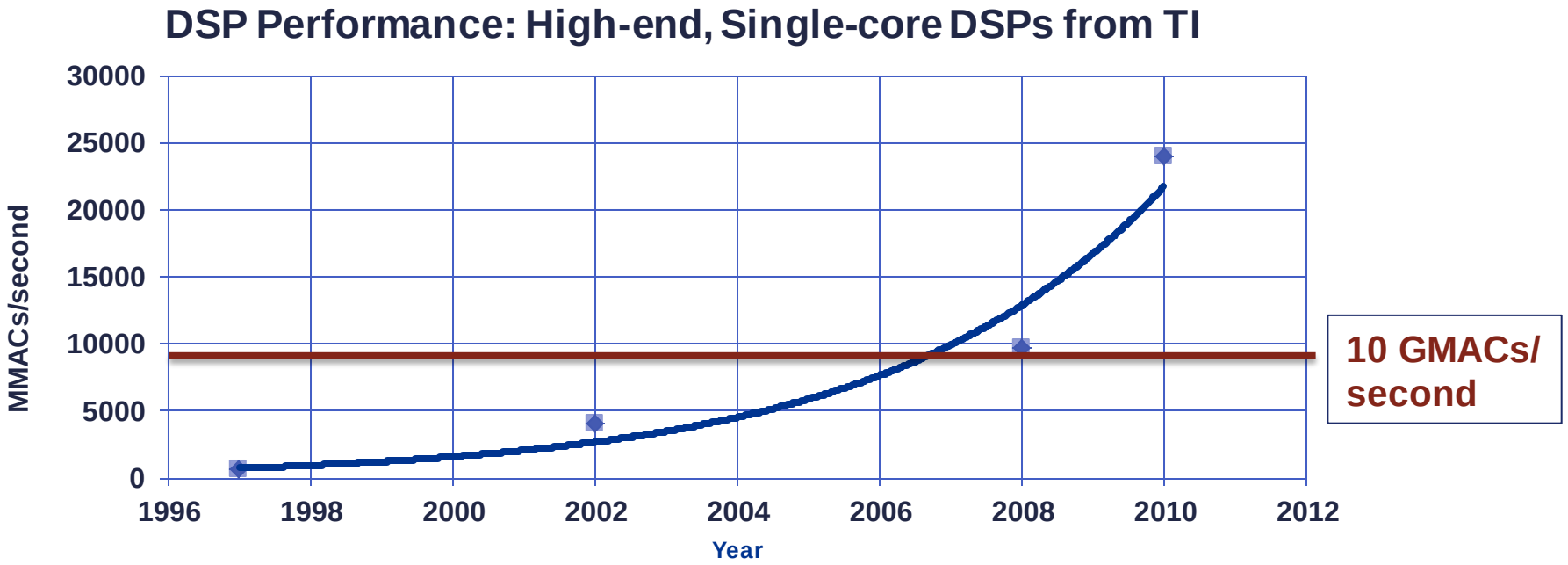
www.youtube.com/watch?v=ykDDxWbt5Nw

Libraries and SDKs: AR and SLAM

- Augmented reality SDKs
  - Identify and track markers, images, or objects
  - Estimate pose of tracked objects, allowing graphical content to be overlayed
- Simultaneous Location and Mapping (SLAM)
  - Often uses vision in conjunction with other sensors (accelerometer, gyroscope)
  - Create a map of the environment
  - Identify user's location and orientation in the environment
- Examples: Vuforia, Metaio, Wikitude

Enabling Embedded Vision

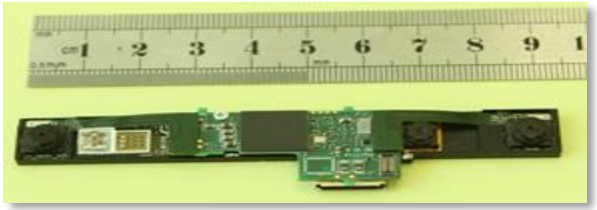
Enabling Embedded Vision: Processor Performance



Source: BDTI Analysis

Trend: Vision-specific Processor Chips

- Analog Devices BF609
- Freescale S32V
- Inuitive NU3000
- MobileEye EyeQ4
- Movidius Myriad 2
- Texas Instruments TDA3x

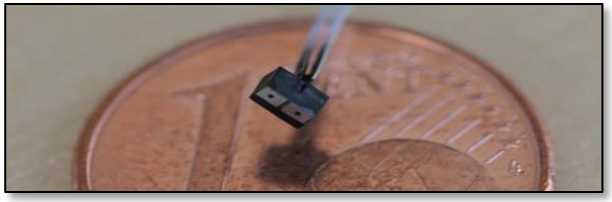


Inuitive M3 Reference Design

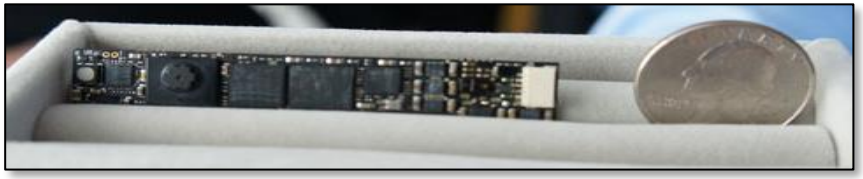
Movidius Myriad 2

Advances in Image Sensors

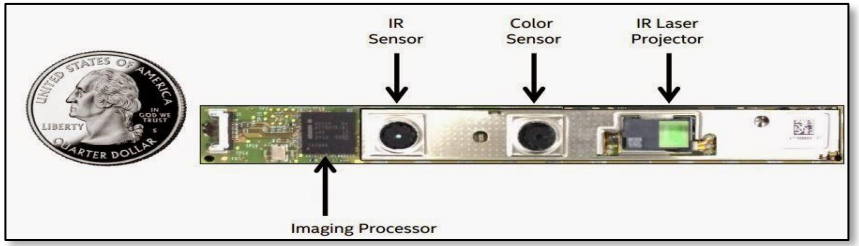
Heptagon



www.izm.fraunhofer.de



SoftKinetic (Image:Engadget)



Intel

Vision in Embedded Systems

Continental Augmented Reality Head-Up Display

www.youtube.com/watch?v=3uuQSSnO7IE

Dyson Vacuum Robot with SLAM

www.youtube.com/watch?v=oguKCHP7jNQ

Smart Signs with Viewer Analytics

www.youtube.com/watch?v=wvfe8tlhsNA

OpenVX—Power Efficient Vision Acceleration

- Out-of-the-Box vision acceleration framework
  - Enables low-power, real-time applications
  - Targeted at mobile and embedded platforms
- Functional Portability
- Performance portability across diverse hardware
  - Higher-level abstraction hides hardware details
- Enables low-power, always-on acceleration

Embedded Vision in the Cloud

Retail Analytics from Prism Skylabs

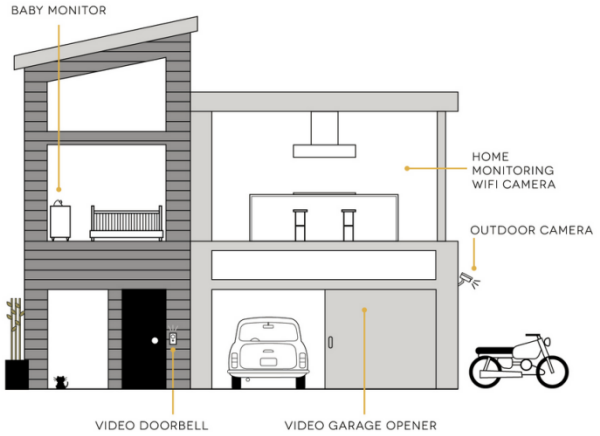
www.youtube.com/watch?v=aqbAoTT2ZJU

Cloud-based Vision APIs: Orbeus

- Cloud-based vision service for image recognition
- Recognizes faces, objects, scenes, landmarks—and their attributes

Cloud-based Vision APIs: Tend Insights

- Cloud-based vision service for connected home applications
  - Baby monitor, pet monitor, video doorbell, home security



Challenges and Techniques

What Makes Embedded Vision Hard?

- Infinitely varying inputs in many applications…
  - Uncontrolled conditions: lighting, orientation, motion, occlusion
- Lead to ambiguity…
- Leads to the need for complex, multi-layered algorithms…
- Leads to high computation requirements…
- Which, combined with cost, size, and power consumption constraints, creates design challenges…
- Hence, many vision applications require parallel and/or specialized processors
- And, most product creators lack experience with embedded vision

www.selectspecs.com

Empowering Product Creators to Harness Embedded Vision

The Embedded Vision Alliance (www.Embedded-Vision.com) is a partnership of 50+ leading embedded vision technology and services suppliers

Mission: Inspire and empower product creators to incorporate visual intelligence into their products

The Alliance provides low-cost, high-quality technical educational resources for engineers

- Alliance website offers tutorial articles, video "chalk talks," forums
- *Embedded Vision Insights* newsletter delivers news and updates
- Embedded Vision Summit conferences provide practical learning, exciting demos and keynotes, unique networking opportunities

Conclusions

- "Embedded vision" enables systems and apps that extract meaning from visual inputs
- **Embedded vision upgrades what devices know about the world,** enabling them to be:
  - **More responsive**
  - **More personal and secure**
  - **Safer, more autonomous**
  - **Easier to use**
- Thanks to improved processors, sensors , algorithms, tools and APIs **embedded vision can be deployed widely**
- **Leverage the Embedded Vision Alliance** to accelerate your success in embedded vision
  - www.Embedded-Vision.com

Thank You!

More?

To get a copy of these slides, and links to videos of many cool vision-enabled products, email me:

bier@embedded-vision.com

Back-up Slides

More Links for Later

Mercedes: www.youtube.com/watch?v=WGgSyA8HXyY

Philips: www.youtube.com/watch?v=2M7AFoqJyDI

IKEA: www.youtube.com/watch?v=DhbHnec4se0

LEGO: www.youtube.com/watch?v=mUuVvY4c4-A
www.youtube.com/watch?v=Td7cKB2BxIo

Amazon: www.youtube.com/watch?v=bnqnvL8B0k0
www.youtube.com/watch?v=8gy5tYVR-28

Stanley: www.youtube.com/watch?v=orTO3E0Vvok

Audi: www.youtube.com/watch?v=2YqflcbCVZg

Tesco: www.youtube.com/watch?v=bMCw7-lYUKw

Major League Baseball: bit.ly/1qylyRI

CENTR Cam: vimeo.com/91037496

Alliance Member Benefits

- Alliance Member companies position themselves as leaders in front of thousands of product creators who visit the Alliance web site each month
- Multiple Embedded Vision Summit conferences introduce Member companies and their products to hundreds of prospective customers
- Our Member companies meet quarterly to develop business partnerships and gain insights into embedded vision markets and technology trends
- We secure frequent press coverage on embedded vision topics, gaining exposure for our members as thought leaders