

Embedded Vision in Consumer Products

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Any sufficiently **advanced technology** is
indistinguishable from **magic**.

Arthur C. Clarke

The Magic of Embedded Vision

- The number of active cameras in use will exceed the human population over the next three years.
- The vast majority of these will be interfaced with an embedded processor.
- A large fraction of these processors will be capable of running embedded vision applications.

*Embedded Vision has the potential to be the magic behind hundreds of innovative **products** !*

Embedded Vision

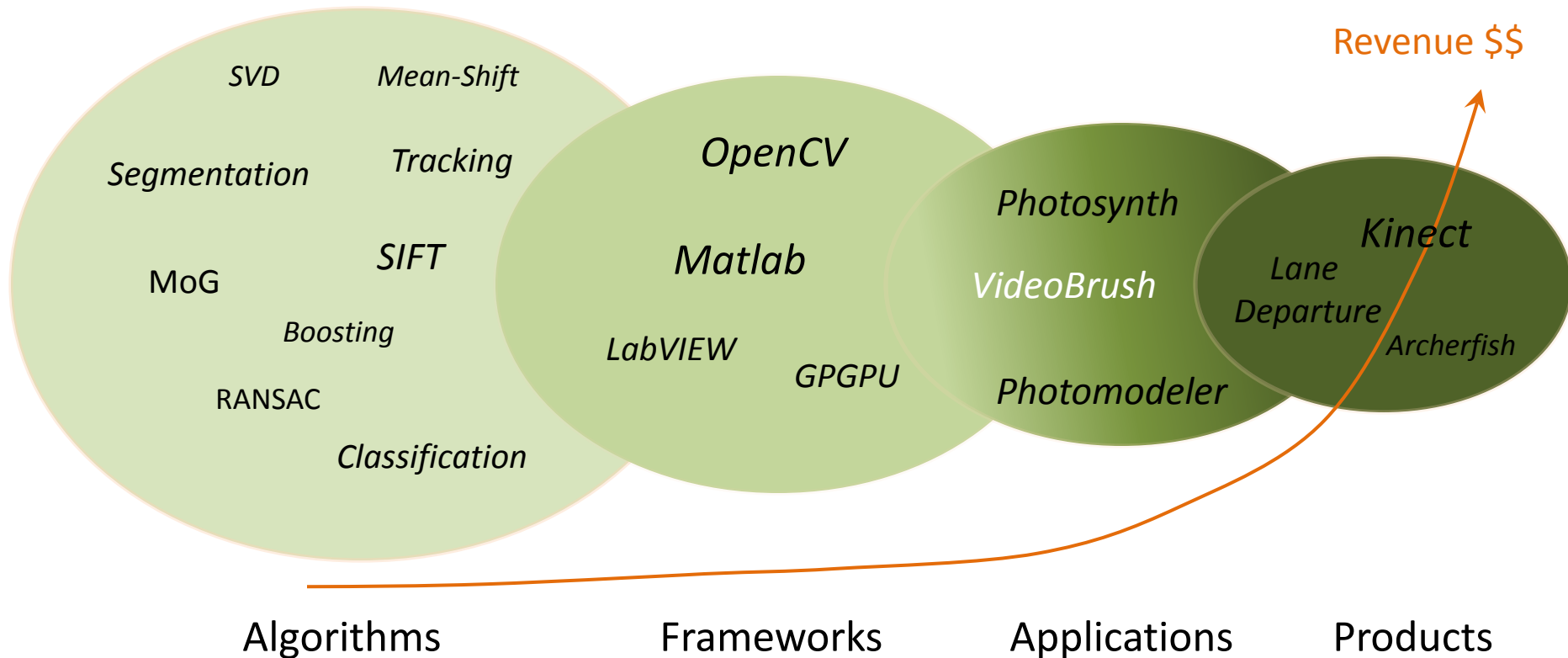
Teaching machines to see... *and understand*

- Perception and Cognition
 - What does the camera see ?
 - What does it mean ?
- Related fields
 - Image Processing
 - Pattern Recognition
 - Machine Learning

Embedded Vision Applications

Real-Time Processing	<i>Automated Inspection</i> <i>Face & Smile Detection</i>	<i>Automotive</i> <i>Security</i>	<i>Robotics</i> <i>Gaming</i>
Offline Processing	<i>Medical Diagnostics</i> <i>Remote Sensing</i>	<i>Image Stitching</i>	<i>Entertainment Video Indexing</i> <i>Video Search</i>
	Still Images	Video	

Technology -Product Funnel



Parameter Soup

An embedded vision product designer has too many parameters to trade off...

Auto-Gain

Range Images

SIMD

Dynamic Range

Resolution

Frame Rate

Fixed Point

White Balance

Vector Math

Pixel Format

Stereo

Focus

Accelerated Vision Blocks

Image Statistics

Framebuffer

The Archerfish Story ...from lab to market...



Exit Sentry



Check Video



Archerfish

Market Needs

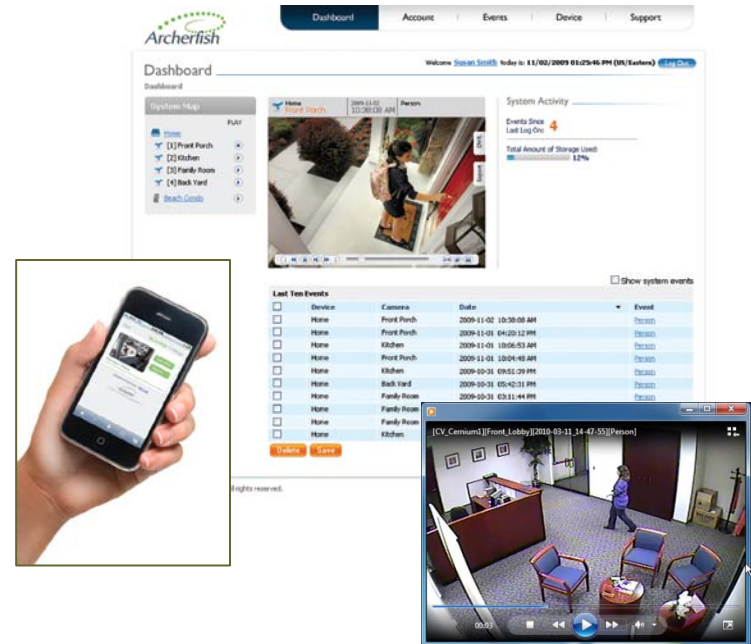
- With the exception of web access, the ability of users to interact with surveillance video hasn't changed in 50 years.
 - Need to watch everything to see anything
 - Human attention spans are limited
 - Generally, nothing is happening
 - ***Video monitoring is a major waste of time***



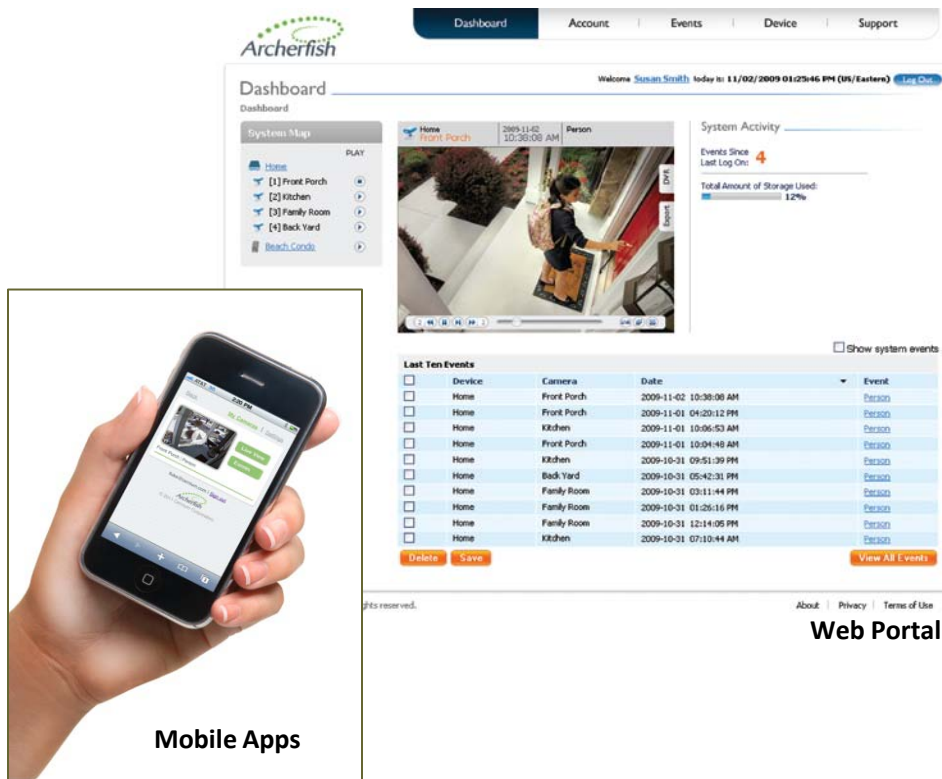
- Efforts to combine detection technology with video monitoring are either too expensive or fail to perform
 - Motion detection – Users learn that there's a lot of uninteresting motion in the world
 - Industrial analytics – High end “smart” surveillance cameras and encoders typically cost >\$1000 per camera
 - Difficult to install and maintain, requiring knowledge of IP and frequent tuning of analytics

Solution

- Deliver relevant, real-time video information
- Make full use of mobility
- Without cluttering mailboxes and storage equipment
- On competitively priced, easy-to-install devices



Archerfish – The Best Self-Monitored Video Surveillance System Ever



Pushes relevant video to users wherever they are through a rich, web-based interface:

- Live or DVR playback view of any location, from anywhere
- *Accurate, personalized* event reporting
 - People
 - Vehicles
 - Motion
- Alerts
 - Any email or mobile endpoint
 - Multiple users (e.g. “friends & family”, police)
 - Text, image, video
- Event search
 - Type
 - Time
 - Location

Examples



4:43 am - Suspect



5:00 am - Police Arrive



5:10 am - Arrest



Package Delivered



Car in driveway

Product Planning

- Desired features
 - Built-in video compression
 - Video Recording (DVR)
 - Advanced Video Analytics (segmentation, classification,tracking)
 - Wireless
 - Weatherproof
- Retail price under \$300
- Compact, novel form factor (cell phone sized)
- Time-to-market
 - Under 12 months, lab to store shelves

Platform Decision

	Compression	Recording	Analytics	BOM	Compact	Time-to-Market
Embedded PC (x86)	●	●	●			●
FPGA + Host	●	●	●		●	
Codec + Host	●	●		●	●	●
DSP + Host	●	●	●	●	●	●

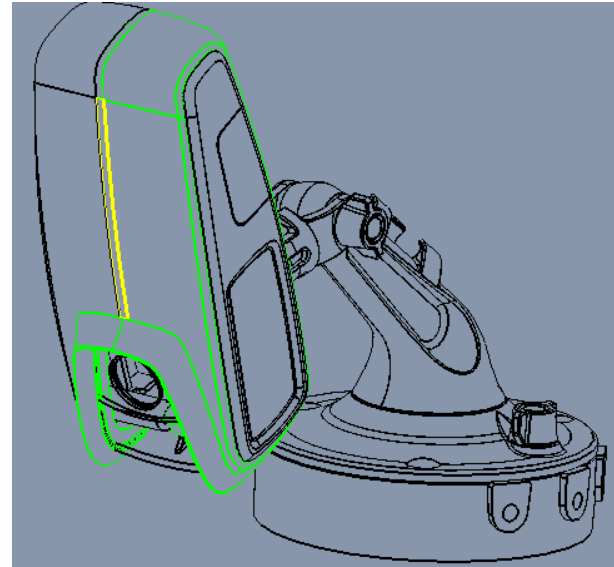
Approximate Timeline

Milestones	Weeks from start
Industrial Design, High level EE design, high risk firmware tasks completed.	8
Hardware EVT, ME complete, first proto boards with optimized firmware.	14
Manufacturer selection, board spin 2, fully functional firmware. <i>FIRST ARTICLE</i>	18
DVT Phase, molds completed, packaging design complete, production firmware delivered.	24
Pilot Production build; Large scale beta testing.	28
Volume Production; GA .	36

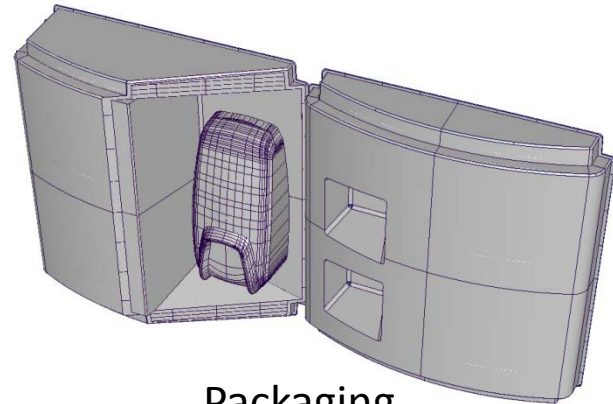
Electrical



Mechanical



Industrial



Packaging

Lessons Learned

- Customer Education is a big challenge for an embedded vision product
 - Need to get beyond the “coolness factor”
- Packaging is critical for a consumer-facing product
 - Product needs to sell itself, sitting on a shelf or in an online catalog.
- Post Sales
 - Initial installation experience
 - Simplify setup and installation – it is not just about embedded vision technology

eye think.



Meet Solo, the First Thinking Camera™. Solo is a smart, wireless security camera and recorder with Homeland Security technology. It understands what it sees and sends video alerts only when important things happen, so you can rest easy – no matter where you are. Other cameras just watch. Solo thinks.

See **Video Monitoring Done Right™** at thinkingcamera.com.

Archerfish
solo

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cameraderie



Meet Solo, the First Thinking Camera™. Solo and your smart phone are going to be good friends, because Solo sends video alerts when it sees events that are important to you. It's the only smart, wireless security camera and recorder – no wonder it gets along so well with your phone.

Discover **Video Monitoring Done Right™** at myarcherfish.com.

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D E M O

Guidelines for Embedded Vision Platforms

- Software
- Software
- Software
- Memory
- Processing Blocks
- Optics and ISP
- Peripherals

Software

- It is the Software that sells the Hardware !
- Optimized vision libraries are a great start, but...
 - Need complete peripheral / driver stacks
 - Informed and easily accessible support resources
 - Not just through the distributor.
 - Online forums, wikis, community projects work well.

Software

- Most Embedded Vision products start as Matlab or OpenCV programs !
- Some make it to a real-time PC implementation.
- A few get optimized for an embedded platform.
 - Use custom logic, FPGAs
- Pre-compiled, optimized building blocks for vision are key.
- High level software APIs that abstract the hardware greatly improve the odds of a successful embedded implementation.
- But the challenge is....
- Lack of standards is causing confusion about which accelerated blocks to provide.

The Memory Hierarchy

- Algorithms are not strictly feed-forward or single function
 - Each pixels gets examined multiple times
 - Intermediate images are reprocessed
- Embedded implementations require significant re-factoring to complete all pixel operations while data is on-chip.
 - Limits choice of algorithms (that do local processing)
 - Embedded port is expensive
- Tiered memory architectures vs programmable pipelines that have access to a high speed framebuffer.

Processing Blocks

- Low-level image processing
 - Histograms, normalization, convolution, feature extraction
- Blobs and Background
 - Segmentation, classification
- Matching and Correspondence
 - RANSAC
- Recognition
 - Large vector math, linear algebra, dynamic lookup tables

Optics, Imager and ISP

- The most critical component of a vision system
- Garbage in gives garbage out
- Optics
- Imager
- ISP
 - Tuning of ISP for compression is at odds with tuning for vision

Greater integration of optics, imagers and processors will enable "active vision" systems.

Peripherals

- Hardware codec
 - Concurrent with vision processing (not shared)
- Digital Video and Camera interfaces
 - Flexibility is good, but canned out-of-box solutions for popular imagers reduces risk and time to market.
- USB
 - Multiple host/OTG ports
- High speed bus
 - For co-processor, FPGA, custom logic
- Encryption

The Road Ahead for Embedded Vision Products

This is a great time to be in computer vision

- 1970s – Databases
- 1980s – Desktop Computing
- 1990s – The Internet
- 2000s - Social networking, Smartphones
- 2010s – Vision ?

Top 10 List

Why is this the decade of embedded vision ?

10. Seeing is believing !
9. Gesturing to our TV is easier than clicking the remote.
8. We are not getting any better at driving – better let our cars drive themselves.
7. Watching security video is a waste of time.
6. Augmented reality is better than reality.

Top 10 List

Why is this the decade of embedded vision ?

5. We cannot remember everyone in our social network and expect our smartphones to recognize them for us.
4. We would love brick-and-mortar stores to track our every move, just as their online counterparts do.
3. Our digital cameras should know when it is the right moment for the perfect shot.
2. The consumer electronics industry needs the next big thing after flat screen TVs, smartphones and tablets.
1. Because it is magic... and a lot of fun. Ask the 10M+ Kinect users.

Let the *magic* begin !