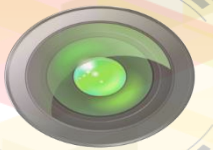
Computer Vision at the Edge and in the Cloud: Architectures, Algorithms, Processors, and Tools



IEEE Signal Processing Society Santa Clara Valley Chapter -- April 11, 2018

Jeff Bier
Founder, Embedded Vision Alliance
General Chairman, Embedded Vision Summit
President, BDTI

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A World-Changing Technology

- Visual perception is rapidly becoming ubiquitous, because:
  - **Value:** Perceptive devices can be much more capable, safer, more autonomous, more secure and easier to use
  - **Effectiveness:** Vision algorithms are becoming good enough to be useful in the real world
  - **Affordability:** Advances in enabling technologies are shrinking the cost and power consumption required to deploy vision

The Big Picture

"Computer vision" has crossed the chasm from expensive niche technology to become "embedded vision," a ubiquitous technology

- Rapidly expanding, large-scale deployments in diverse markets: consumer, automotive, healthcare, entertainment, defense, retail, security, …
- Implemented in embedded systems, the cloud, mobile devices, wearables

Making Things More Autonomous, Efficient, Capable, Ease to Use

Image: technicultr.com

Image: DJI

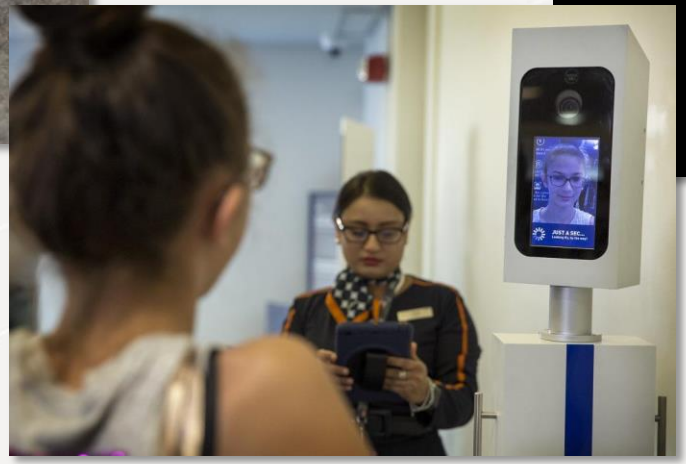
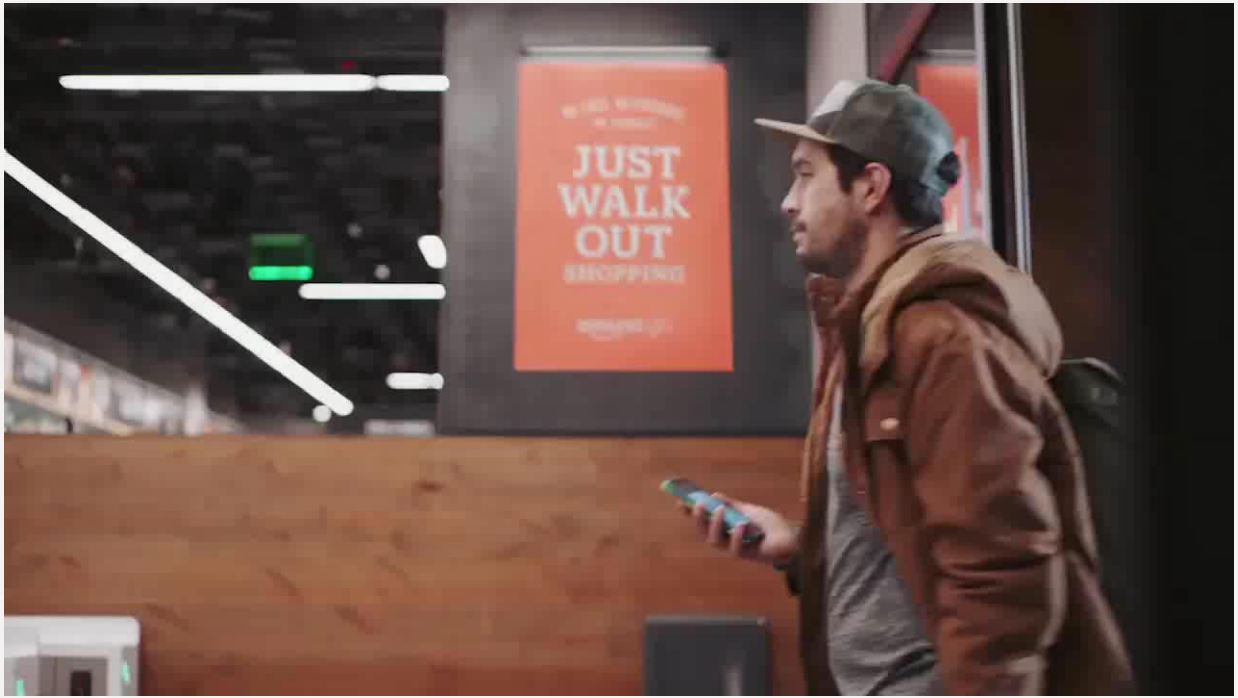


Image: WBUR

Amazon Go



https://www.youtube.com/watch?v=NrmMk1Myrxc

Perception Algorithms are Hard

dot.gov

xkcd.com

Breakthrough

- Over the past 5 years, deep neural networks have enabled big advances in accuracy for many machine perception tasks

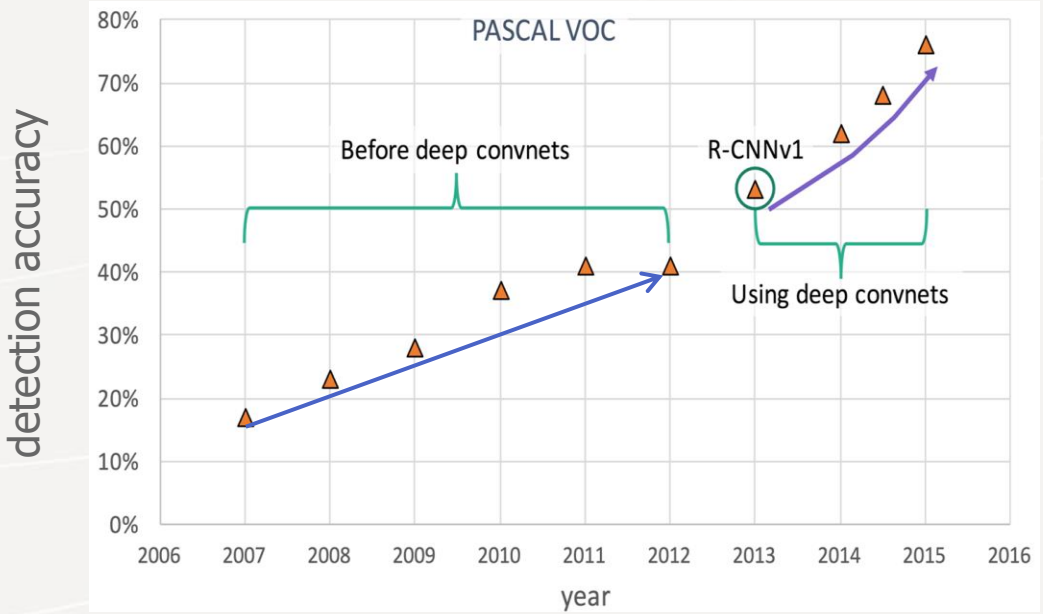
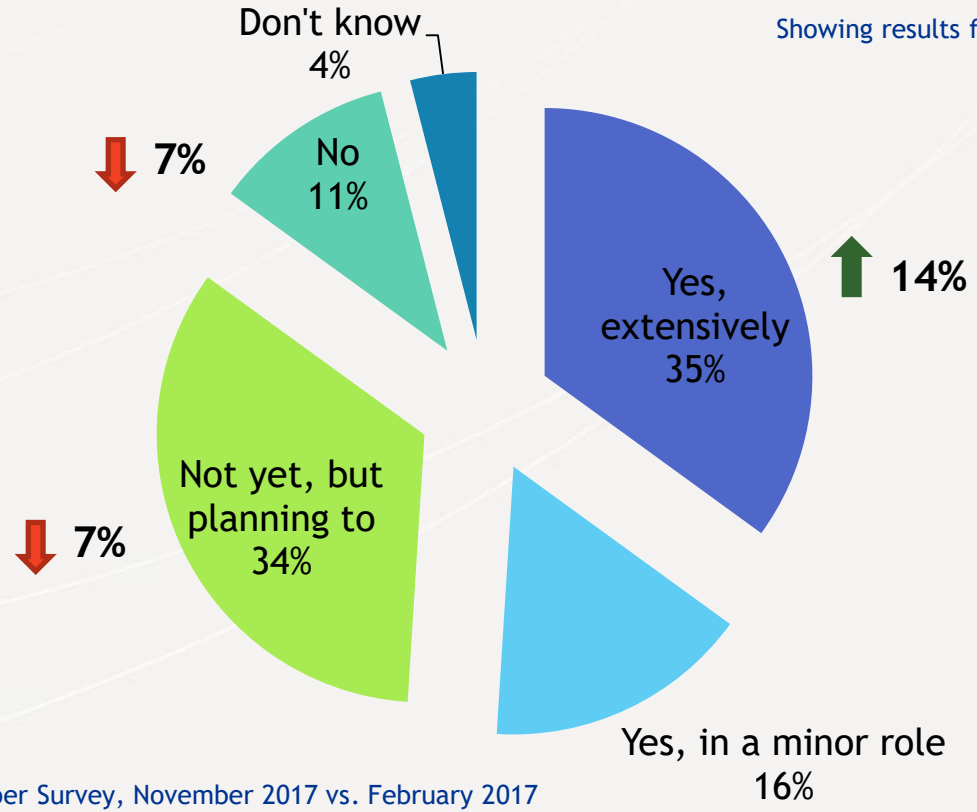


Image: R. Girshick

Use of Neural Networks to Perform Computer Vision Functions

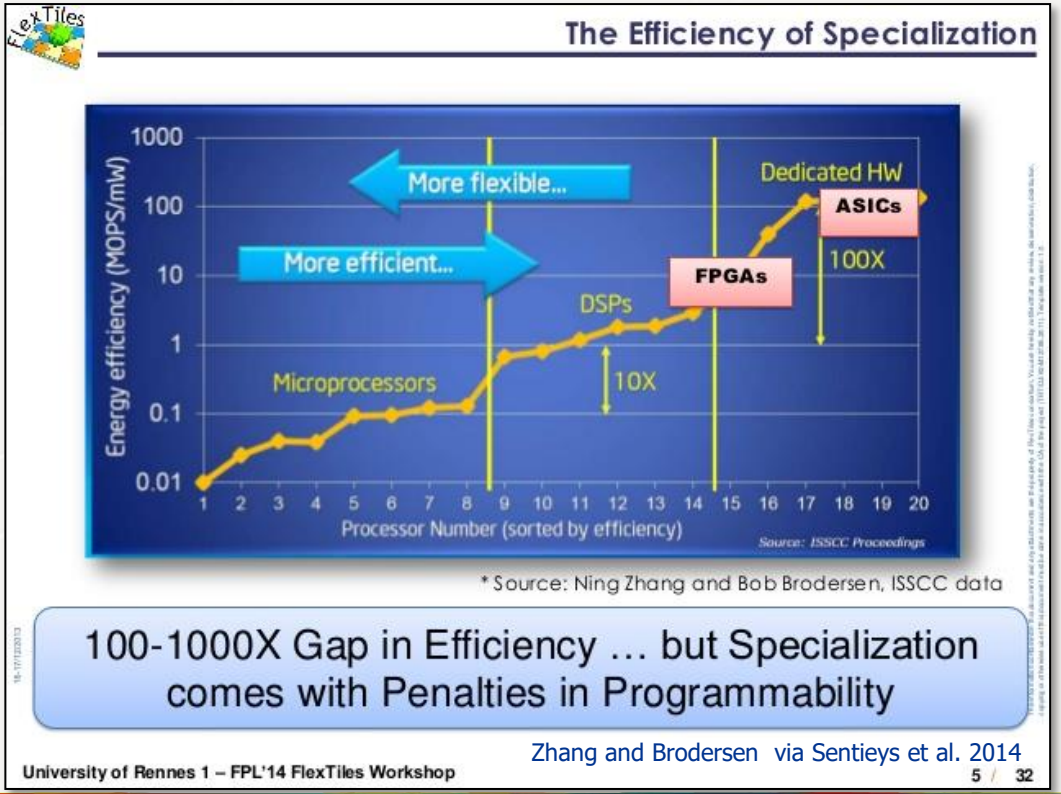
Showing results for end-product developers only



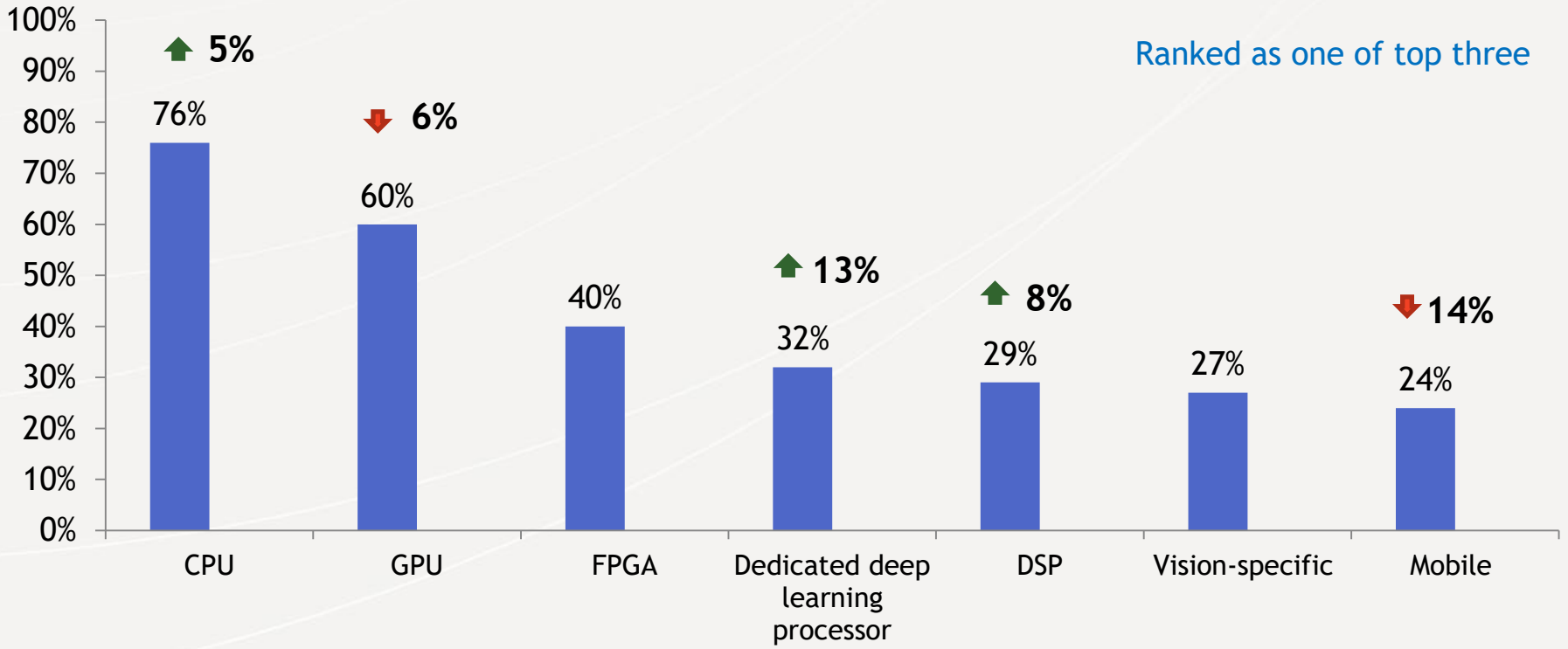
Embedded Vision Alliance Developer Survey, November 2017 vs. February 2017

Processors

For decades, chip designers have created specialized processors to get big gains in cost/performance and energy-efficiency



Type of Processor Used for Vision Tasks

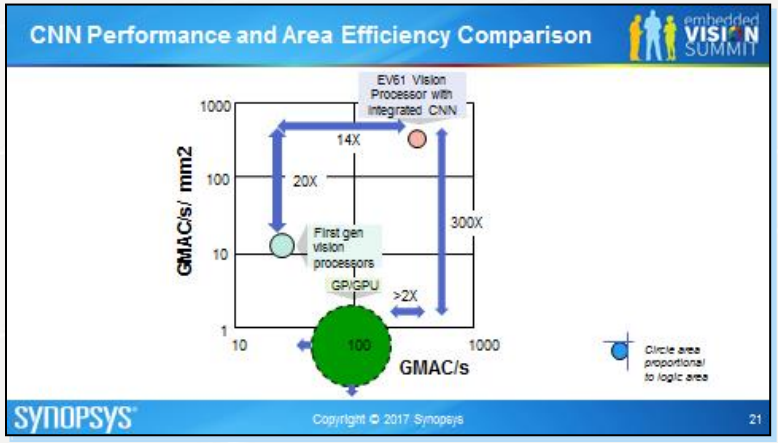


Embedded Vision Alliance Developer Survey, November 2017 vs. February 2017

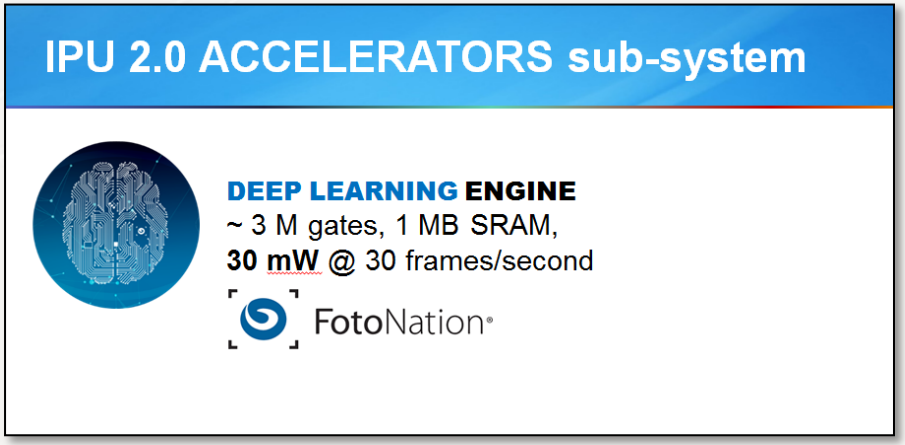
Processors

Today, dozens of chip and IP core suppliers are creating processors specialized for deep neural networks

15x-300x



Pierre Paulin, Synopsys



Petronel Bigioi, FotoNation

Cloud - Fog - Edge

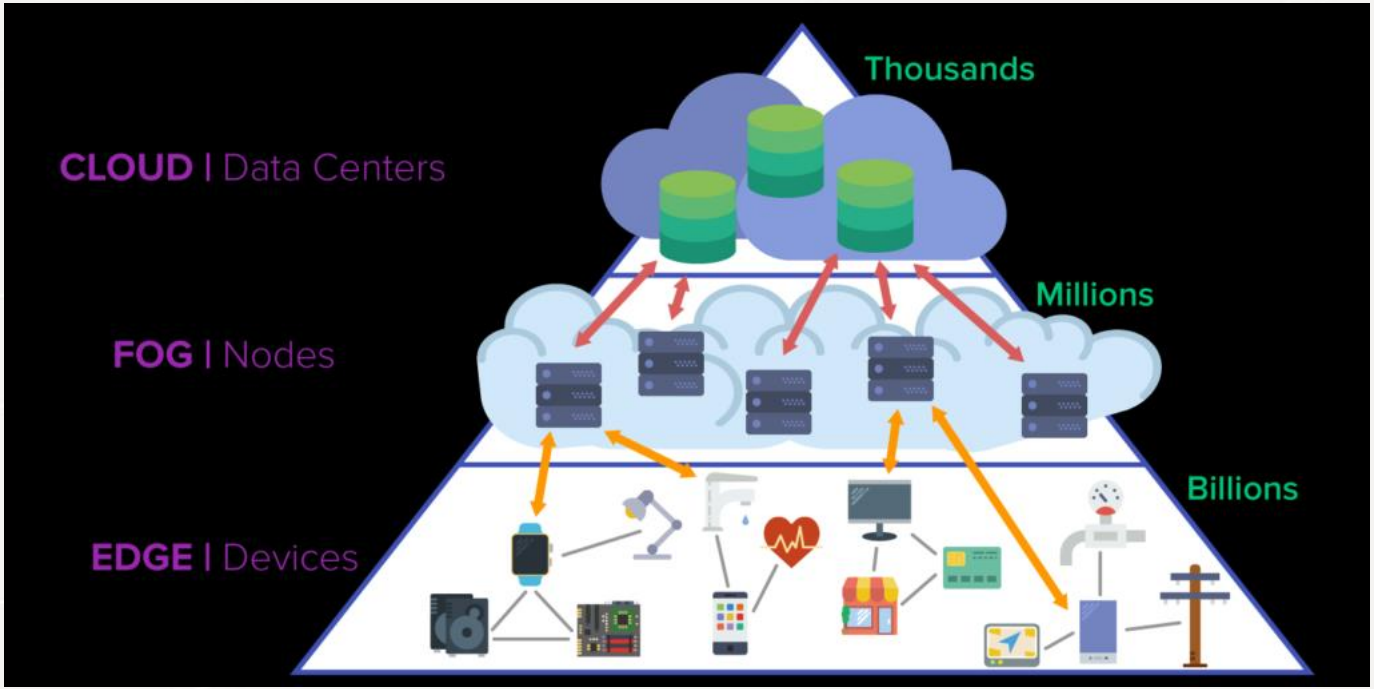


Image: erpinnews.com

Attributes of Cloud Computing

5 Essential Characteristics of Cloud Computing

Ref: The NIST Definition of Cloud Computing
http://csrc.nist.gov/publications/nistpubs/800-145/SP800-145.pdf

On-demand self-service | Ubiquitous network access | Location transparent resource pooling | Rapid elasticity | Measured service with pay per use

Source: http://aka.ms/532

Image: microsoft.com

Levels of Cloud Service

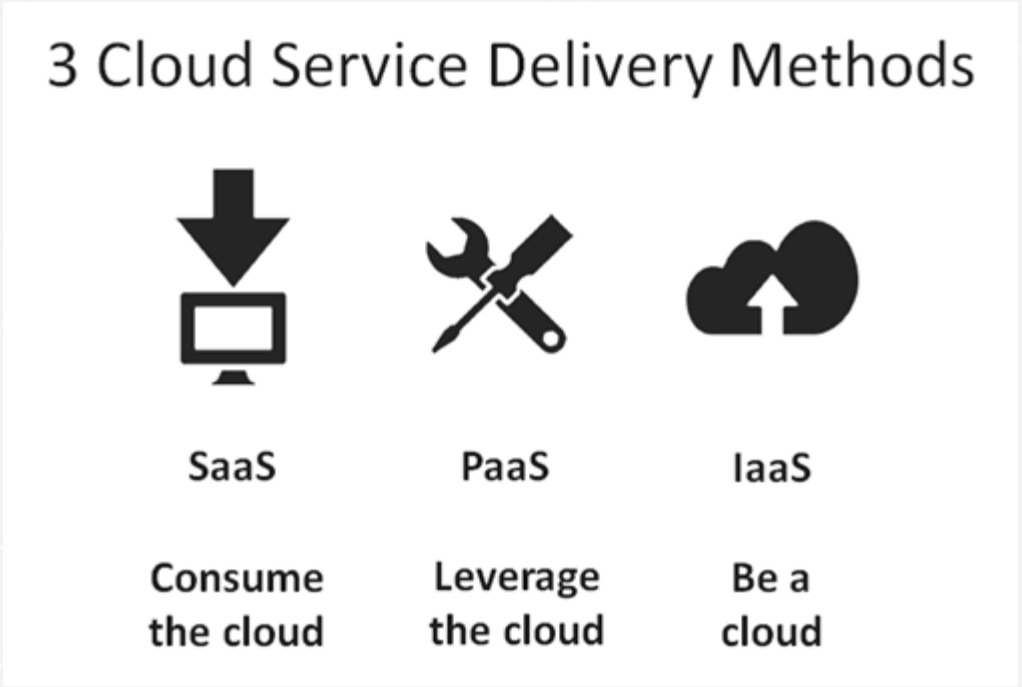


Image: microsoft.com

Public Cloud vs. Private Cloud

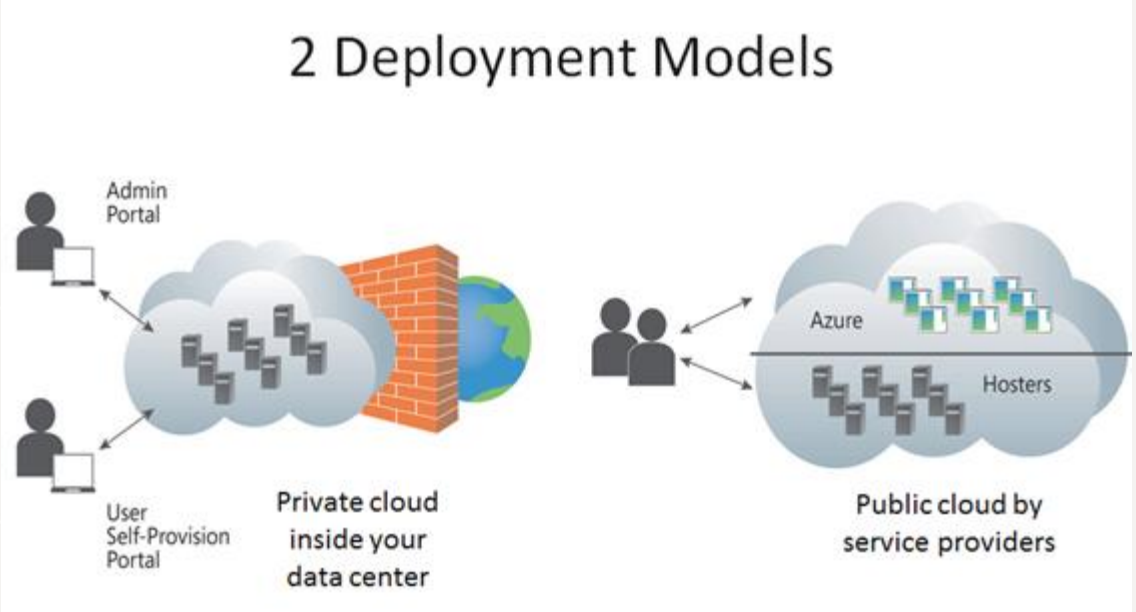
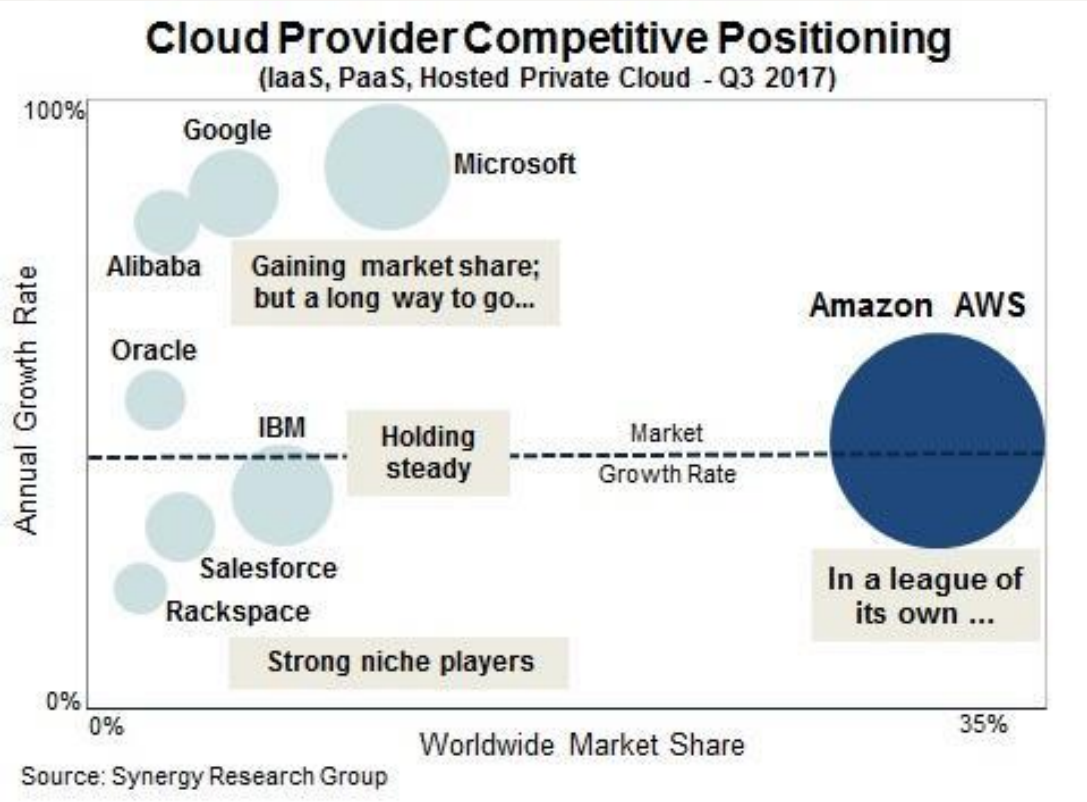


Image: microsoft.com

Cloud Providers



Off-the-shelf Cloud Computer Vision APIs

- Cloud-hosted APIs support common vision functions:
  - Object recognition/detection
  - Face recognition
  - People tracking
  - Age, gender, emotion analysis
  - Optical character recognition (including handwriting)
  - Scene analysis

clarifai

amazon web services

gumgum

Google Cloud Platform

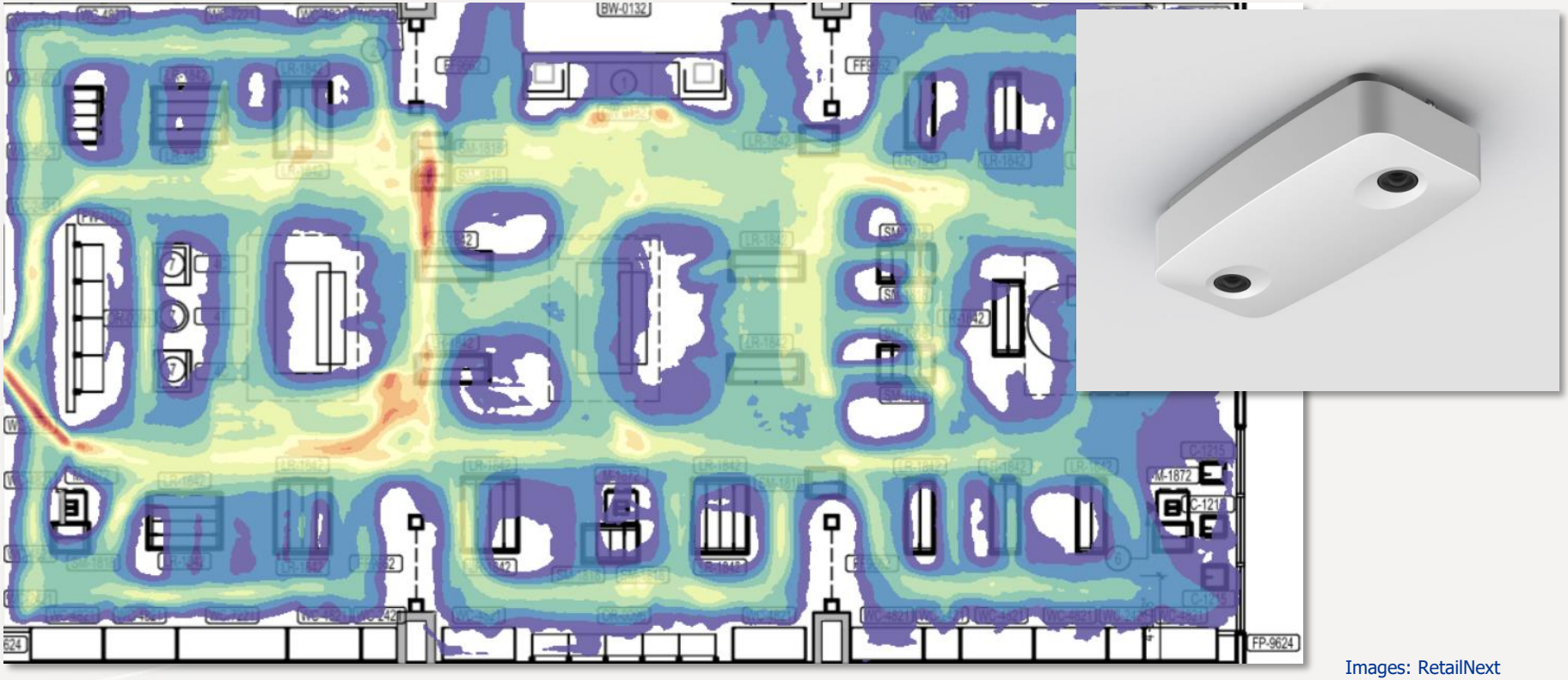
Microsoft Azure

IBM Watson

Tools and Frameworks to Build Your Own

- Cloud-hosted tools and frameworks facilitate creating your own vision functions and applications:
  - Pre-configured virtual machines (e.g., AWS AMIs)
  - Higher-level platforms (e.g., Amazon SageMaker)

Edge or Cloud?



Images: RetailNext

Trade-offs

	Edge	Cloud
Time-to-market		✔✔✔
Upgradability		✔✔
Accuracy		✔✔✔
Coordination among distributed devices		✔✔✔
Device cost		✔✔
Recurring costs	✔✔✔	
Internet connectivity, bandwidth required	✔✔✔	
Response time	✔✔✔	
Privacy/security	✔	

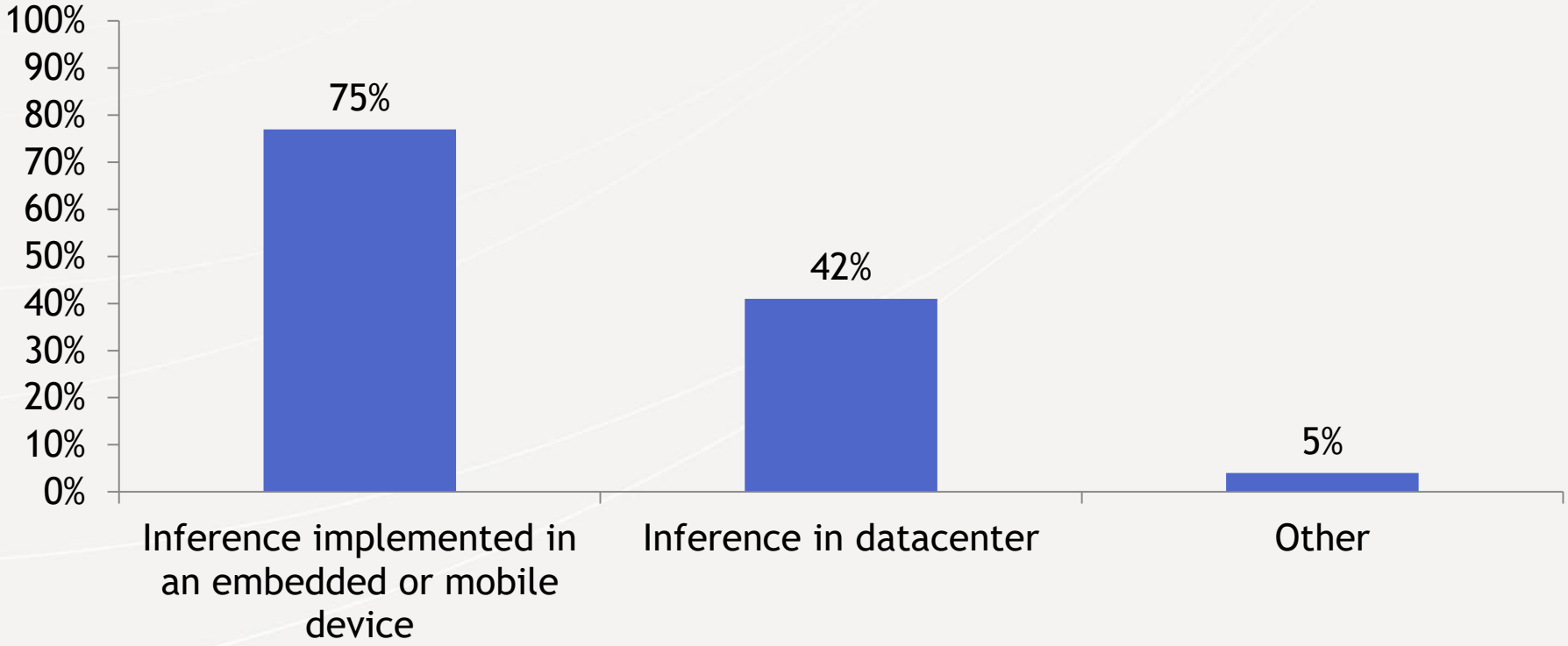
✔ = Advantage

Technology Advances Unevenly

	Edge	Cloud
Latest algorithms	✔✔	✔✔✔
More powerful and efficient processors	✔✔✔	✔
Better software development tools	✔	✔✔✔

✔ = Available sooner

How is Your Neural Network Deployed?



Embedded Vision Alliance Developer Survey, November 2017

DJI Phantom 4

https://www.youtube.com/watch?v=JJPSSqMQajA

Case Study: Remote Check Deposit

Image: Bank of America

Case Study: Camio Video Monitoring

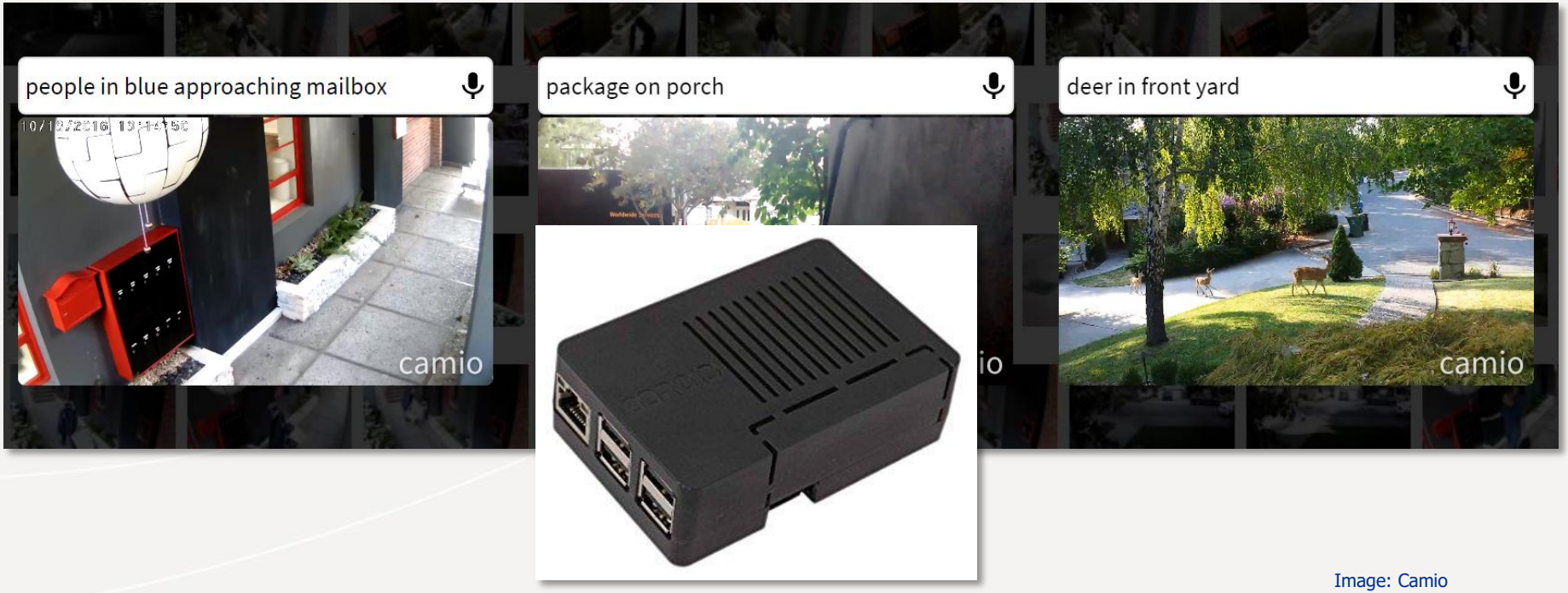


Image: Camio

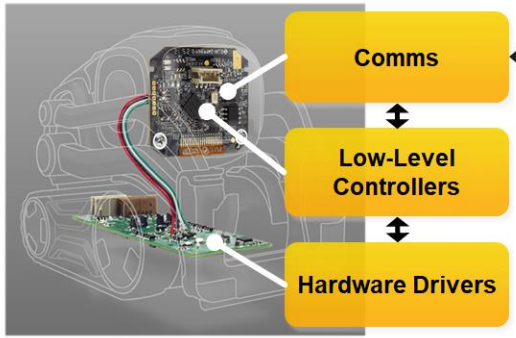
Cozmo by Anki

https://www.youtube.com/watch?v=o2FAMzhi2Eo

Case Study: Anki's Cozmo Interactive Robot

Image: Target.com

- Use Smart Device for heavy computation
  - Reduce robot cost
  - Better development environment



CLAD via Wifi

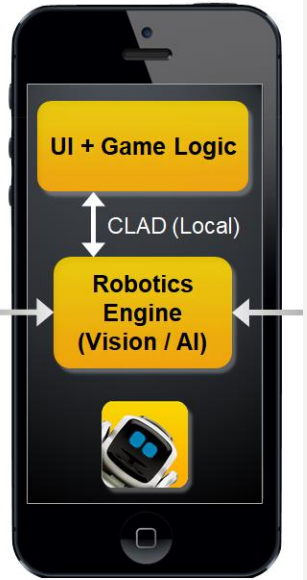
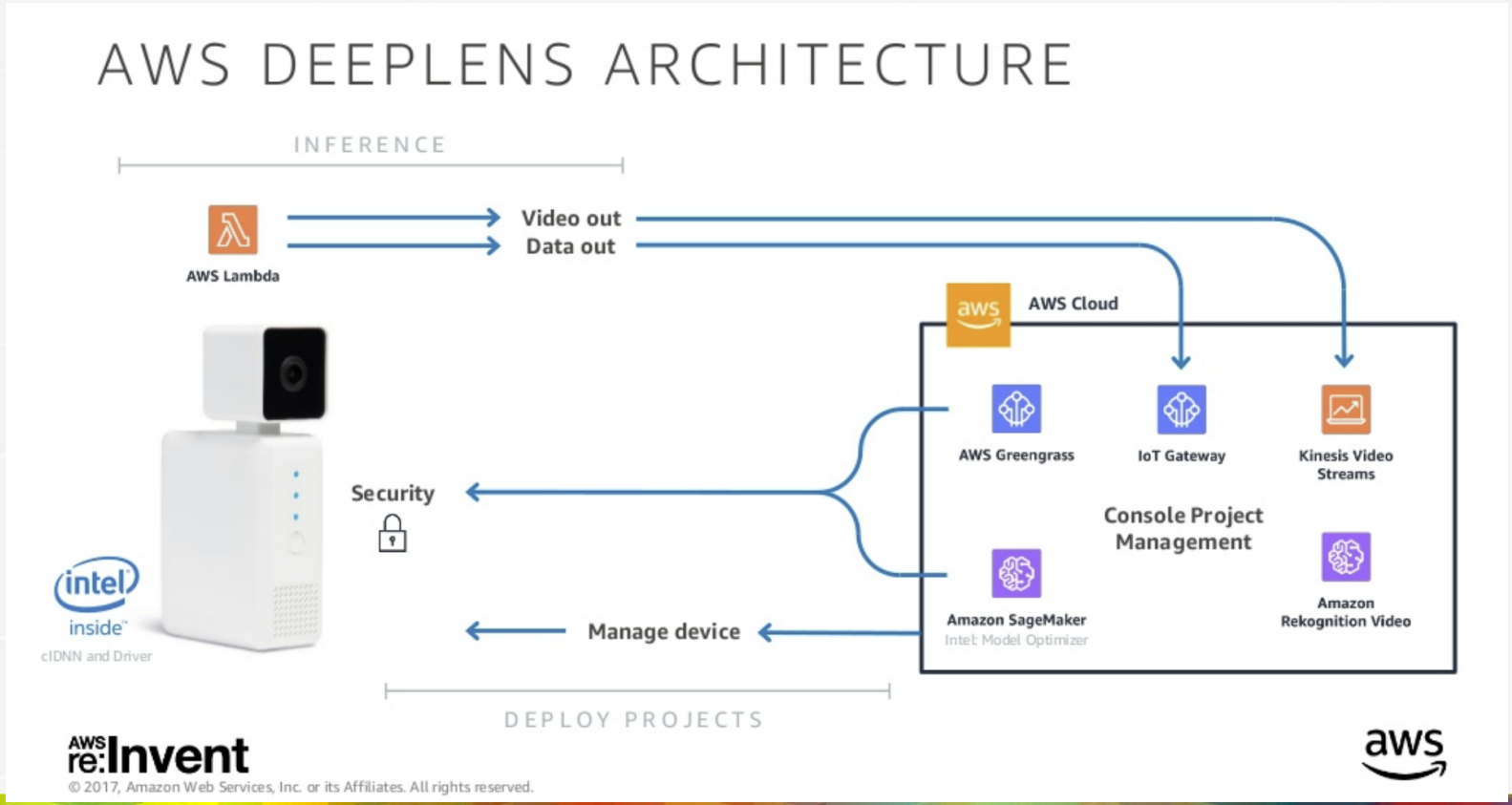


Image: Anki

AWS DeepLens



Dee — DeepLens Educating Entertainer

https://www.youtube.com/watch?v=dTXbIzhq_po

What Does This Mean?

- Thanks to improved algorithms, processors, tools and cloud services, thousands of diverse systems are now integrating vision…
- …making them safer, more autonomous, easier to use and more capable
- Cloud platforms and services ease development and deployment for many applications
- The best allocation of processing to edge, fog and cloud requires balancing complex trade-offs unique to each application

Empowering Product Creators to Harness Embedded Vision

The **Embedded Vision Alliance** (www.Embedded-Vision.com) is a partnership of 75+ leading embedded vision technology and systems companies

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

The Alliance provides practical technical educational resources for product developers

- Website offers tutorial articles, video presentations, etc.
- Register for the newsletter at www.Embedded-Vision.com

Alliance membership provides companies with early insights and connections to customers and partners

Join Us At the Embedded Vision Summit

The only industry event focused on enabling developers to create "machines that see"

- *"Awesome! I was very inspired!"*
- *"Fantastic. Learned a lot and met great people."*
- *"Wonderful speakers and informative exhibits!"*

Embedded Vision Summit 2018 highlights:

- **Inspiring keynotes** by leading innovators
- Practical **technical, business and product talks**
- Learn **edge and cloud vision** techniques and trade-offs
- New: Hands-on **TensorFlow class** May 21

- *Visit www.EmbeddedVisionSummit.com for details*

embedded VISION SUMMIT 2018

Enabling Computer Vision, At the Edge and In the Cloud

May 21-24, 2018
Santa Clara, California

Embedded Vision Alliance Member Companies

Questions?

Email me for:

- PDF file of these slides
- Details about the Embedded Vision Summit, May 21-24, 2018 in Santa Clara, California
- Information about how your company can become a Member of the Embedded Vision Alliance

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