Smart surveillance systems

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http://www.site.uottawa.ca/~laganier/research.html

uOttawa

Outline

- The evolution of surveillance technologies
- Overview of surveillance system architectures
- Some recent research

(very) short bio

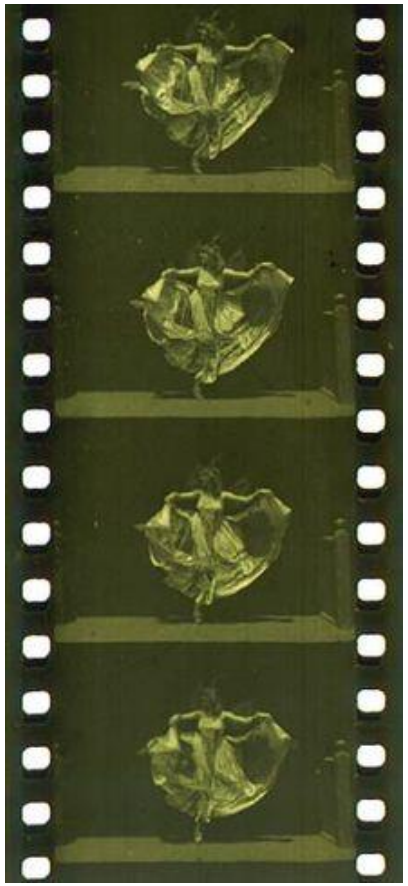
- Researcher in computer vision since 1985
- Professor at the University of Ottawa since 1995
- Researcher in smart video surveillance since 2000
- Author of OpenCV cookbook, Packt Ed, 2011
- Co-founder of Visual Cortek in 2006 -> iWatchLife in 2009
- Chief Scientist at Cognivue 2011
- Co-founder of Tempo Analytics 2016
- Consultant in computer vision
  - Synopsys, Correctional Service Canada, …

A look at Video Surveillance

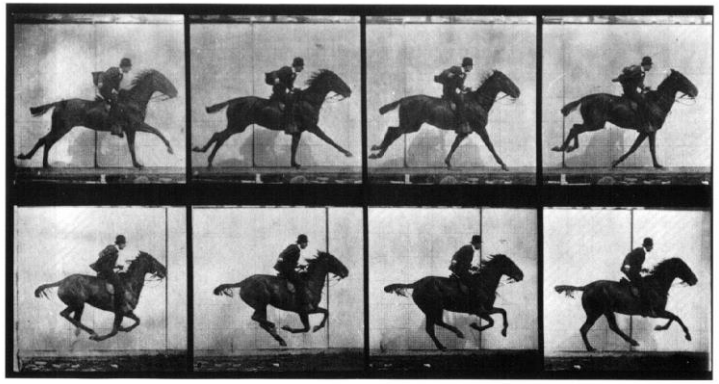
- Video :
  - **Temporal sequence of images (5fps to 30 fps)**
- Surveillance:
  - **Scene and Event** monitoring
- Give access to scene events whenever they become of interest
  - Past & Current events
  - To capture and understand behaviors
- For decades this objective was fulfilled through **recording**
  - Recording is not anymore a technological challenge!
  - 99% of all videos ever produced has been generated this decade !
  - Our challenge is rather what to do with all the captured visual data?

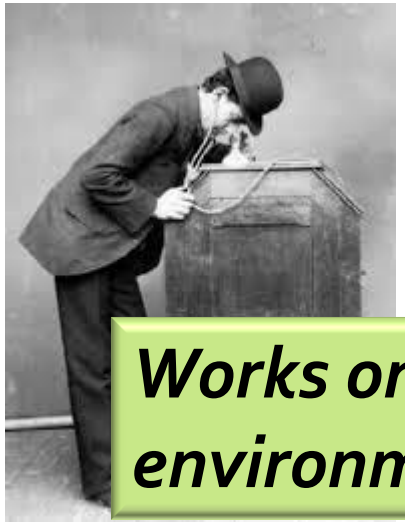
Visual surveillance: a historical overview…

1880 - Chronophotography



- 1882 Etienne-Jules Marey's chronophotographic gun
- 1894 Thomas Edison's Kinetoscope

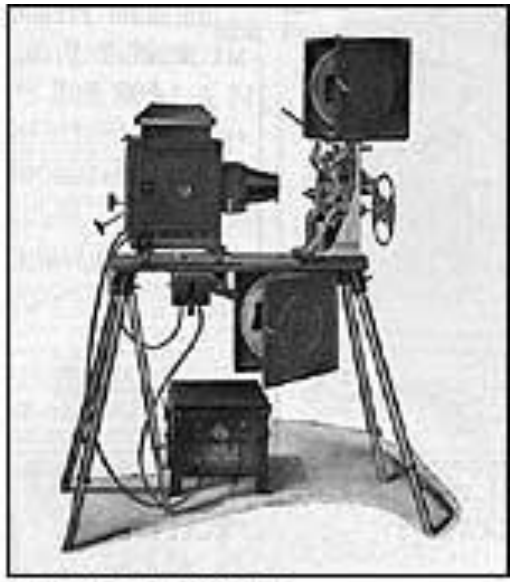


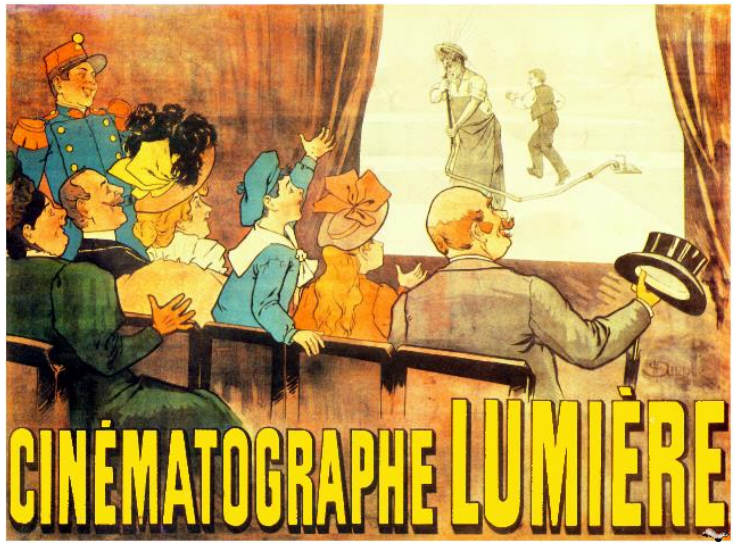


Works only in controlled environments!

1895 - The motion picture

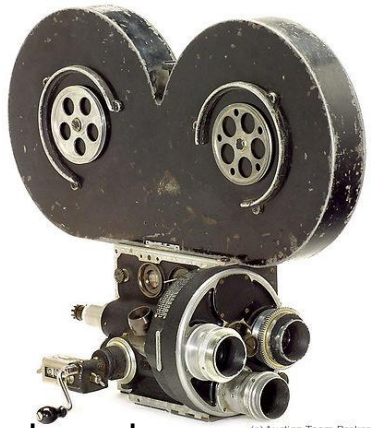
- 1895 Louis Lumière's cinematograph
  - Portable motion-picture camera
  - Film processing unit
  - Projector
- The birth of cinema…

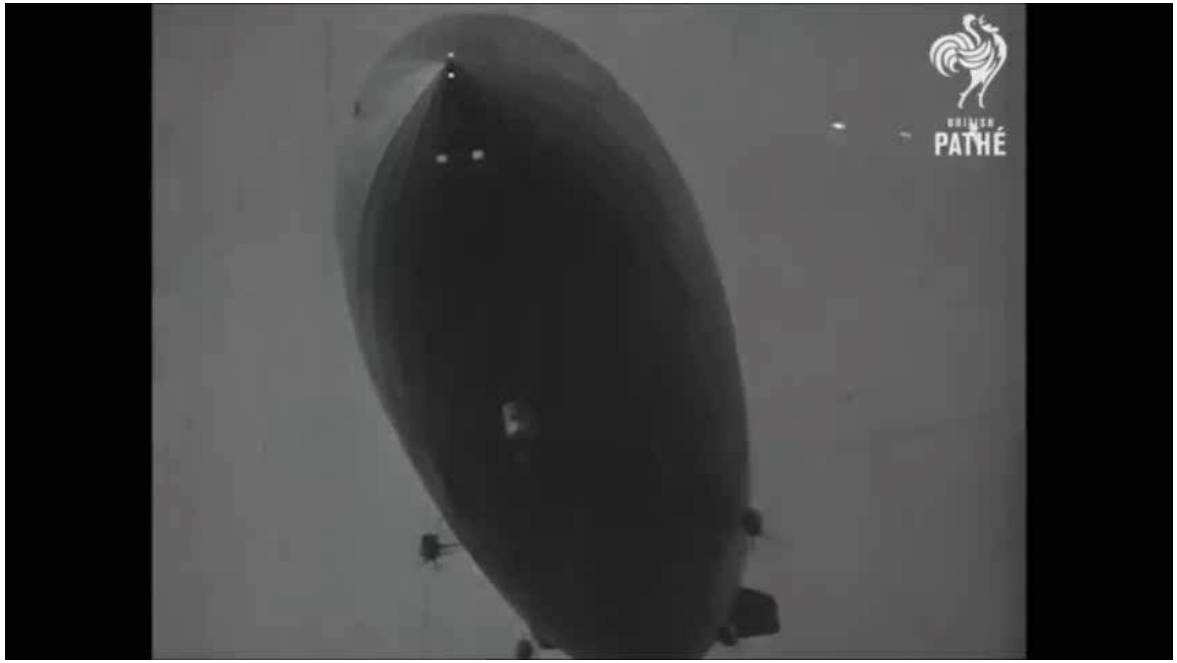




The motion picture

- 1908 Newsreel
  - Short film of news
    - Recording events of interest
  - Projected in cinema before main feature film





1937 – Hindenburg tragedy

Expensive and cumbersome!

1936 - Hand-held camera

- The Univex A8 (8mm) by Universal Camera corp
- Cameras can now be **everywhere anytime**!

Hand-held camera

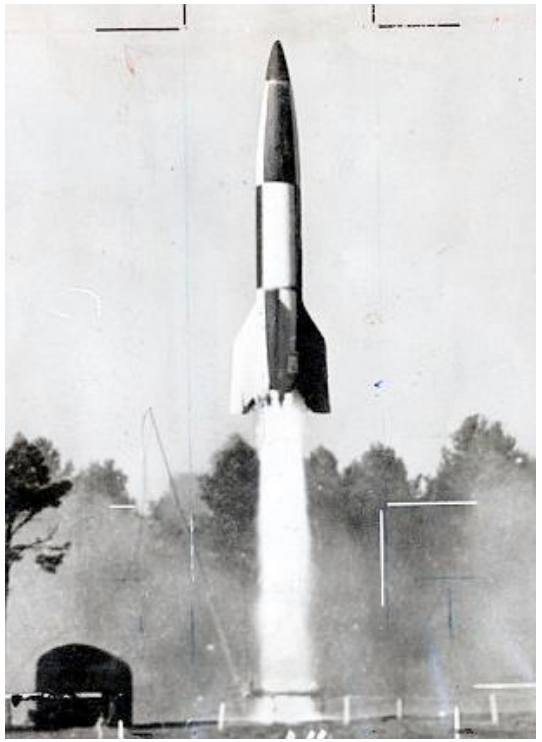
- Spontaneous capture of event of interest

1963 – Zapruder film of Kennedy assassination

Not always on;
No instant access!

1942 - Close-circuit television (CCTV)

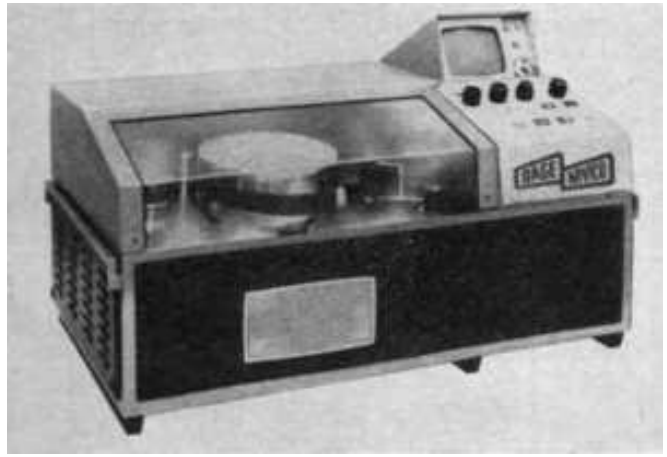
- 1942 to monitor the launch of V2 rockets
- Live remote viewing of scenes and events becomes possible



No recording!

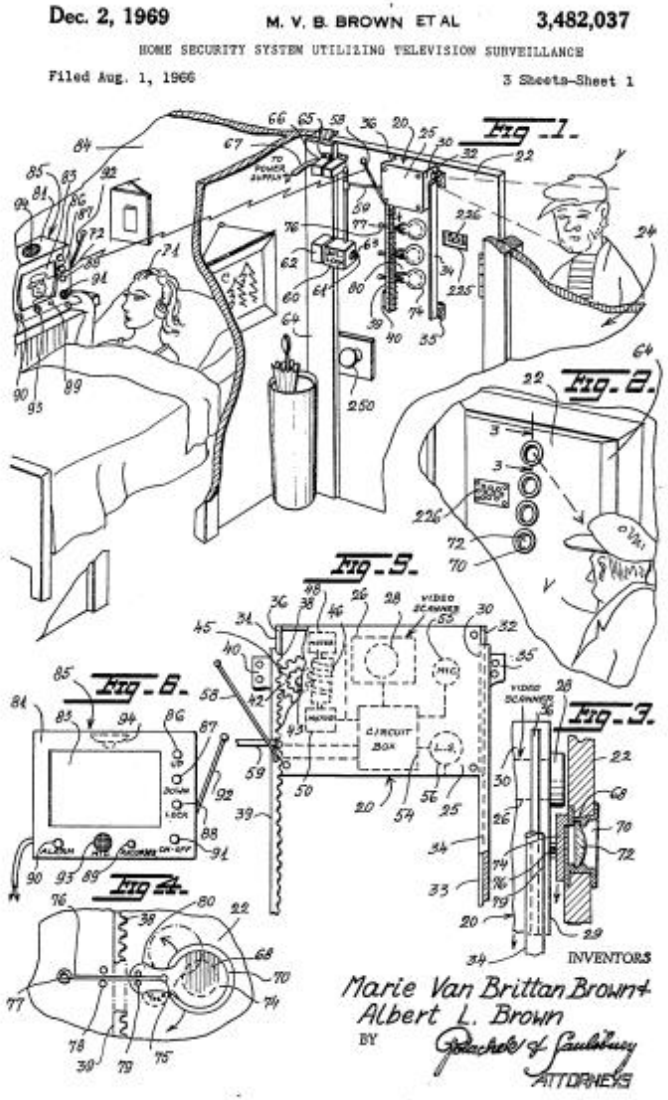
1951 - The Video Recorder

- Video tape recorder invented by Charles Ginsburg at Ampex corporation
- To record live image from a television camera



1966 - The first home video surveillance system

- When CCTV is coupled with VCR, we obtain a video surveillance system
- 1966 Marie Van Brittan Brown's patent
  - HOME SECURITY SYSTEM UTILIZING TELEVISION SURVEILLANCE


Dec. 2, 1969 M. V. B. BROWN ET AL 3,482,037

HOME SECURITY SYSTEM UTILIZING TELEVISION SURVEILLANCE

Filed Aug. 1, 1966 3 Sheets-Sheet 1

Fig. 1.

Fig. 2.

Fig. 5.

Fig. 6.

Fig. 4.

Fig. 3.

INVENTORS

Marie Van Brittan Brown

Albert L. Brown

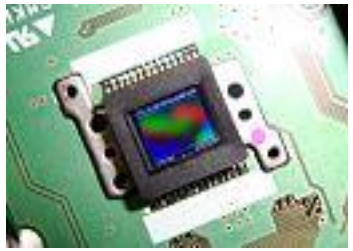
BY

ATTORNEYS

CCTV surveillance systems

- A cassette is only 8 hours of recording
- Decrease temporal resolution
  - Time lapse
- Decrease spatial resolution
  - 4-screen display

Human operator required!



1976 – CCD cameras

- **Announcing the digital imaging revolution**
- 2009 Nobel prize in Physics winners Willard Boyle and George Smith
- The capture of Pixels

IEEE TRANSACTIONS ON ELECTRON DEVICES, VOL. ED-23, NO. 7, JULY 1976 661

The Inception of Charge-Coupled Devices

WILLARD S. BOYLE, FELLOW, IEEE, AND GEORGE ELWOOD SMITH, FELLOW, IEEE

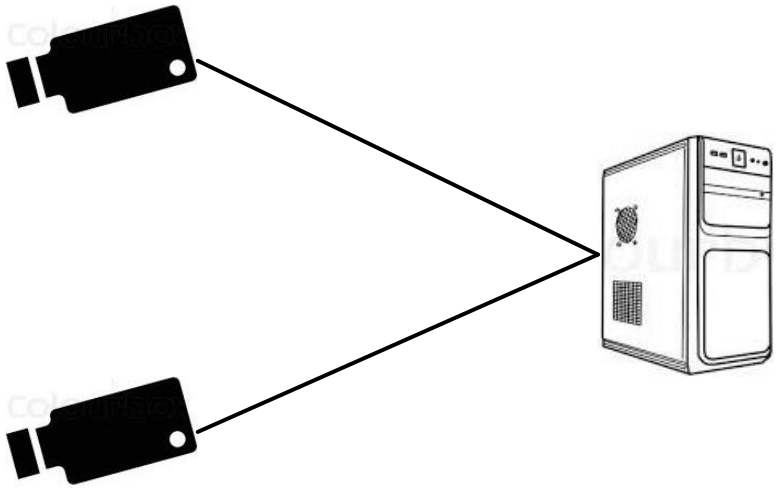
IT WOULD seem that the authors of the papers in this special issue have a very heavy responsibility. Much has been written about the mental processes that lead to innovation but this is one of the rare times that a group of people who themselves have participated in the act of innovation have been asked to shed some light on the factors

crete components. The late Jack Morton, who was at the time Vice-President of the Electronics Technology area, was a strong proponent of the magnetic bubbles program but felt, at the same time, that surely there must be some analogous devices using semiconductors. He was both persuasive and Vice-President, so his admonitions to de-

1990 - Digital video recorders

- 1998 - TIVo : digital recording of TV programs
- **The era of digital visual information**
  - Videos are saved on hard disk
  - Recording became cheap
- 1994 – first USB camera
  - Quickcam Connectix

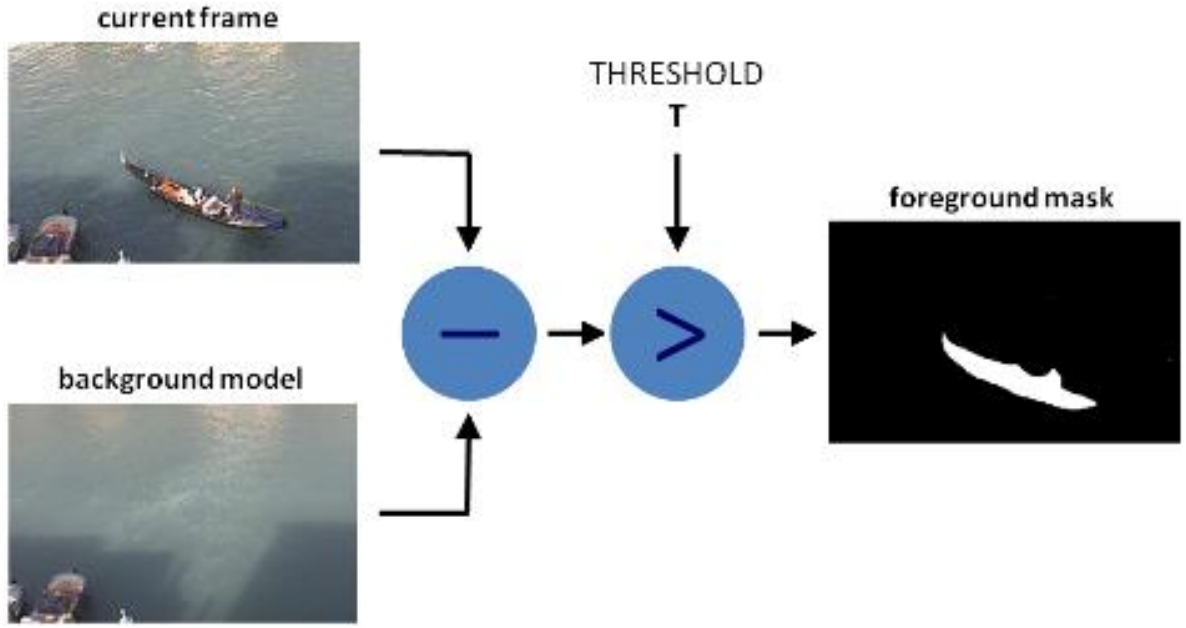
2000 - Smart surveillance



- Few cameras connected to one PC

Analyzing picture elements a.k.a. Pixels

- Basically motion detection
  - At the pixel level
- Connect them together
  - Spatially: blob analysis
  - Temporally: tracking



Example: detecting birds in vineyards

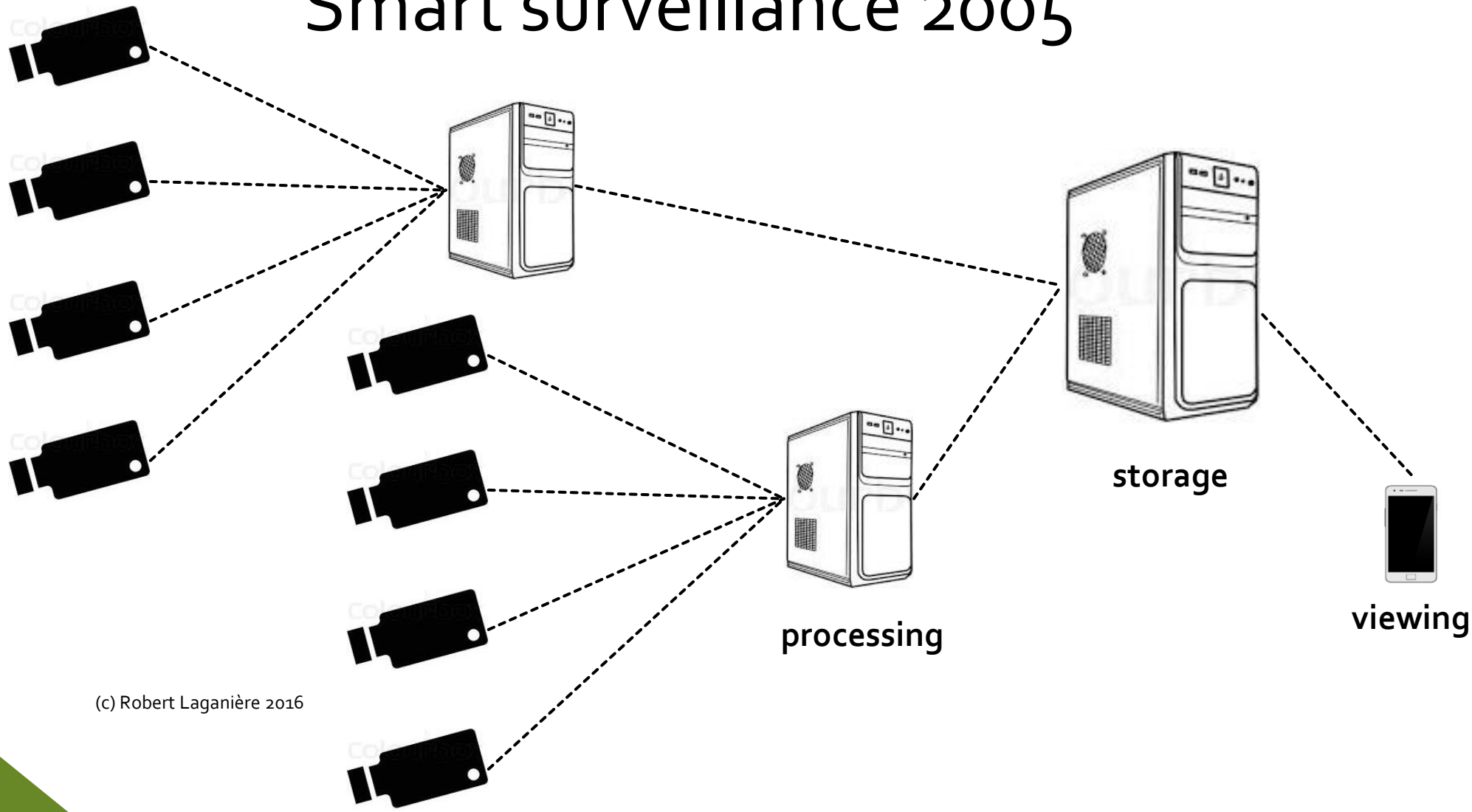
http://www.site.uottawa.ca/~laganier/surveillance/

1996 – IP cameras

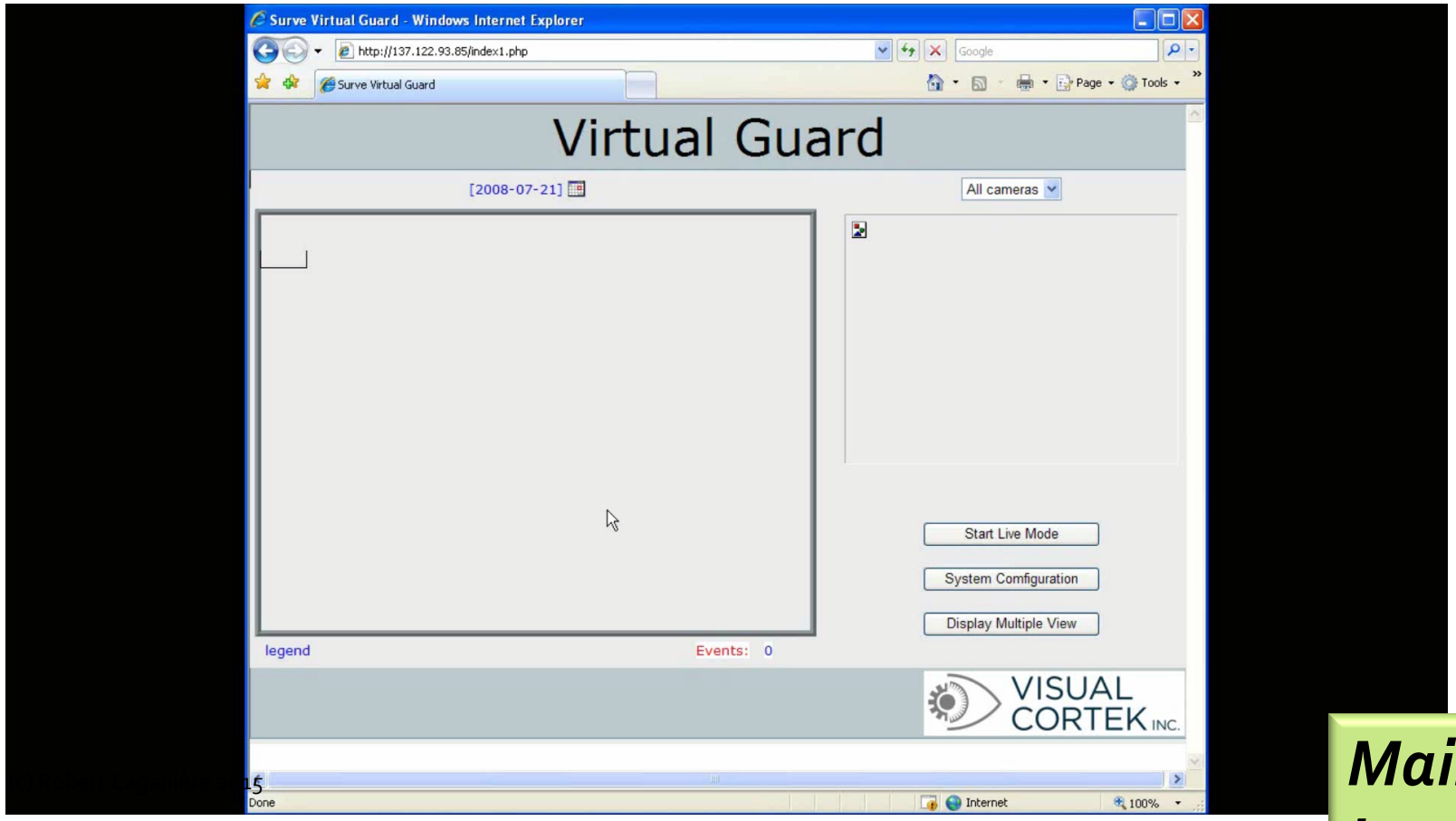
- By Axis communications
  - End of closed circuit surveillance
- Cameras can be accessed from everywhere

High bandwidth requirements!

Smart surveillance 2005

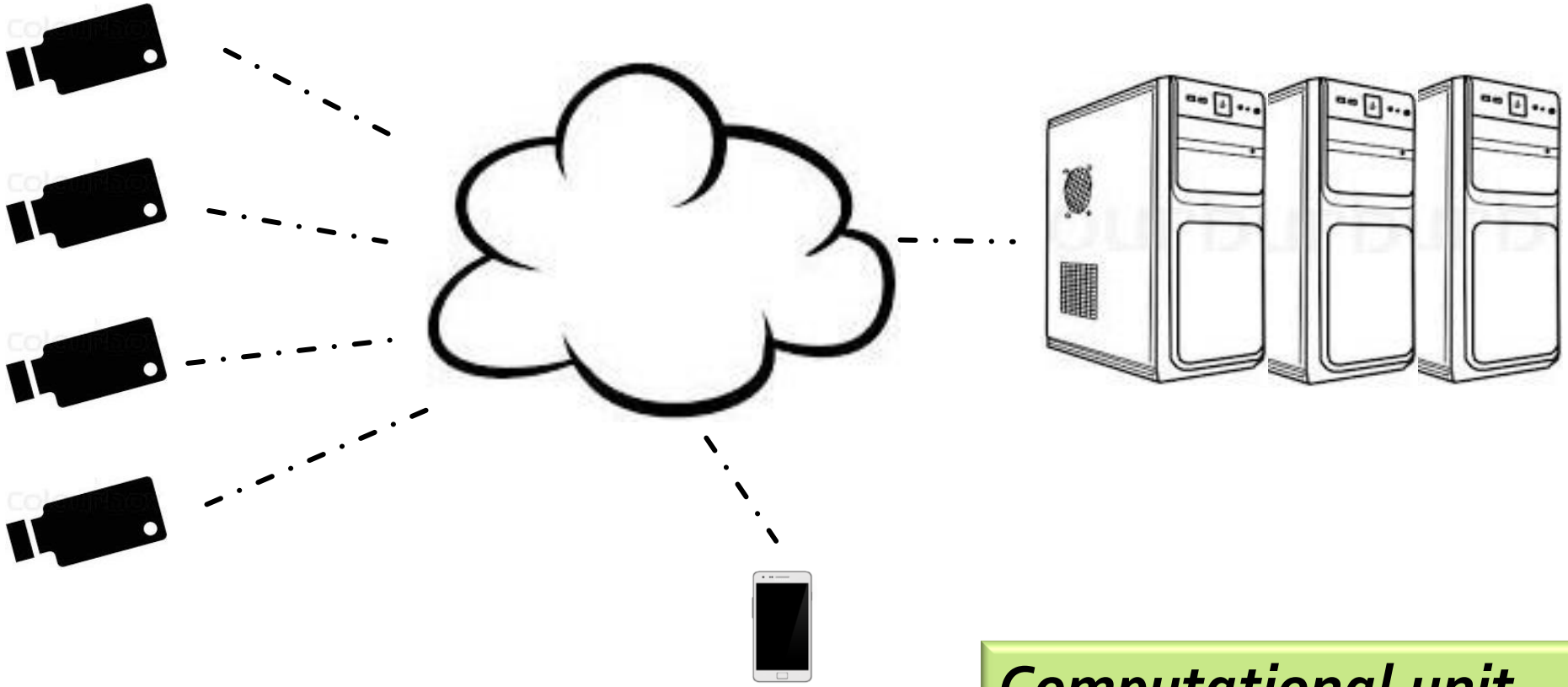


Remote home monitoring



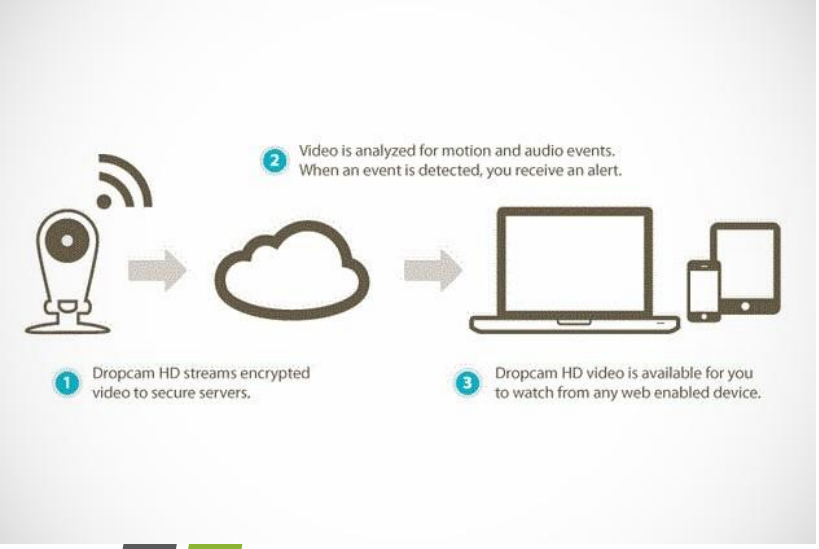
Maintenance; integration!

2010 – Cloud-based video surveillance

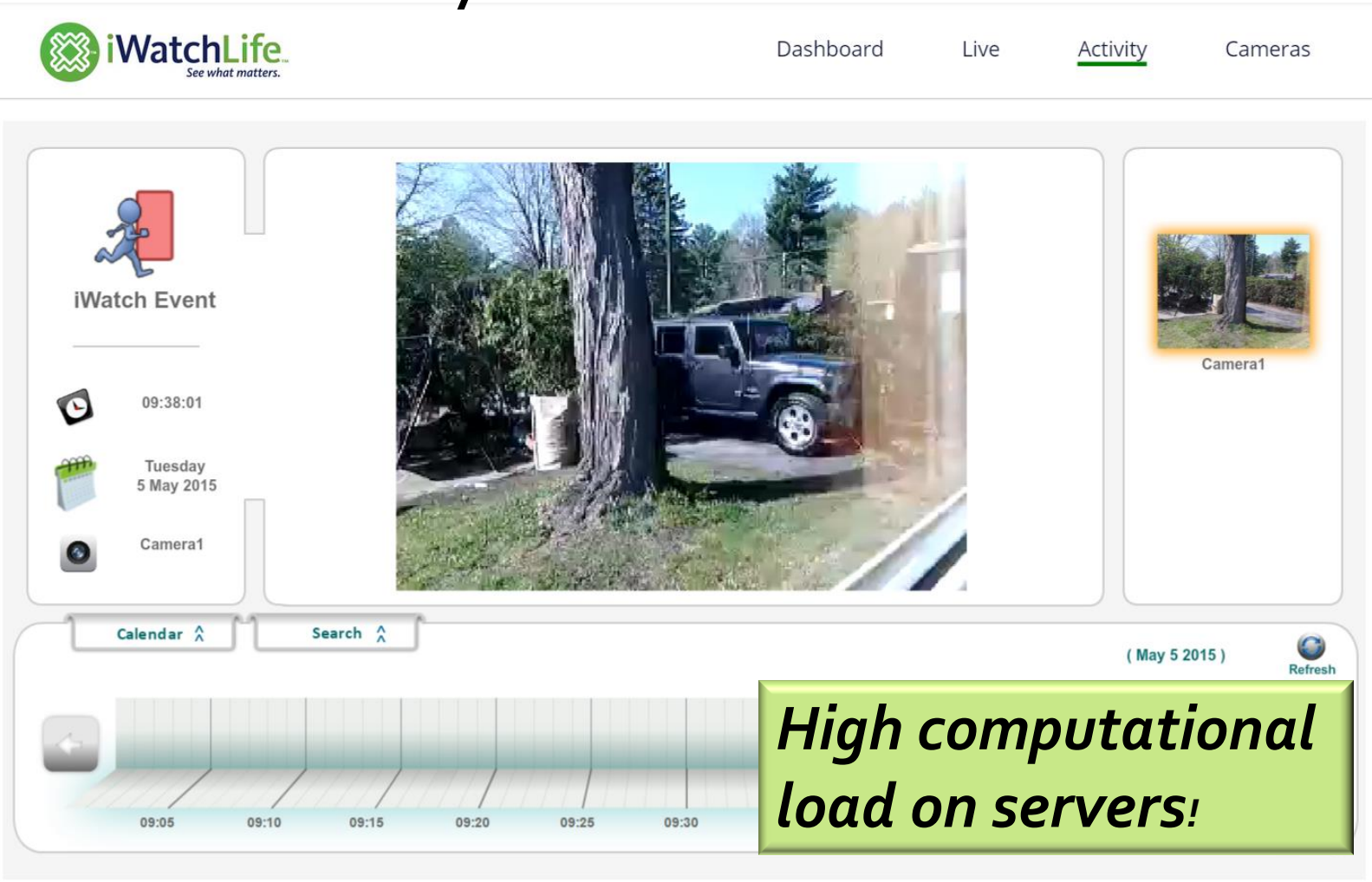


Computational unit removed from the home!

Cloud-based video monitoring systems

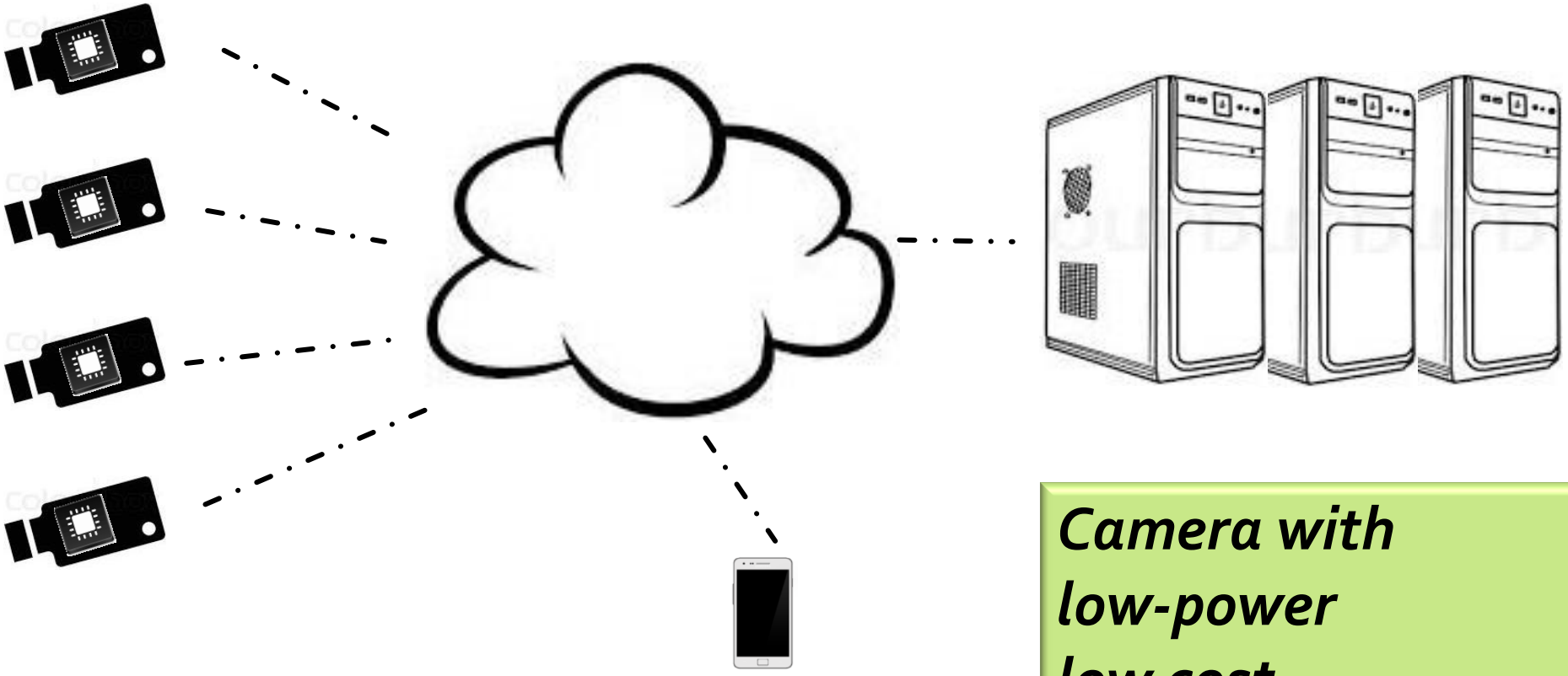


- Part of the connected home (IoT)
- DropCam
  - Check-in from anywhere
- iWatchLife
  - See what matters
- The camera becomes an integrated component
  - Not a device and software hooked to your computer



High computational load on servers!

2015 – smart cameras



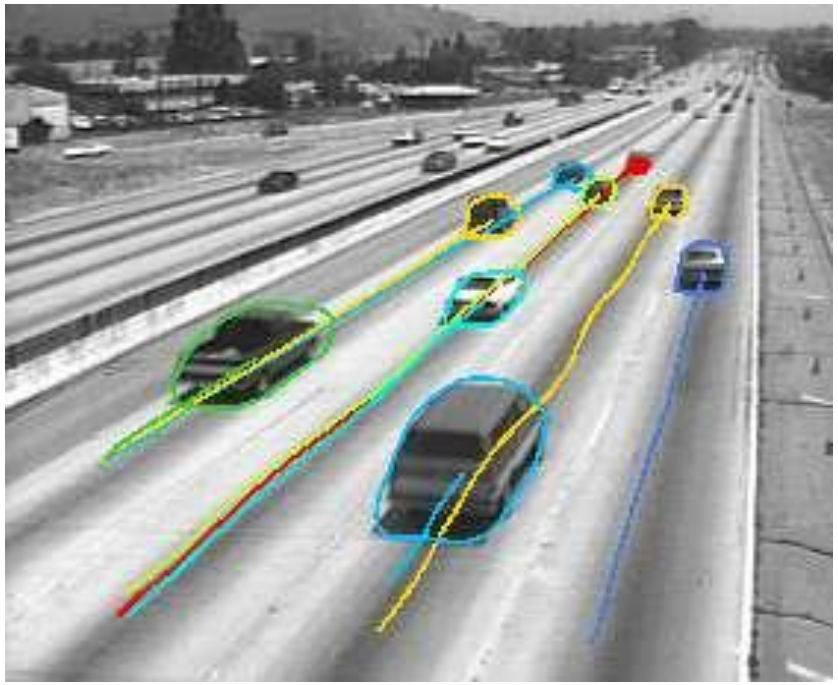
Camera with low-power low cost embedded intelligence!

Why Smart cameras?

- Make data processing closest to the source
- To achieve effective scene and event monitoring
  1. **More sophisticated vision algorithms required**
     - Recent advances in computer vision
  2. **Higher-level information extraction required**
     - Recent advances in machine learning

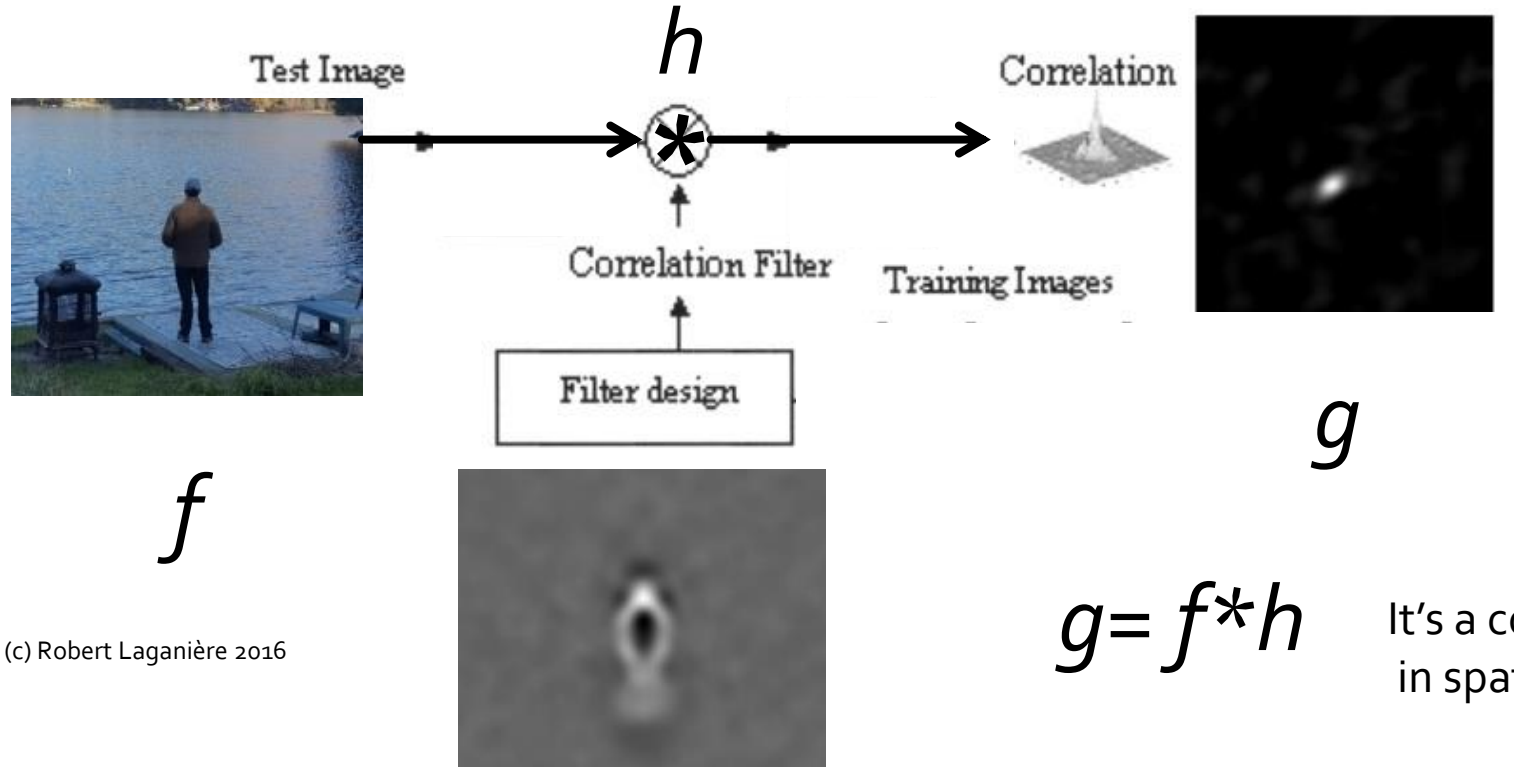
Low latency
Security and privacy
Bandwidth optimization

Progress in machine vision example: visual tracking



Progress in machine vision example: visual tracking

- Track objects using correlation filters

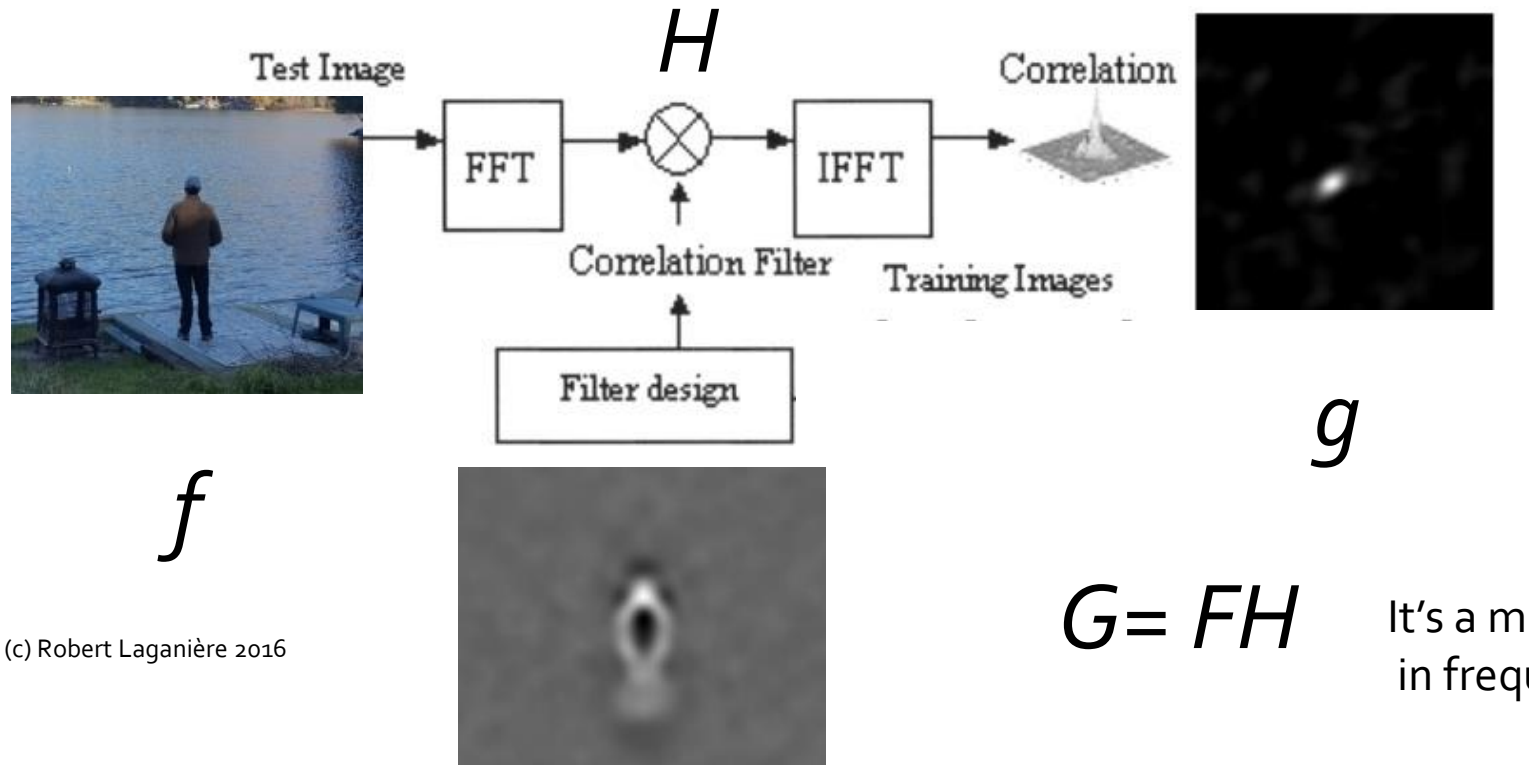


$g = f * h$

It's a convolution in spatial domain

Progress in machine vision example: visual tracking

- Filters easy to learn
- FFT and Multiplication are super-fast



$G = FH$

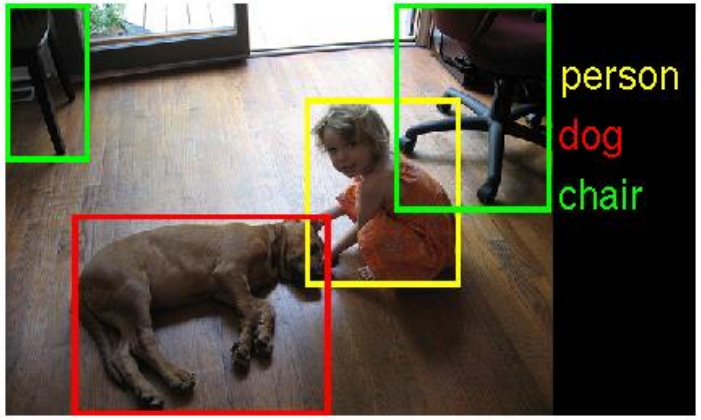
It's a multiplication in frequency domain

Progress in machine vision example: visual tracking

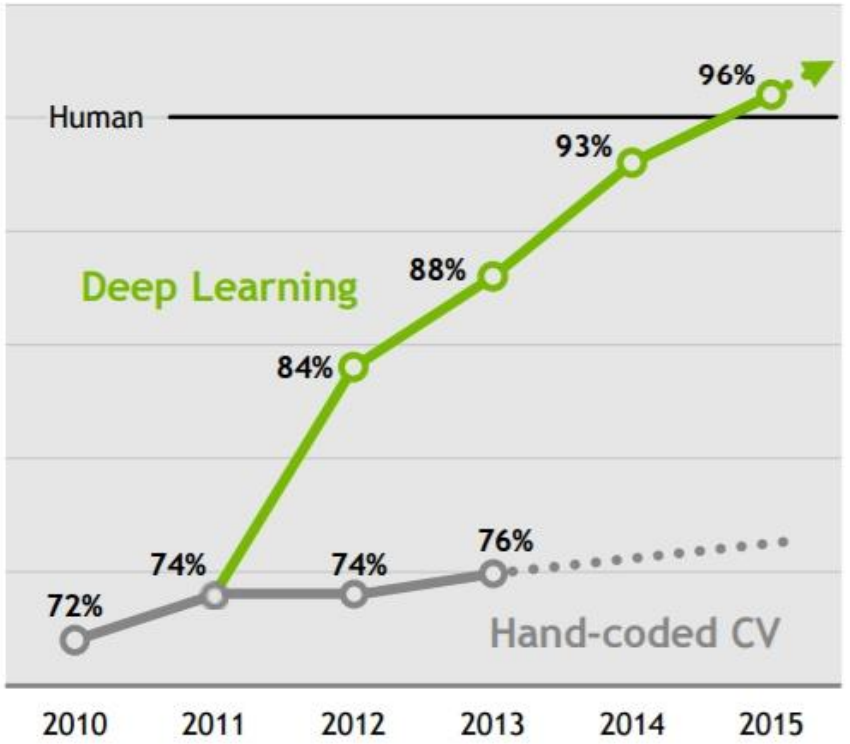
- Reliable Real-time algorithms in the wild!
- sKCF
  - VOT2015 best real-time tracker

http://www.site.uottawa.ca/research/viva/projects/project/tracking.html

Progress in machine learning
Deep Learning

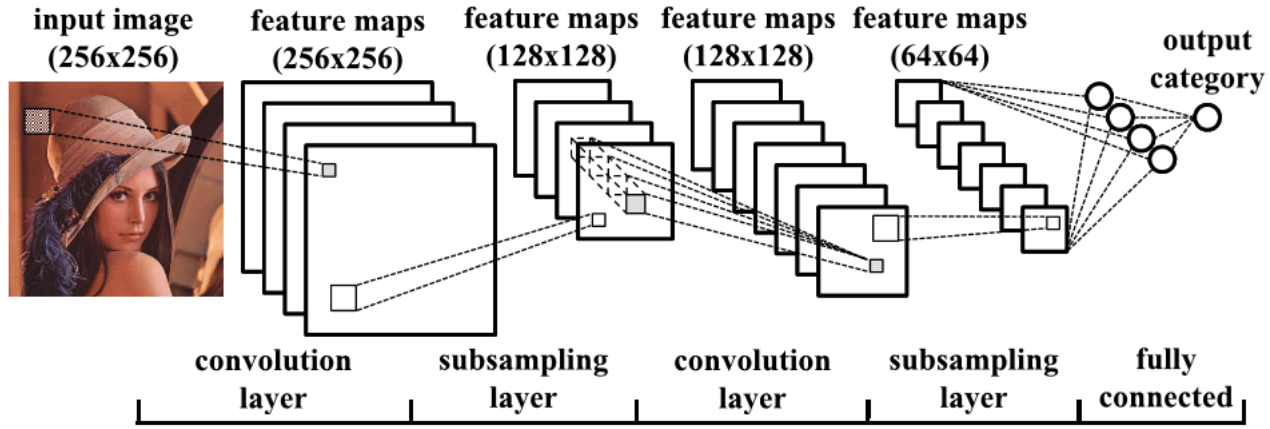


- Impressive detection results are obtained using Deep Learning
  - Computational power (GPU)
  - Big data (Facebook, Google, etc)



Progress in machine learning
Convolutional Neural Networks

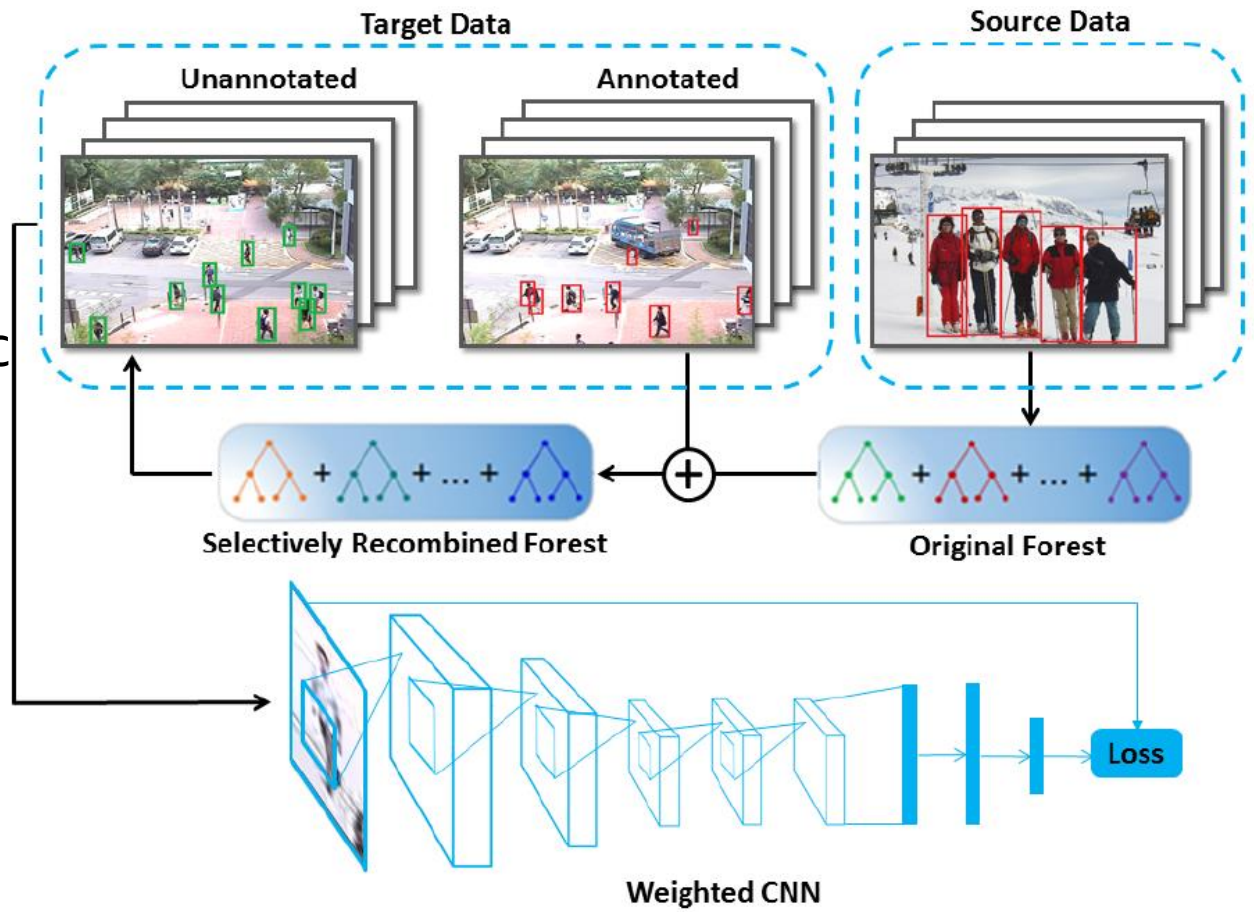
- A series a filters are applied
  - Kernels have to be learned
- Deep because they have many layers
- Deep because everything is learned
  - From pixels up to prediction



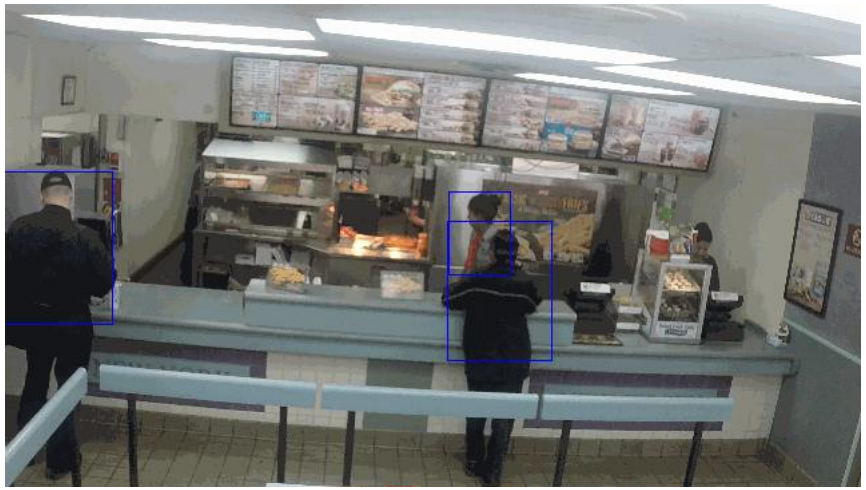
Progress in machine learning example: people detection

- Objective:

To adapt a generic detector to a particular domain



Progress in machine learning example: people detection



Detection and tracking in smart cameras

The camera produces objects, not only pixels !

Another example: to produce video summaries

- When one wishes to review the hours of videos produced by a surveillance camera
- A good video summary condenses hours into seconds without loosing the interpretability

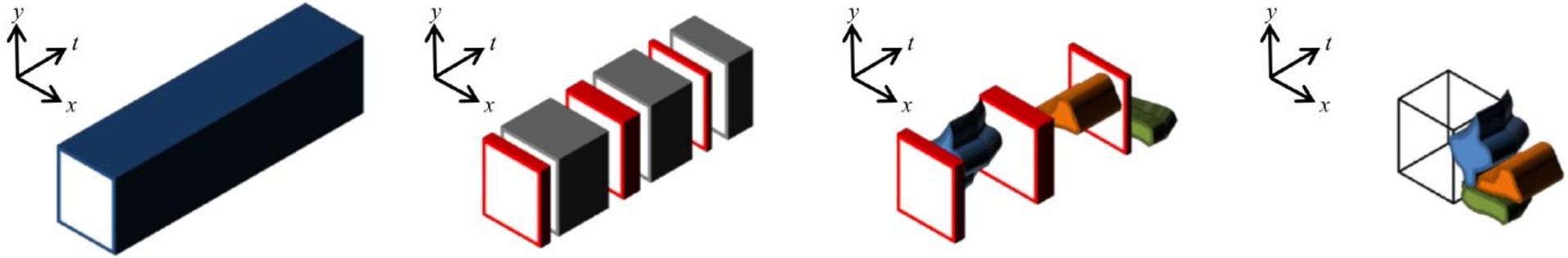
Summarization: at the pixel level (simple frame skipping)

- 1. Remove sequences without motion
- 2. Accelerate the video

http://www.site.uottawa.ca/~laganier/projects/videosurv/summarization.html

Summarization: at the object level

- 1. identify the objects in the sequence
- 2. Compact them spatially and temporally
- 3. make them to co-occur when they do not intersect in



Summarization without object intersection

http://www.site.uottawa.ca/~laganier/projects/videosurv/summarization.html

Summarization with some collisions

http://www.site.uottawa.ca/~laganier/projects/videosurv/summarization.html

Today -Specialized Surveillance Analytics

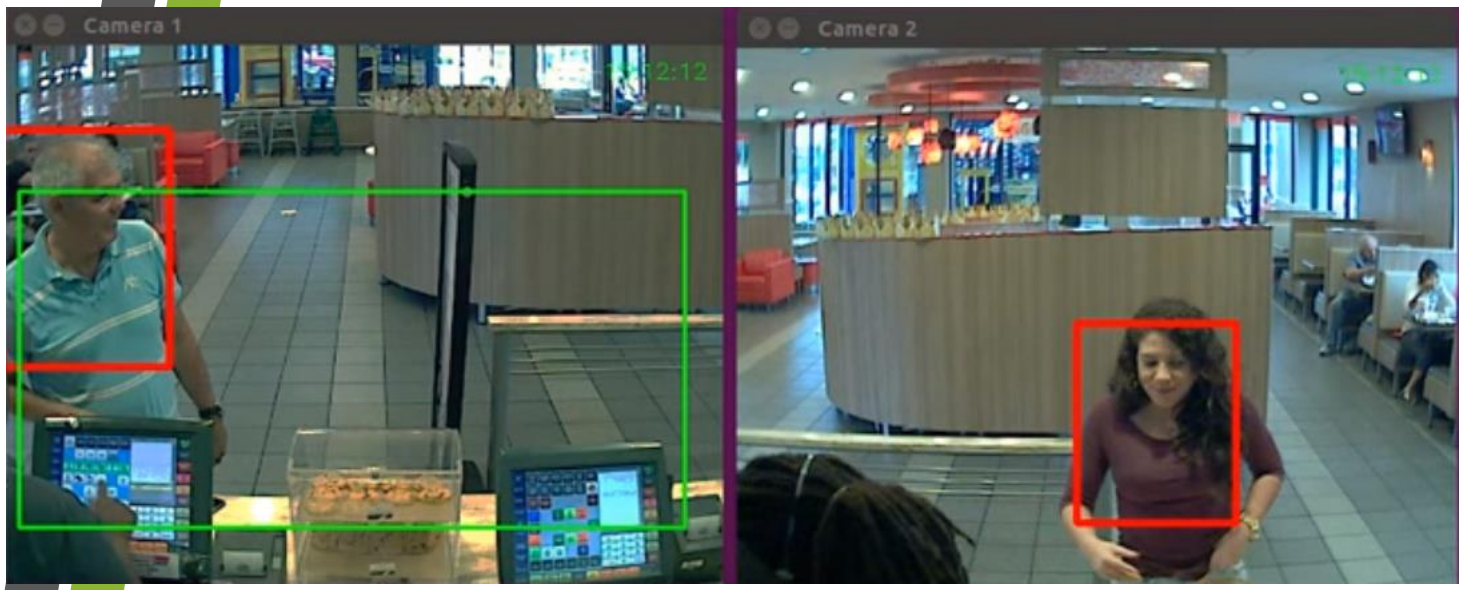
tempo

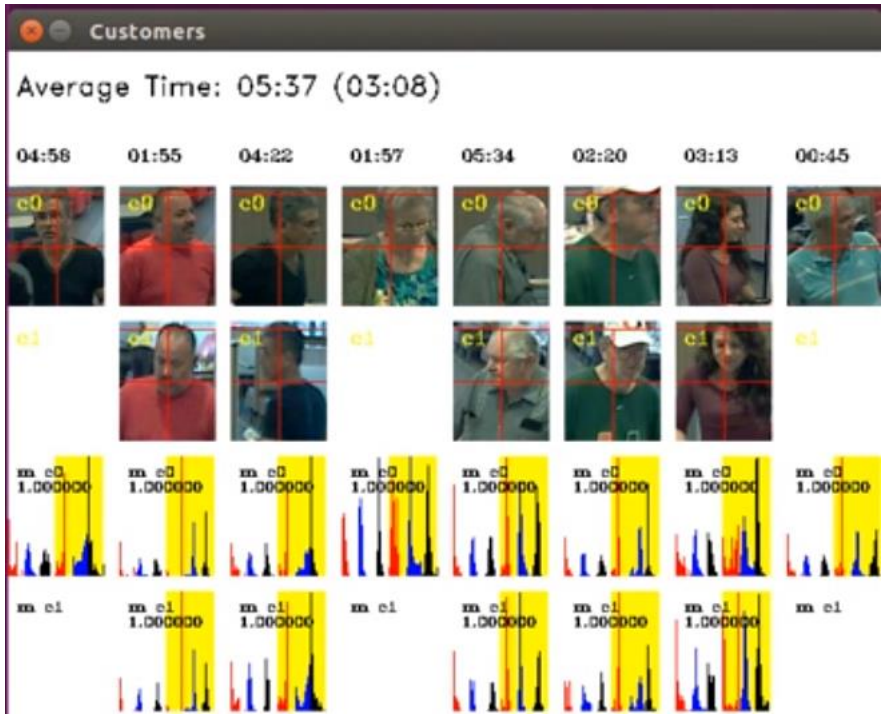
- One solution fits all – not possible
- Deploy smart surveillance in specific domain
  - Scope the solution
  - Extract rich data

SPORTLOGiQ

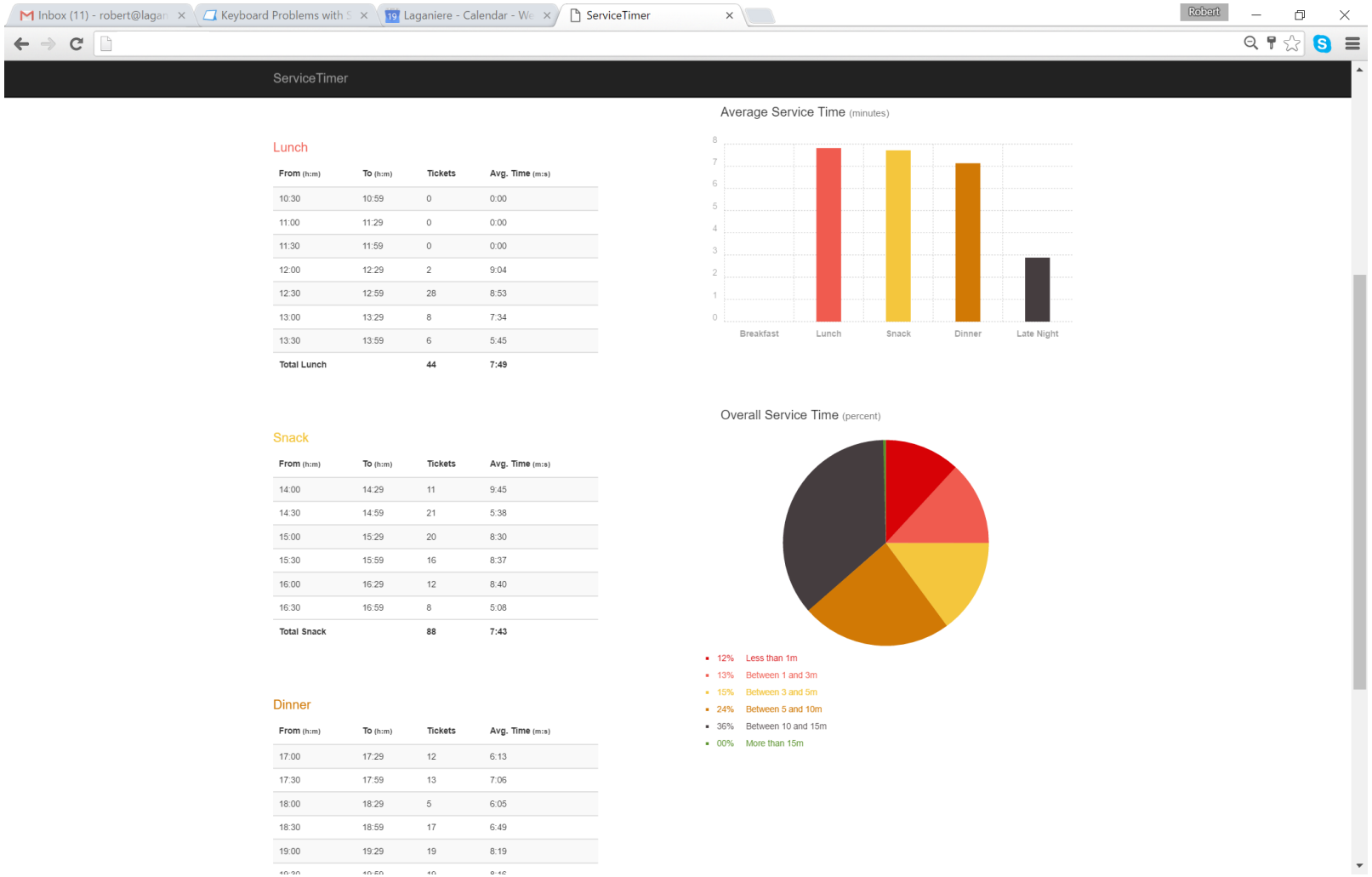
miovision
rethink traffic

Customer tracking at service point





From video to data

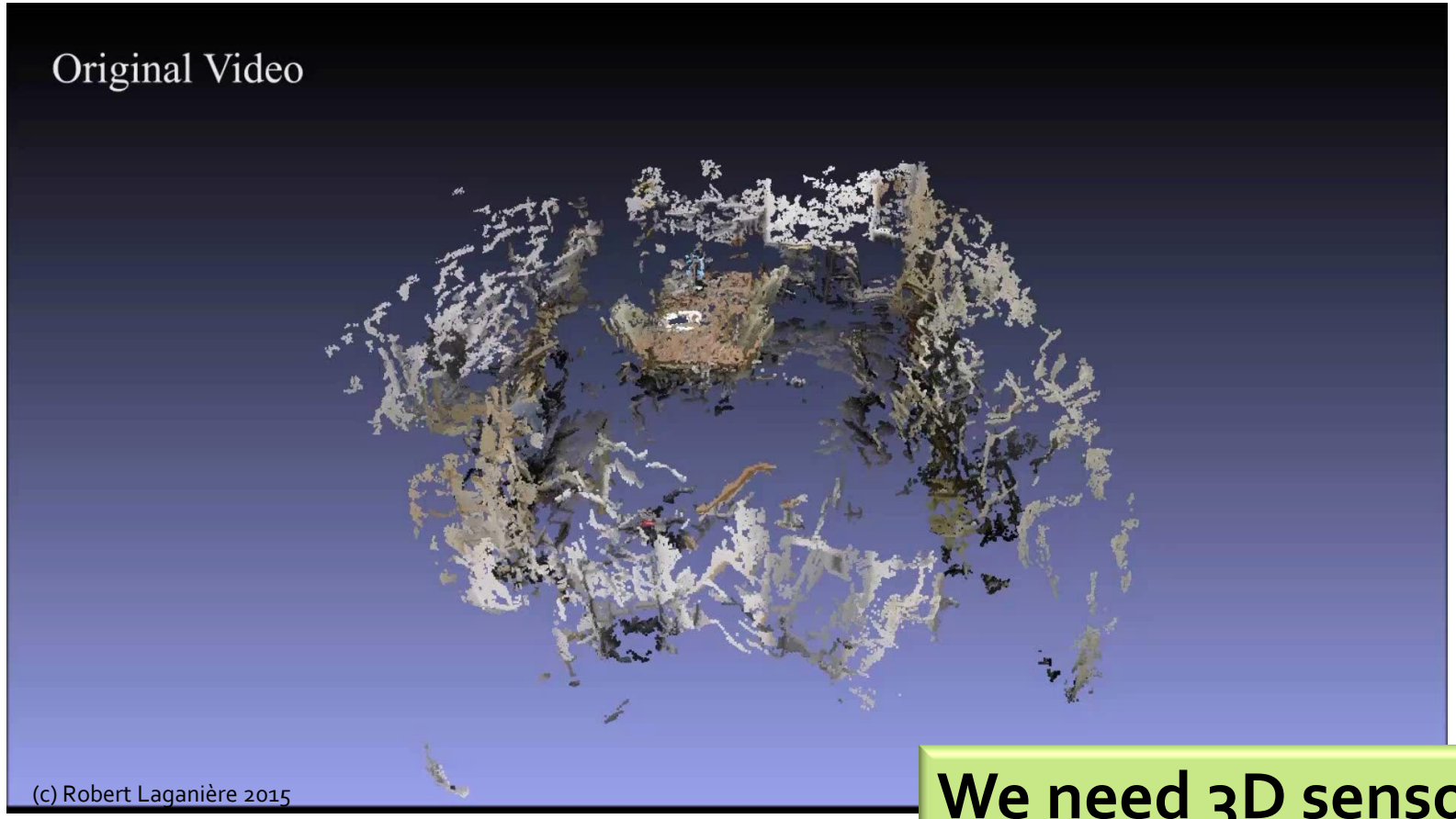


Richer data analytics module required

Future – Depth camera + Moving cameras

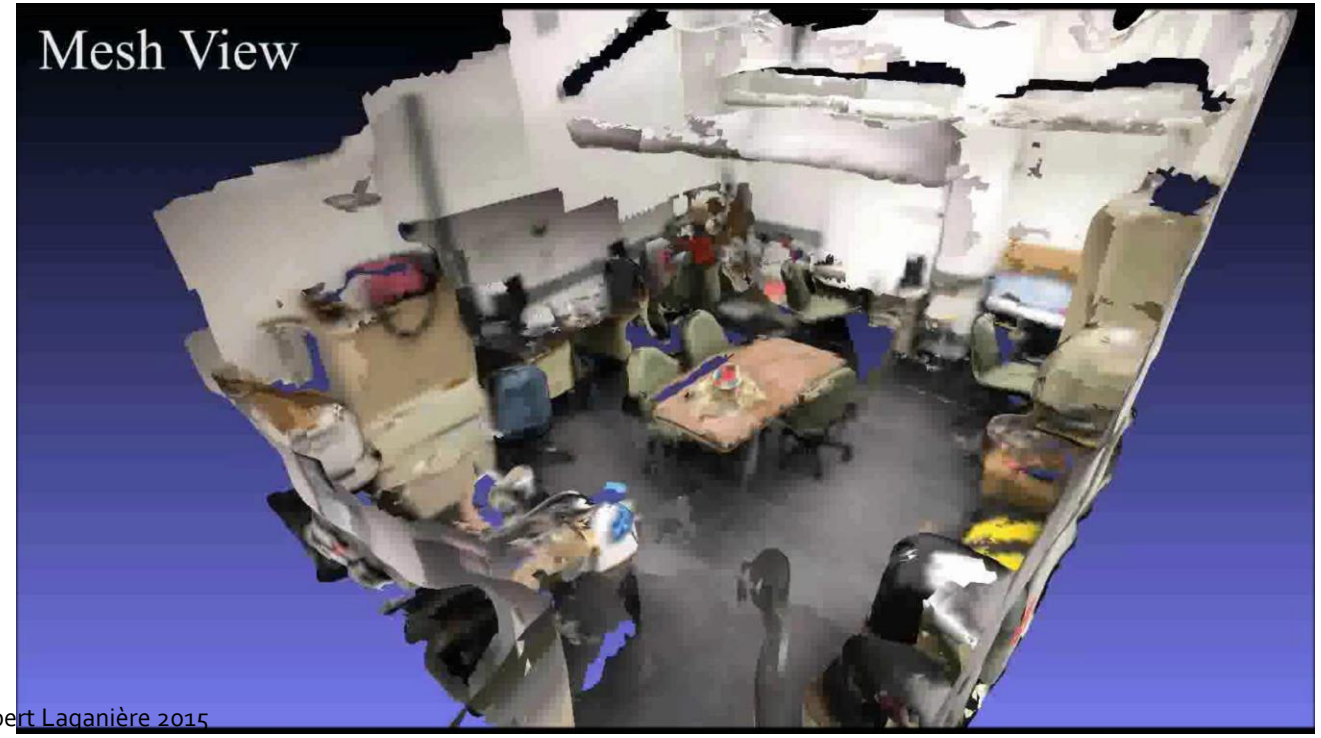
Another example: scene change detection (patrolling robots)

3D scene reconstruction



We need 3D sensors to better identify the scene objects!

3D reconstruction of a room



Using structured-light sensor

Scene change detection results

And more moving cameras…

- Action cameras
  - Capture and follow users performing actions
- Assistive cameras
  - Give feedback to users about the observed scene
- Life logger
  - Record important moments in life
- Flying camera
  - Autonomous drones