



# How to Learn Deep Learning? (1/2)

## (如何學習人工智慧-深度學習?)

National Cheng Kung University  
Dept. of Computer Science and Information Engineering  
Robotics Lab.

國立成功大學 資訊工程系 機器人實驗室

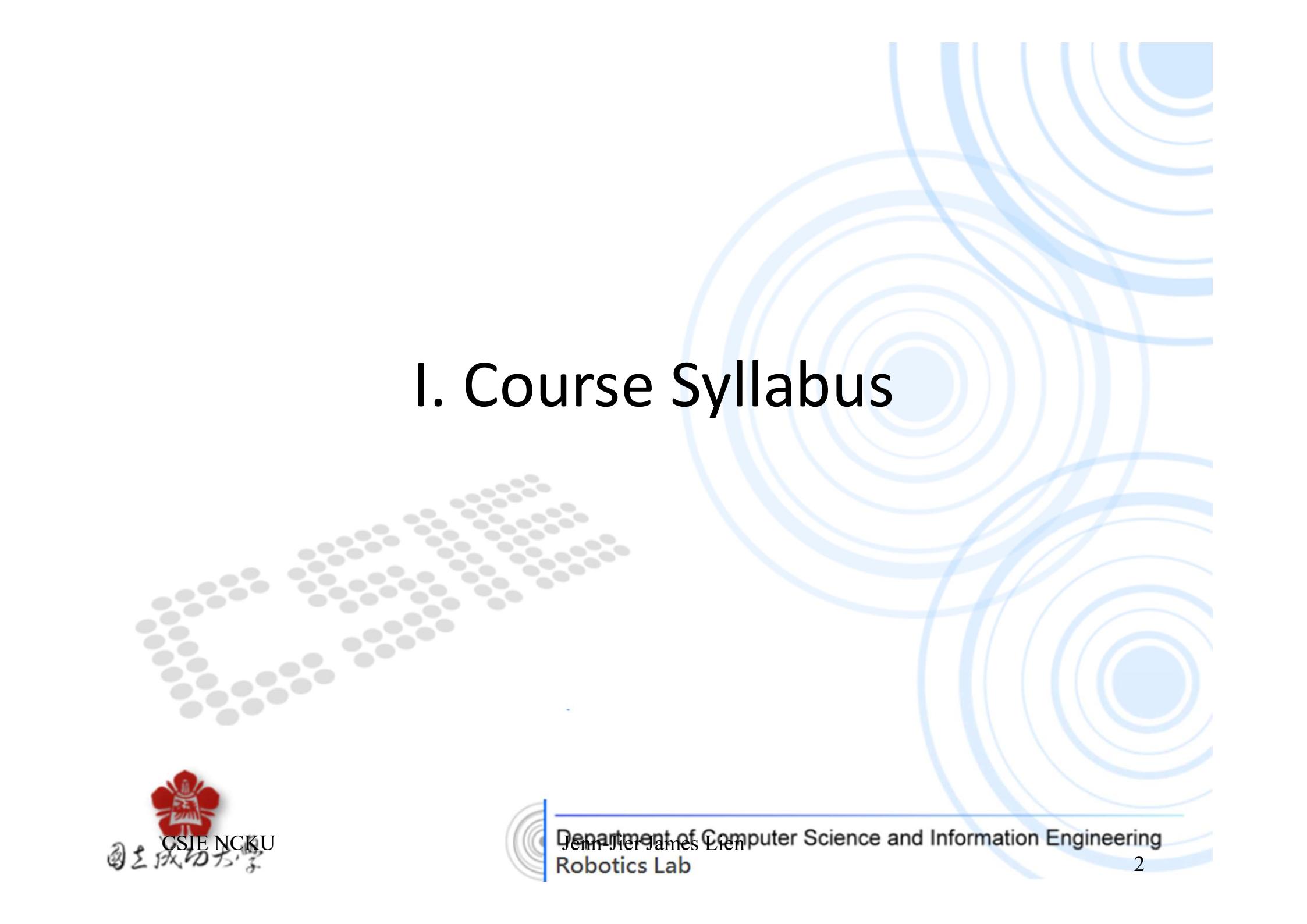
(Jenn-Jier James Lien / 連震杰)

<http://robotics.csie.ncku.edu.tw>

[jjlien@csie.ncku.edu.tw](mailto:jjlien@csie.ncku.edu.tw)

Department of Computer Science and Information Engineering  
Robotics Lab





# I. Course Syllabus



# Computer Vision and Deep Learning – Basic Courses and Books

- **Undergraduate:**
  - **Linear Algebra**
  - **Introduction to Probability and Stochastic**
  - **Signals and Systems**
    - Alan V. Oppenheim and Alan S. Willsky, *Signals and Systems*, 2<sup>nd</sup>, 1996.
- **Graduate**
  - **Probability and Stochastic**
  - **Digital Signal Processing**
    - A.V. Oppenheim, R.W. Schafer, and J.R. Buck, *Discrete-Time Signal Processing*, Prentice Hall, 2<sup>nd</sup>, 1999. ISBN: 0137549202.
  - **Digital Image Processing**
    - R.C. Gonzalez and R.E. Woods, *Digital Image Processing*, Prentice Hall, 3rd, 2007. ISBN: 013168728X.
  - **OpenCV**
    - G. Bradski and A. Kaehler, *Learning OpenCV, Computer Vision with the OpenCV Library*, O'Reilly, 2008. ISBN-10: 0596516134 or ISBN-13: 978-0596516130.
  - **Computer Vision**
    - R. Szeliski, *Computer Vision: Algorithms and Applications*, Springer, 2010. ISBN-10: 1848829345 or ISBN-13: 978-1848829343.
    - R. Hartley and A. Zisserman, *Multiple View Geometry in Computer Vision*, Cambridge University Press, 2nd, 2004. ISBN: 0521540518.
  - **Machine Learning and Pattern Recognition**
    - C.M. Bishop, *Machine Learning and Pattern Recognition*, Springer, 2007. ISBN: 0387310738.
  - **Deep Learning**
    - I. Goodfellow, Y. Bengio and A. Courville, *Deep Learning*, MIT, 2016. ISBN: 0262035618

# Computer Vision and Deep Learning – Relative Conferences and Journals

## □ Conference – CV and Deep Learning:

- **CVPR:** Computer Vision and Pattern Recognition
- **ICCV:** International Conference on Computer Vision
- **ECCV:** European Conference on Computer Vision
- **ACCV:** Asian Conference on Computer Vision
  
- **NeurIPS:** Advances in Neural Information Processing Systems
- **ICML:** International Conference on Machine Learning
- **arXiv**
  
- ICME:
- ICPR:
- ICIP:
  
- eCVW: Embedded Computer Vision Workshop

## □ Conferences - Robot:

- **IROS:** IEEE International Conference on Intelligent Robots and Systems
- **ICRA:** International conf. on Robotics and Automation
- **SMC:** IEEE International Conference on Systems, Man, and Cybernetics

## □ Journal – CV and Deep Learning:

- **IJCV:** International Journal on Computer Vision
- **IEEE tPAMI:**
- **Image and Vision Computing**
  
- **IEEE tVisualization and Computer Graphics**
- **SIGGRAPH:**
  
- **Pattern Recognition**
- **IEEE tIP**
- **IEEE tCSVT**
- **IEEE tMM**

## □ Journal – Robot:

- **IEEE tRobotics and Automation**

# Computer Vision and Deep Learning: FTP Site and Website

## **□ FTP site to download and upload:**

- IP: 140.116.154.1
- Port: 21
- ID: cvdl2019
- Password: cvdl2019

## **□ Download lectures: After 17:00 every Wednesday**

## **□ Website:**

- <http://robotics.csie.ncku.edu.tw/course.html>

## **□ Office Hour: CSIE 9F Robotics Lab**

- Monday – 15:00~17:00
- Tuesday – 20:00~22:00



# OpenCV and Deep Learning: FTP Site and Website

## **□ FTP site to download and upload:**

- IP: 140.116.154.1
- Port: 21
- ID: opencvdl2019
- Password: opencvdl2019

## **□ Download lectures: After 17:00 every Thursday**

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## R.1 Profile in Academia – Education: ~ 1998

EMG: Electromyography

ECE: Electrical and Computer Engineering

RI: Robotics Institute

SCS: School of Computer Science

CMU: Carnegie Mellon U.

UPMC: U. of Pittsburgh Medical Center

### □ Education:

- 1985/09 ~ 1989/05 - B.S. Dept. of **Biomedical Engineering**, Chung Yuan Christian University, Taiwan.
- 1991/08 ~ 1993/05 - M.S. Program of **Biomedical Engineering**, ECE, Washington U., St. Louis, MO.
- 1993/08 ~ 1998/04 - Ph.D. ECE, U. of Pittsburgh, Pittsburgh, PA.
  - Research Assistant: Research conducted at the **RI, SCS, CMU**.
  - Dissertation Title: “Automatic **Recognition of Facial Expressions** Using Hidden Markov Models and Estimation of Expression Intensity”
  - Advisor: **Takeo Kanade**, RI, SCS, **CMU**.
    - > Member of National Academy of Engineering
    - > Fellow of the American Academy of Arts and Sciences

### □ Apply facial expression analysis dissertation work to plastic surgery and EMG at **UPMC**

- 1) Original **motion trajectory** uses attached circle **dots** and manually mark dot center frame by frame



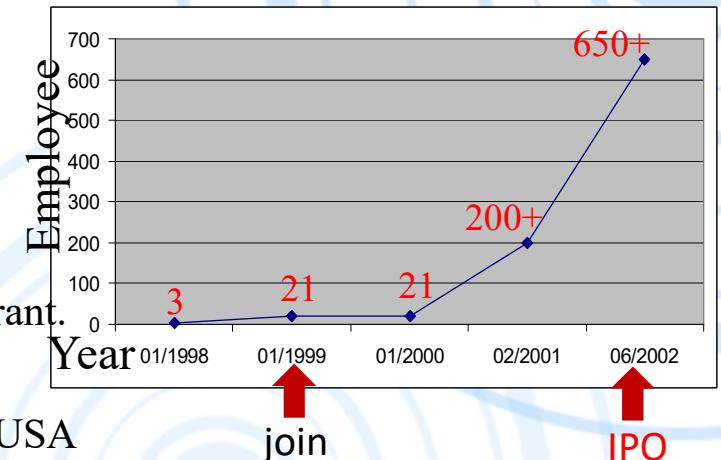
- 2) **Facial expression analysis** uses computer vision with optical **flow** tracking for motion trajectory



# R.1 Profile at Face Recognition Company – Visionics (IPO VSNX): 1999~2002, USA

## □ Biometrics technology: Face and fingerprint recognition

- Capital: US\$40M
- Award: DARPA FERET Face Recognition Competition: No.1 in 2002 & 2004
- Grant: Project leader for US\$5M DARPA surveillance grant.
- Business: Government - Surveillance in Birmingham, UK
  - Surveillance for Customs & Border Protection, USA
- Strategy:
  - Merge small (200+ employees) and then big (400+) fingerprint companies
  - Partnership with NEC, Japan – made face detection chips in 2005.
- Stock: IPO VSNX at Nasdaq in 2002



1) Surveillance and security:  
Preprocessing and display



Face and  
fingerprinting  
images  
→  
Recognition  
result:  
ID, profile,  
record...



2) Central management system (CMS) and database center:  
Recognition process and data management

# Media: Newspaper about Human-Computer Interaction

- 1998/08/03: *Washington Post*, *Washington Times*, and *Pittsburgh Post-Gazette* –  
"Look Closely: Computer program reads deep into our true feelings by analyzing our facial expressions."
- 2001: ABC, NBC, and CBS TV Channels and Discovery Channel in USA: "Surveillance – Security via CCTV"



## Lie detector

*Is this woman  
truly surprised?*

*A computer  
can tell whether  
facial expressions  
are genuine.*

**Science, Page A-6**

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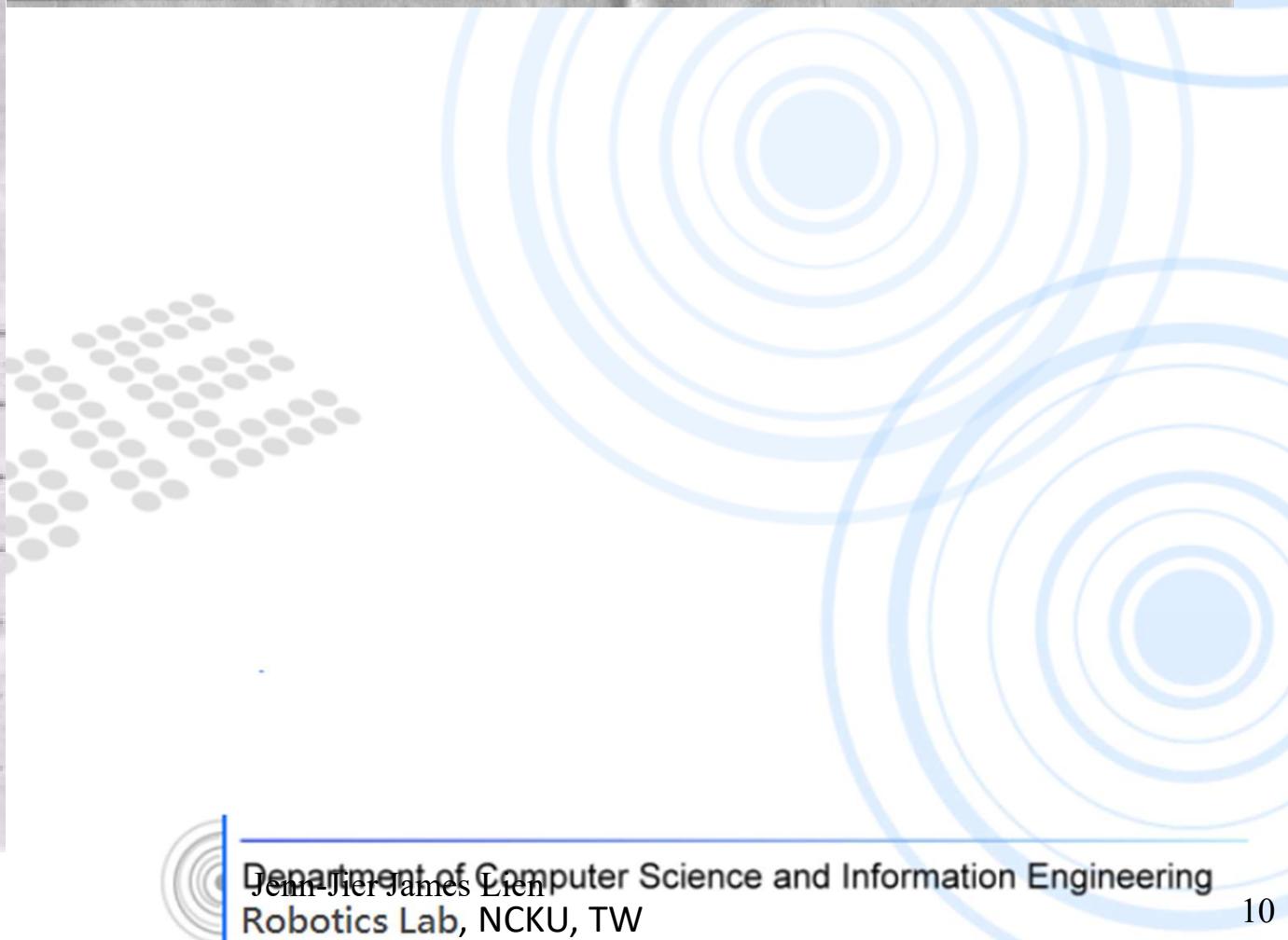
**BIG UNIT MENACES BUCS/SPORTS, C-1**

# Pittsburgh Post-Gazette

ONE OF AMERICA'S GREAT NEWSPAPERS

MONDAY, AUGUST 3, 1998

VOL. 72, NO. 3 8/3/98



Department of Computer Science and Information Engineering  
Jenq-Jer James Lin  
Robotics Lab, NCKU, TW

# LOOK CLOSELY

*Computer program reads deep into our true feelings  
by analyzing our facial expressions*

By Sharon Voas  
Post-Gazette Staff Writer

If Detective Sipowicz of "NYPD Blue" had this computer program, he wouldn't have to threaten so many suspects with bad things involving big men in prison.

He'd know if they were telling the truth most of the time.

A computer program just developed here can tell the difference between a spontaneous, or genuine expression, and one that is deliberate, but not necessarily false. In another year of study it's expected the program will be able to detect a true statement from a lie.

When computer analyses of suspects' expressions are used along with lie detector tests, which are accurate about 90 percent of the time, a detective would know most of the time whether a suspect is telling it straight.

This new computer program, developed by researchers at the University of Pittsburgh and Carnegie Mellon University, can discern thousands of facial expressions. The prototype is so precise that it deciphers the order and speed different facial muscles move in to create a genuine expression. That would be virtually impossible for someone to fake.

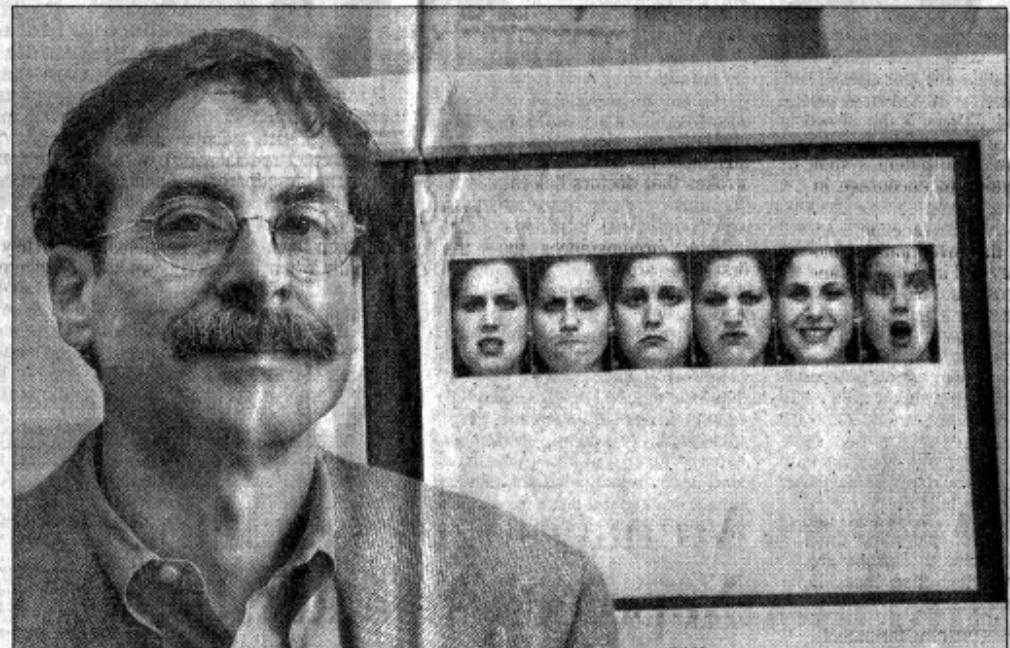
The new program is so far superior to existing methods of analyzing facial expressions that Pitt researcher Jeff Cohn says it's like inventing a new microscope.

"You can see so much more, and you can see things you couldn't see before," Cohn said.

The program has potential in mental health research as well, by revealing true feelings and helping doctors learn if a patient is really suicidal.

The program may make a big step toward developing computers users can actually talk to, as if talking to another human, instead of using keyboards and mice. But to have a conversation like two humans would, the computer would have to read the user's expressions. Also, the program may help movie animators draw more realistic expressions.

Automated Face Analysis, the official name of the program, was developed by Cohn, an associate professor of psychology and psychiatry at Pitt, Takeo Kanade, director of The Robotics Institute at Carnegie Mellon, James Lein, who recently received his doctorate in electrical engineering from Pitt, and Adena Zlochower,



Tony Tye/Post-Gazette

Jeff Cohn, associate professor of psychology and psychiatry at Pitt, says of the new program: "You can see so much more, and you can see things you couldn't see before."

a doctoral candidate in psychology at Pitt.

Only one other group of researchers from the Salk Institute and the University of California at San Francisco is using a similar program of computer vision and facial analysis. Marian Stewart Bartlett, of the Salk Institute, said these programs will be especially useful for psychological research because researchers will no longer have to rely on inferring what the patient might feel. They will know.

"Facial expression is an important mode of human expression," Cohn said. "It regulates social behavior.

It's important to people's self-presentation and to how they are perceived."

Facial expressions tell so much that we sometimes have "gut feelings" that something just doesn't feel right, even though we can't explain why.

For instance, President Clinton's chin boss is giving him trouble these days.

When a person smiles a genuine smile, his whole face moves, with the muscles around the eyes contract-

SEE FACES, PAGE A-7



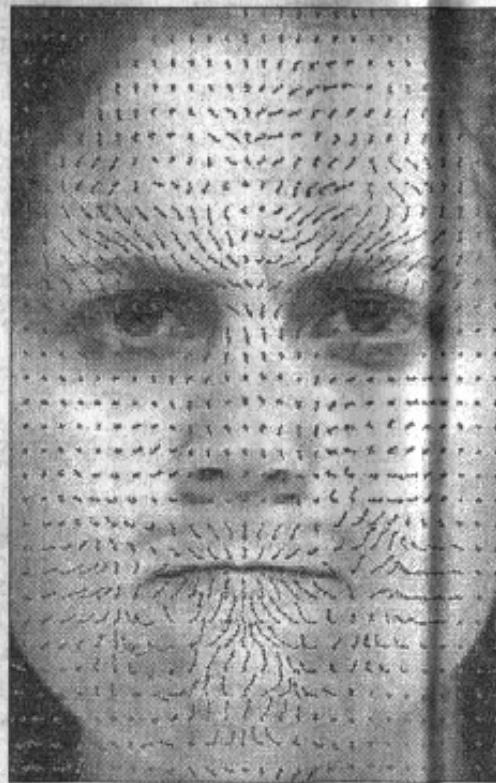
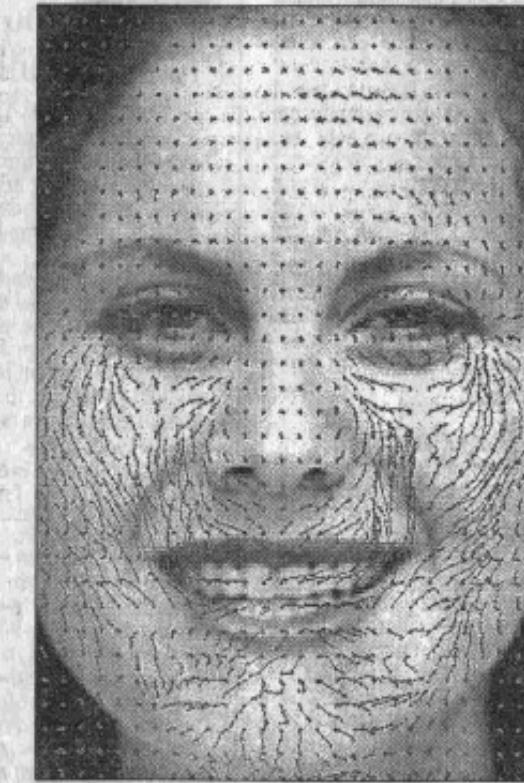
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國立成功大學

Department of Computer Science and Information Engineering  
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Robotics Lab, NCKU, TW

# SCIENCE & ENVIRONMENT

PITTSBURGH POST-GAZETTE ■ MONDAY, AUGUST 3, 1998



Jeff Cohn/University of Pittsburgh

Adena Zlochower, a Pitt researcher working on a computer analysis of facial expressions, shows how muscles move in some basic expressions.

ABOVE LEFT: In joy, the muscles around her eyes tighten, making her cheeks rise and pulling up the corners of her lips and opening her mouth.

ABOVE CENTER: In anger, her lips press together and pull toward the middle, making a ball-shaped area called the "chin boss" push up. Eyes widen, the lower eyelid tightens and upper eyelids rise. Eyebrows draw together sharply.

ABOVE RIGHT: In surprise, the jaw drops, stretching her mouth down, while her eyes widen and her brows rise.



## SCIENCE &amp; ENVIRONMENT

# Computer deciphers genuine, deliberate expressions

FACES FROM PAGE A-6

ing and the cheeks raising the mouth. The top of Clinton's face smiles, Cohn says, but Clinton pushes his lower lip up into what could be taken for a pout or some expression of sadness. Pulling that lip up tight creates a tennis-ball shaped area on the chin called the chin boss.

"That gives people a mixed message," Cohn said. "They're not quite sure about his smile."

Or take Susan Smith, the South Carolina woman who told police an attacker had kidnapped her 1- and 3-year-old sons, when she had actually belted them into her car and rolled it into a lake where they drowned.

"I knew right off she was lying," Cohn said. "When she was interviewed, she feigned sadness. In sadness, a characteristic is that the inside corners of the brows are pulled together and raised in a triangle, and the lip corners pull down. Very few people can do that voluntarily."

Cohn, 51, leans back in his office chair near a computer screen full of emoting faces. He's slender and wears the moss green cable knit

sweater, khaki shorts and hiking shoes of an intellectual who spends a lot of time hiking or biking in the woods. A slender nose leads from his large blue eyes — that look larger because of thick-lensed, wire-rimmed glasses — to his thick brown and gray thatch of a mustache.

He swivels and sets the faces on the computer screen in motion, or, one could say, in emotion.

The program tracks each and every pixel — the tiniest unit of light on a computer or TV screen — of colleague Zlochower's face all the way through an expression. Little tracker lines on her face show not only which muscles move on different parts of her face, but in what order, with what intensity and how long each part lasts.

Those things weren't known before the development of this program because it uses video.

"Imagine Susan Smith has done some homework and was able to display sadness," Cohn said. "She would still have trouble performing that action in a realistic way because she'd have to pull her eyebrows up and her lip corners down in the right order and fast enough."

Most other methods of facial



Jeffrey Cohn

These images from the Automated Face Analysis Program show how the program tracks the movement of muscles around the mouth and eyes when the subject is registering sadness, fear and disgust.

expression analysis focus on prototypes of a few basic expressions such as anger, joy, disgust, fear, sadness, surprise and so forth.

"But people very rarely show these peak expressions," Cohn said. "There are probably thousands of

common expressions. So Automated Face Analysis examines components of expressions — a furrowed brow, widened eyes, tightened lips. We can [recognize] extreme expressions and subtle expressions."

Automated Face Analysis breaks

components of facial analysis down into AUs, or action units, the smallest unit of change in an expression. How big is an AU?

"Think of Clint Eastwood giving someone a dirty look by narrowing his eyes by tightening his lower

eyelids," Cohn said. "That's an AU-7."

AUs give researchers a much larger vocabulary to describe expressions.

"If we only have the terms for basic expressions, then [researchers] have an inadequate vocabulary to describe expression."

So, instead of saying someone looks happy, which may be deceiving, researchers might say she is displaying an AU-6 + 12 or an AU-6 + 12 + 20, types of smiles.

Other methods of facial analysis also use photos of people looking straight ahead and not moving. But in reality, you may close your eyes and shake your head.

Cohn turns back to the computer and calls up a series of photos of an apple-cheeked baby that start with the glimmer of a smile and move into a full-blown beaming smile that would elicit "ooohs."

As the baby's smile progresses, he throws his head back and to the right. This computer program can account for that as part of the expression.

And babies' expressions are always spontaneous.



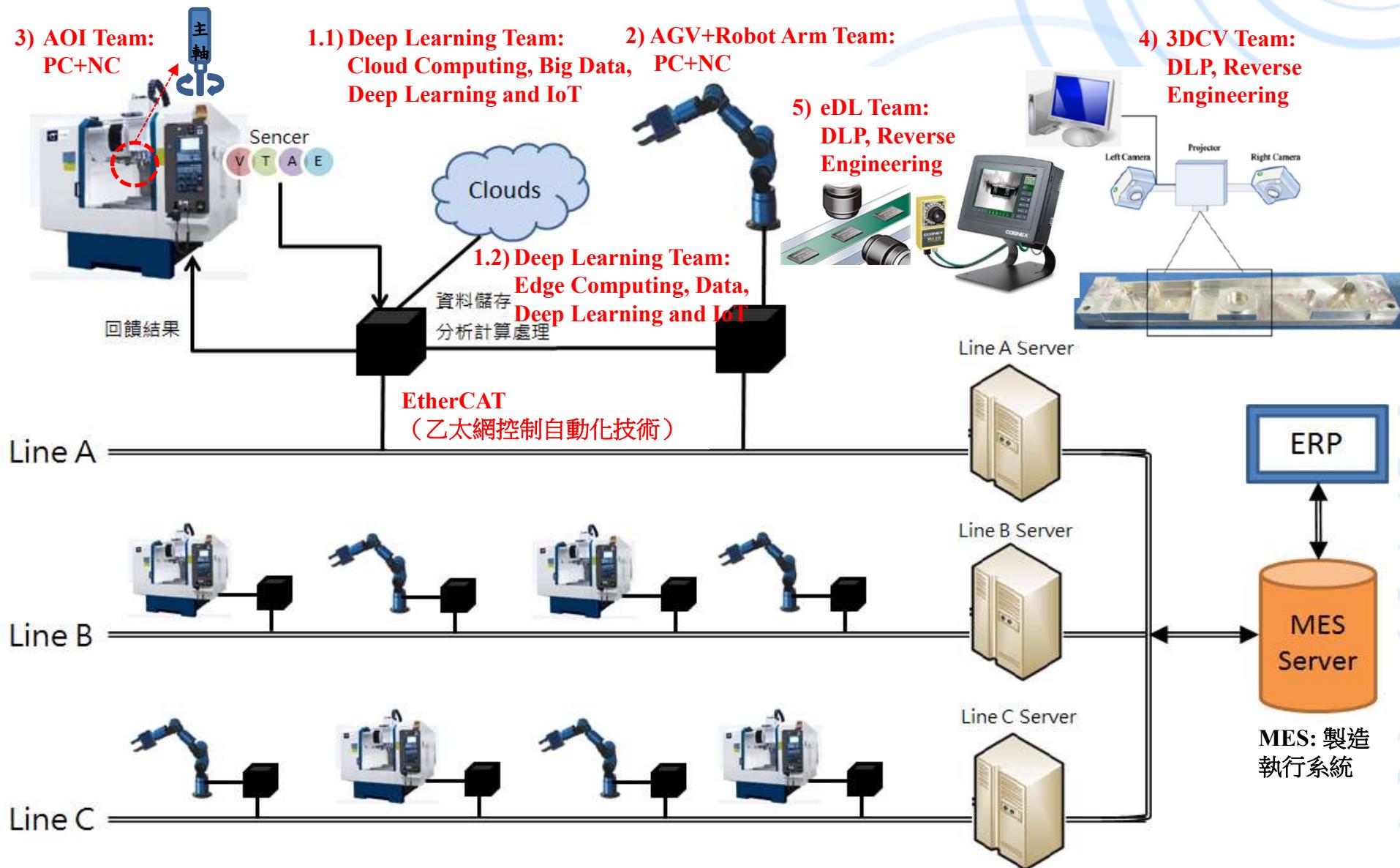
## R.2 Robotics Lab. at NCKU: 2002~

(1/2)

- 約24名研究生 + 4名大學專題生
- 2014 研究組別：AI智慧製造、AI半導體、AI醫材
  - 1. 深度學習組  
(Deep Learning Team)
  - 2. 自走車 + 機械手臂組  
(AGV + Robot Arm Team,  
Automatic Guided Vehicle + Visual-Guided Robot)
  - 3. 自動光學檢測組  
(AOI Team,  
Automatic Optical Inspection)
  - 4. 3D電腦視覺組  
(3D Sensor and CV Team,  
3D Sensor and Computer Vision)
  - 5. 嵌入式深度學習組  
(eDL Team,  
Embedded Deep Learning)
  - 6. 生物醫學工程組  
(BME Team,  
Biomedical Engineering)



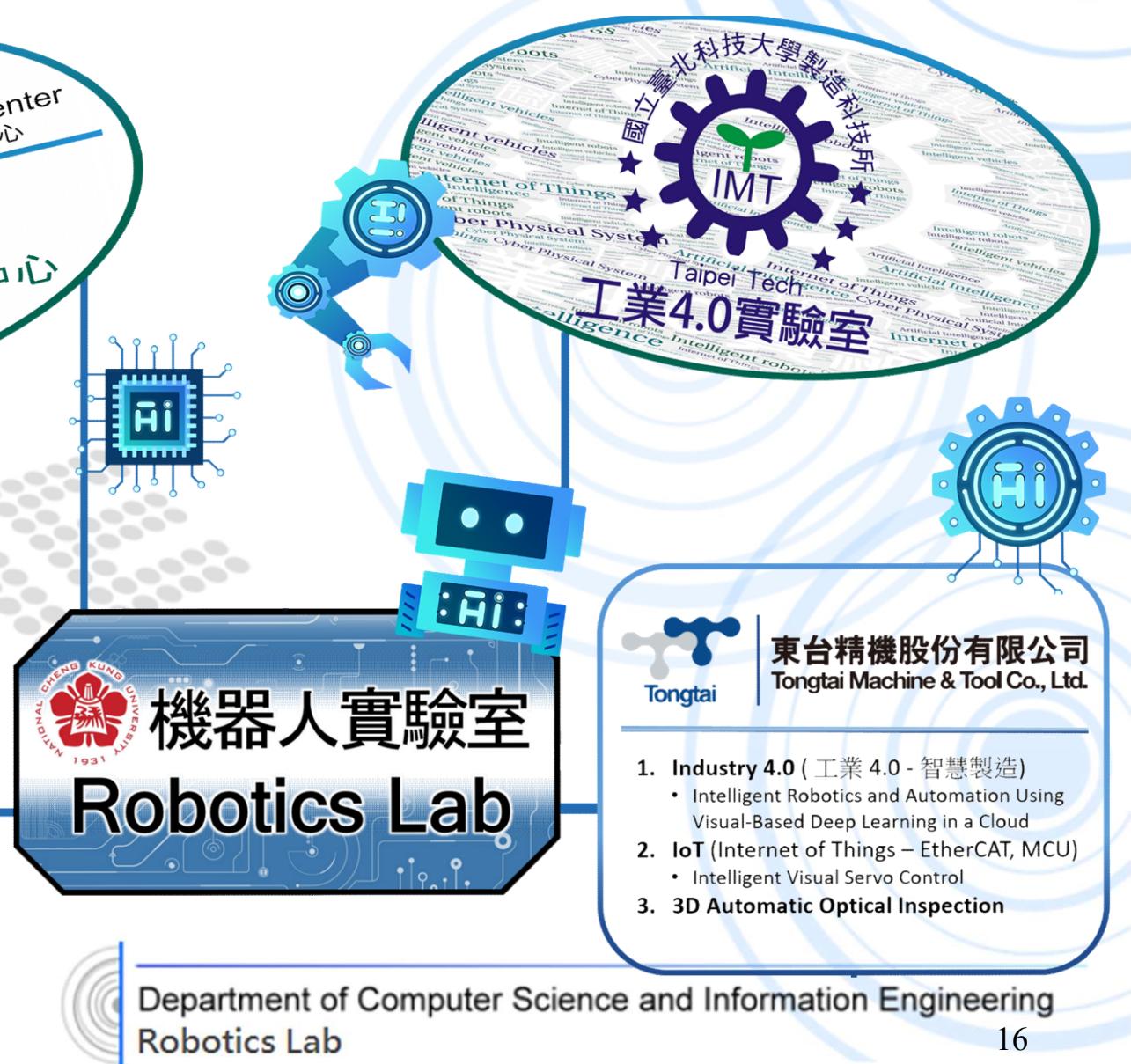
## R.2 Relationship between Teams



## R.2 Robotics Lab. at NCKU: 2002~

(2/2)

□ 2014 合作夥伴與領域：AI智慧製造、AI半導體、AI醫材



# 1.0 History: Computer Vision and Deep Learning

## **1. Industrial Revolution:**

3)1969, Industry 3.0:

Computing and Automation

4)2013, Industry 4.0:

Smart Manufacturing

1)1981, 生產力1.0：程式化

2)1991, 生產力2.0：整線化

3)2001, 生產力3.0：電子化

4)2011, 生產力4.0：智慧化

1990

2000

2010

2020

## **2. OpenCV: Image Processing, Computer Vision, Machine Learning, and Deep Learning**

0)1999, [OpenCV 0.0 Started](#)

1)2007, [OpenCV 1.0: IP+CV](#)

3)2016, [OpenCV 3.0: IP+CV+ML](#)

2)2009, [OpenCV 2.0: IP+CV](#)

4)201x, [OpenCV 4.0: IP+CV+ML+DL?](#)

1)1999, OpenCV Supported by Intel

2)2010, OpenCV Supported by Nvidia

3)2011, OpenCV Supported by Google

## **3. Deep Learning:**

1)1989, LeCun tPami1989

2)1998, LeNet IEEE1998

3)2012, AlexNet NIPS2012

## **4. Robotics Lab.: Computer Vision and Machine Learning – 1991 ~ 2013**

1)1993, Facial Expression Recognition at CMU, USA + DARPA Surveillance (VSAM) Project

2)1999, Face Detection and Recognition Using Stereo at Visionics, USA + DARPA Project

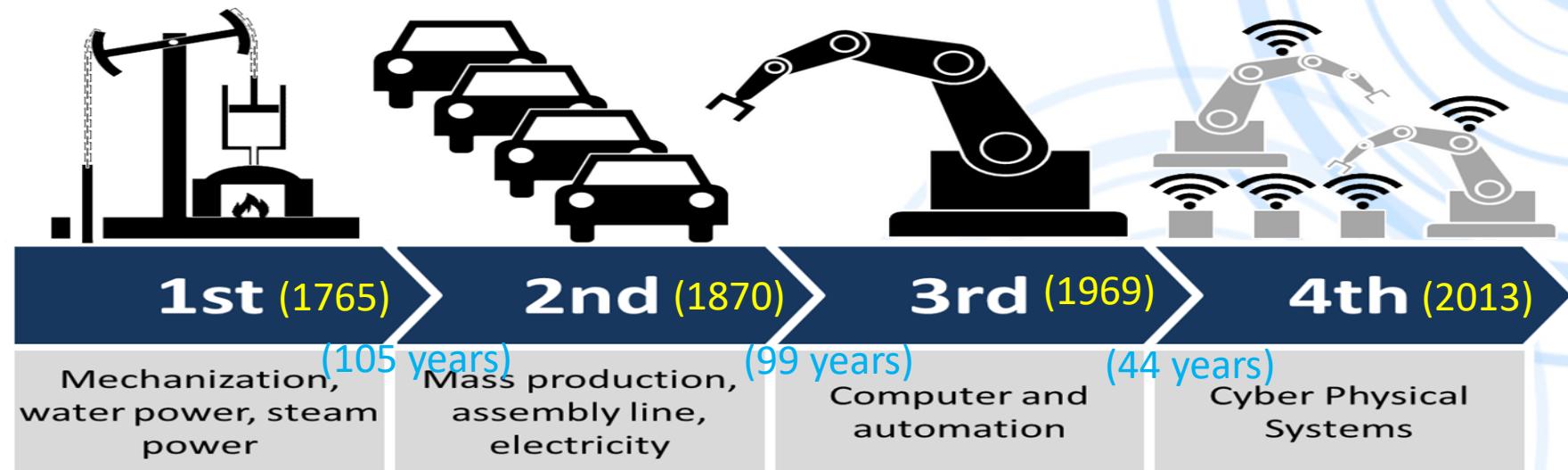
3)2004, Automatic Optical Inspection (AOI System Integration):  
TFT-LCD with 奇美、友達 + Solar Cell with 益通

、

4)2009, eCV Surveillance + ADAS with 美國德儀  
(TI DSP), 智原(ASIC) + Stereo Sensor with 鈺創 +  
Fmbedded AOI with 研華

## **5. Robotics Lab.: Computer Vision and Deep Learning - Since 2014: AI智慧製造+AI半導體+AI醫材**

# 1.1 Industrial Revolution 1.0~4.0: History



工業1.0(18世紀末)  
機械化生產

商業周刊



工業3.0(20世紀中)  
資訊化、自動化



工業2.0(19世紀末)  
電力帶動大量生產



Industrial Revolution 4.0 (2013年德國提出):  
智慧製造

# 1.1 Industrial Revolution 1.0~4.0: Industry 4.0 in 2013

## □ Industry 4.0 – Smart Manufacturing:

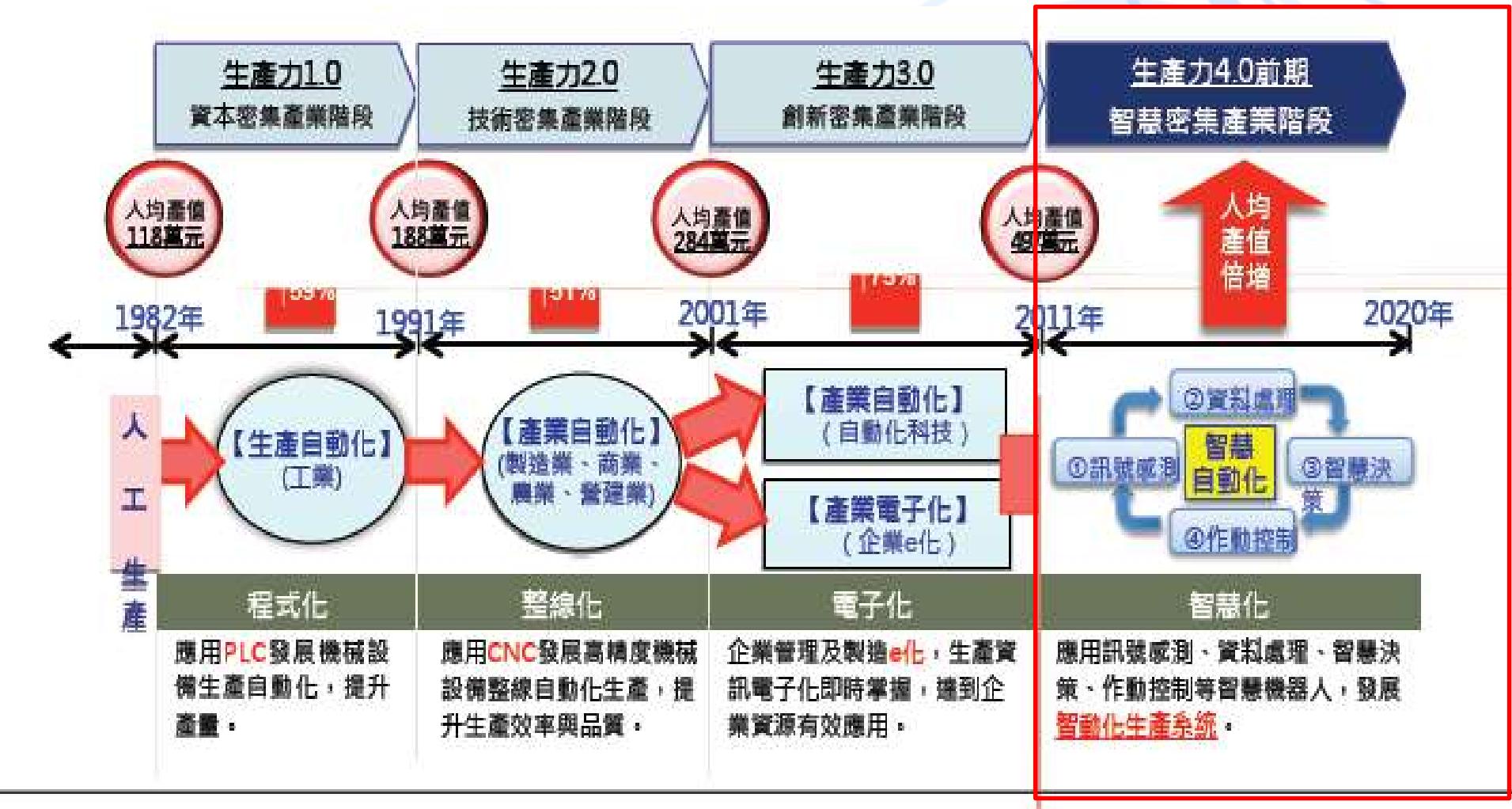
- To connect all means of production to enable their **interaction in real-time**

## □ Technology consists of:

- 1) Cloud
- 2) Big Data Analysis
- 3) Industrial Internet of Things (IoT) : 5G + 3D (RGB-D)
- 4) Cyber Physical System (CPS, 網絡實體系統, 人機物融合系統)
  - (1) Computing (algorithm),
  - (2) Sensor
  - (3) Actuator (controller)



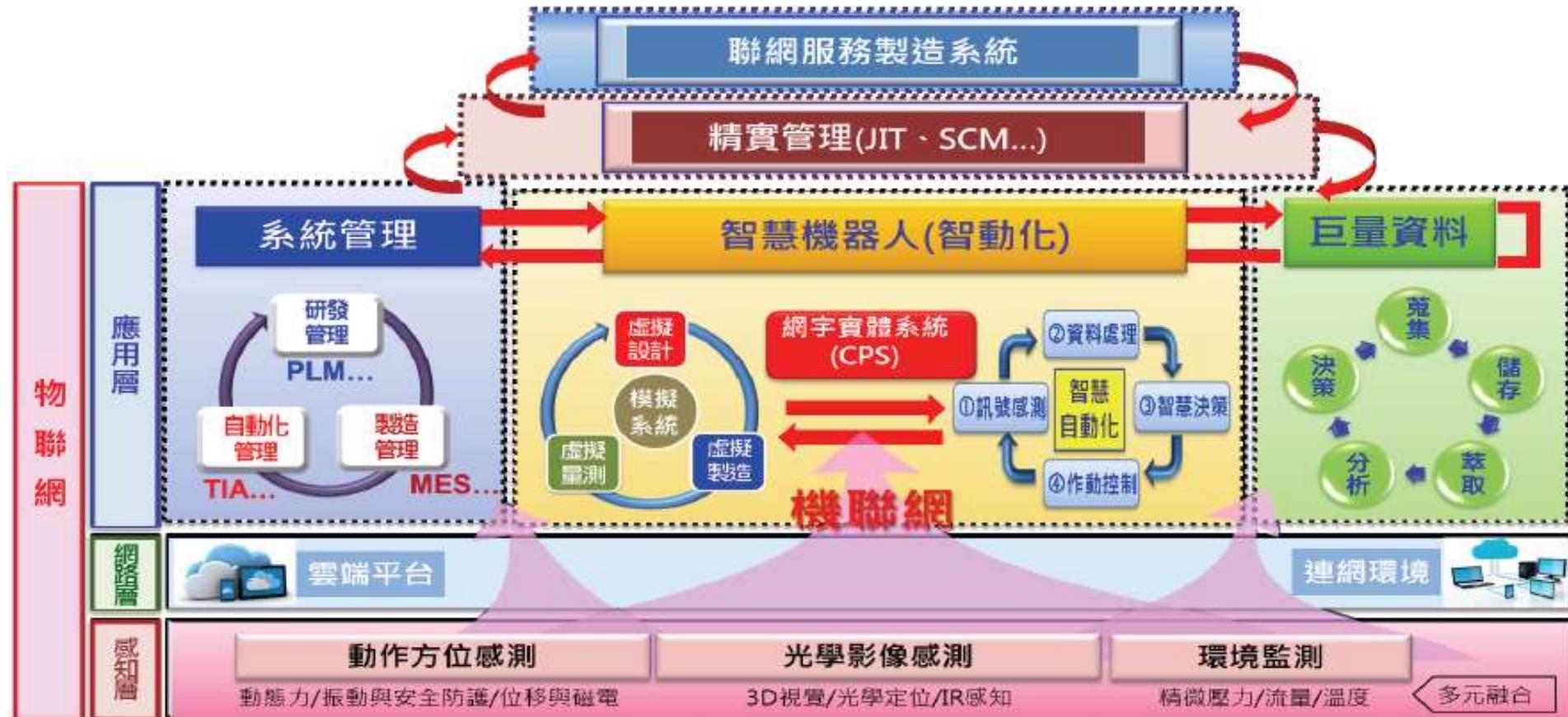
# 1.2 生產力 4.0: IoT (Internet of Things) and Automation – History



# 1.2 生產力 4.0: IoT (Internet of Things) and Automation

## 台灣競爭力優勢分析(生產力4.0系統架構)

– 透過物聯網將生產資訊數位化，並延伸至機器端形成機聯網，再藉由系統管理、巨量資料(製造+服務)技術、以及精實管理，達成聯網服務製造系統之創新營運模式。



備註：1.JIT(Just In Time)；SCM(Supply Chain Management )

2.PLM (Product Lifecycle Management)；MES (Manufacturing Execution System)；TIA (Totally Integrated Automation) 21

# 2.0 History: Computer Vision and Deep Learning

## 1. Industrial Revolution:

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4)2013, Industry 4.0:  
Smart Manufacturing

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2020

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2)1998, LeNet IEEE1998

3)2012, AlexNet NIPS2012

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1)1993, Facial Expression Recognition at CMU, USA

2)1999, Face Detection and Recognition at a Distance Using Stereo at Visionics, USA  
3)2004, Automatic Optical Inspection (AOI System Integration): TFT-LCD, Solar Cell...

4)2009, eCV Surveillance with TI & Faraday

## 5. Robotics Lab.: Computer Vision and Deep Learning - Since 2014: AI智慧製造+AI半導體+AI醫材

# 2.0.0 Computer Vision and Deep Learning – Basic Courses and Books

- **Undergraduate:**
  - **Linear Algebra**
  - **Introduction to Probability and Stochastic**
  - **Signals and Systems**
    - Alan V. Oppenheim and Alan S. Willsky, *Signals and Systems*, 2<sup>nd</sup>, 1996.
- **Graduate**
  - **Probability and Stochastic**
  - **Digital Signal Processing**
    - A.V. Oppenheim, R.W. Schafer, and J.R. Buck, *Discrete-Time Signal Processing*, Prentice Hall, 2<sup>nd</sup>, 1999. ISBN: 0137549202.
  - **Digital Image Processing**
    - R.C. Gonzalez and R.E. Woods, *Digital Image Processing*, Prentice Hall, 3rd, 2007. ISBN: 013168728X.
  - **OpenCV**
    - G. Bradski and A. Kaehler, *Learning OpenCV, Computer Vision with the OpenCV Library*, O'Reilly, 2008. ISBN-10: 0596516134 or ISBN-13: 978-0596516130.
  - **Computer Vision**
    - R. Szeliski, *Computer Vision: Algorithms and Applications*, Springer, 2010. ISBN-10: 1848829345 or ISBN-13: 978-1848829343.
    - R. Hartley and A. Zisserman, *Multiple View Geometry in Computer Vision*, Cambridge University Press, 2nd, 2004. ISBN: 0521540518.
  - **Machine Learning and Pattern Recognition**
    - C.M. Bishop, *Machine Learning and Pattern Recognition*, Springer, 2007. ISBN: 0387310738.
  - **Deep Learning**
    - I. Goodfellow, Y. Bengio and A. Courville, *Deep Learning*, MIT, 2016. ISBN: 0262035618

# 2.0.0 Computer Vision and Deep Learning – Relative Conferences and Journals

## □ Conference – CV and Deep Learning:

- **CVPR:** Computer Vision and Pattern Recognition
- **ICCV:** International Conference on Computer Vision
- **ECCV:** European Conference on Computer Vision
- **ACCV:** Asian Conference on Computer Vision
  
- **NeurIPS:** Advances in Neural Information Processing Systems
- **ICML:** International Conference on Machine Learning
- **arXiv**
  
- ICME:
- ICPR:
- ICIP:
  
- eCVW: Embedded Computer Vision Workshop

## □ Conferences - Robot:

- **IROS:** IEEE International Conference on Intelligent Robots and Systems
- **ICRA:** International conf. on Robotics and Automation
- **SMC:** IEEE International Conference on Systems, Man, and Cybernetics

## □ Journal – CV and Deep Learning:

- **IJCV:** International Journal on Computer Vision
- **IEEE tPAMI:**
- **Image and Vision Computing**
  
- **IEEE tVisualization and Computer Graphics**
- **SIGGRAPH:**
  
- **Pattern Recognition**
- **IEEE tIP**
- **IEEE tCSVT**
- **IEEE tMM**

## □ Journal – Robot:

- **IEEE tRobotics and Automation**

# 2.0.0 Computer Vision and Deep Learning - Functions

## Visual Servo Control:

Robotics / Automatic Optical Inspection (AOI)

2D/3D Sensor (Optics) + Vision + Control +  
Mechanics + Power

Computer Vision: From Theory  
to Application, 2002,  
Jenn-Jier James Lien

TEXTS IN COMPUTER SCIENCE

Computer Vision

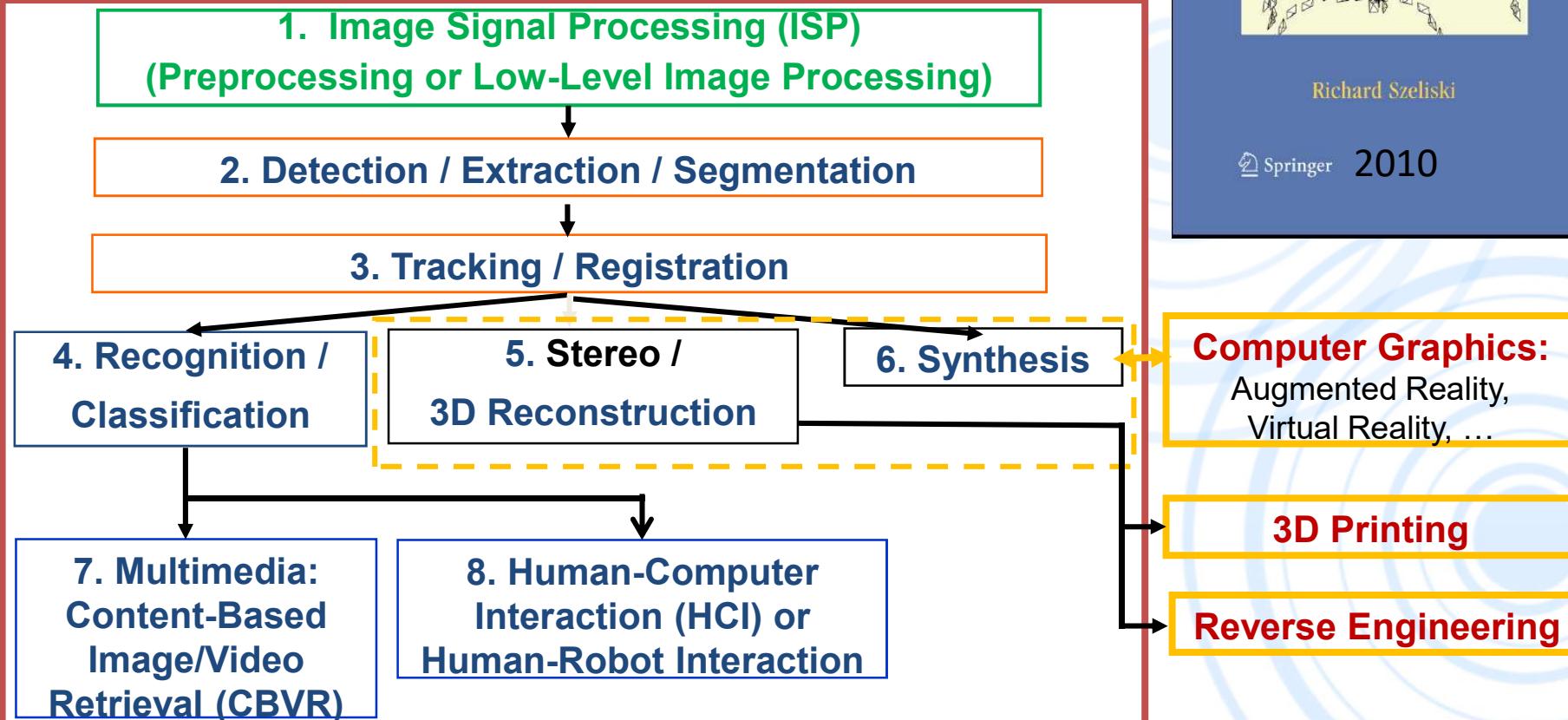
Algorithms and Applications



Richard Szeliski

Springer 2010

## Computer Vision and Pattern Recognition / Deep Learning



ISP (Image Signal Processing):  
Embedded IVA (Intelligent Video Analytics):

Function Block 1

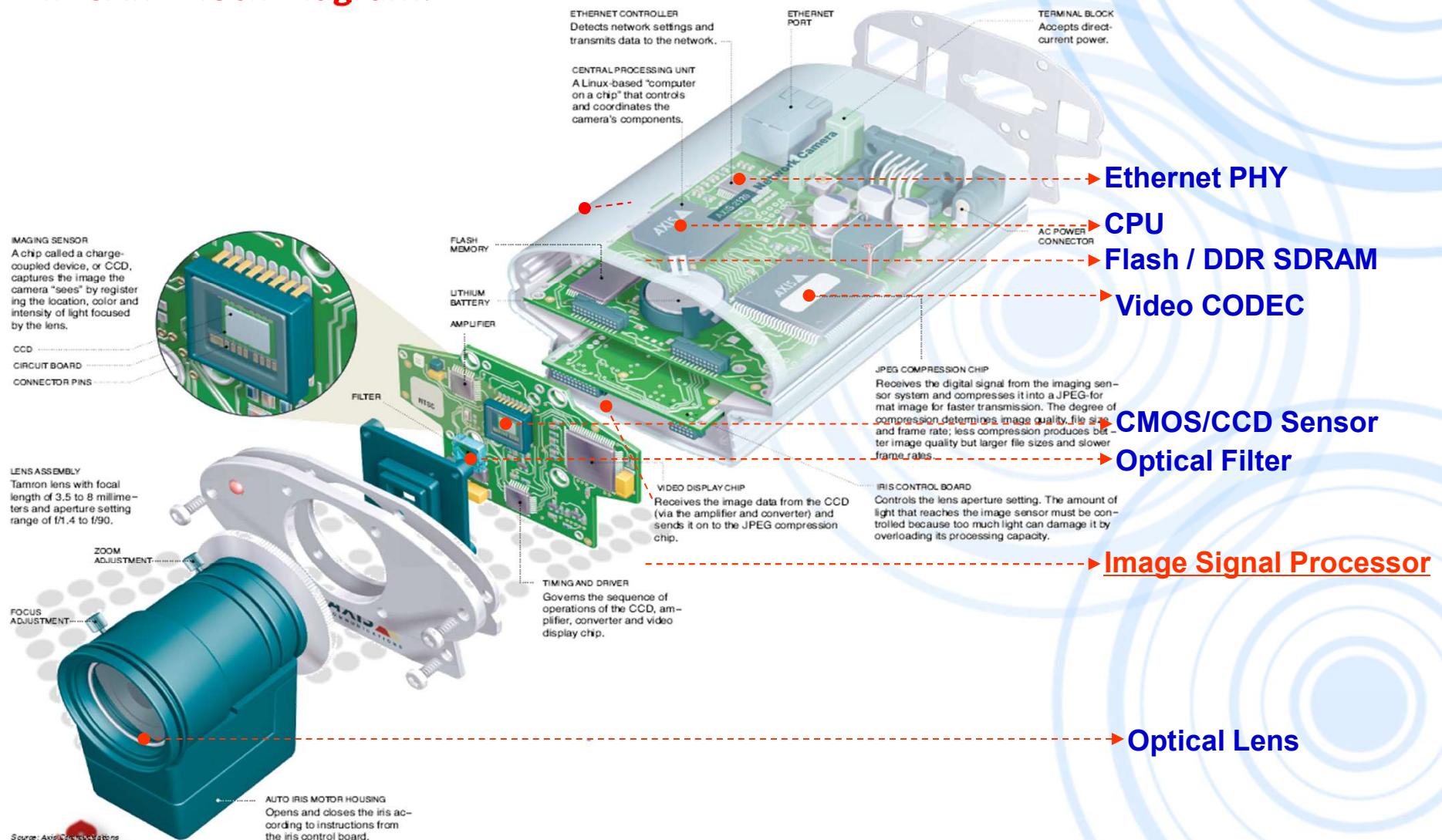
Function Blocks 2~7

ARM: Function Blocks 1~3

DSP: Function Blocks 3~7

## 2.0.1 Image Signal Processing (ISP): Sensor – IP Camera (1/2)

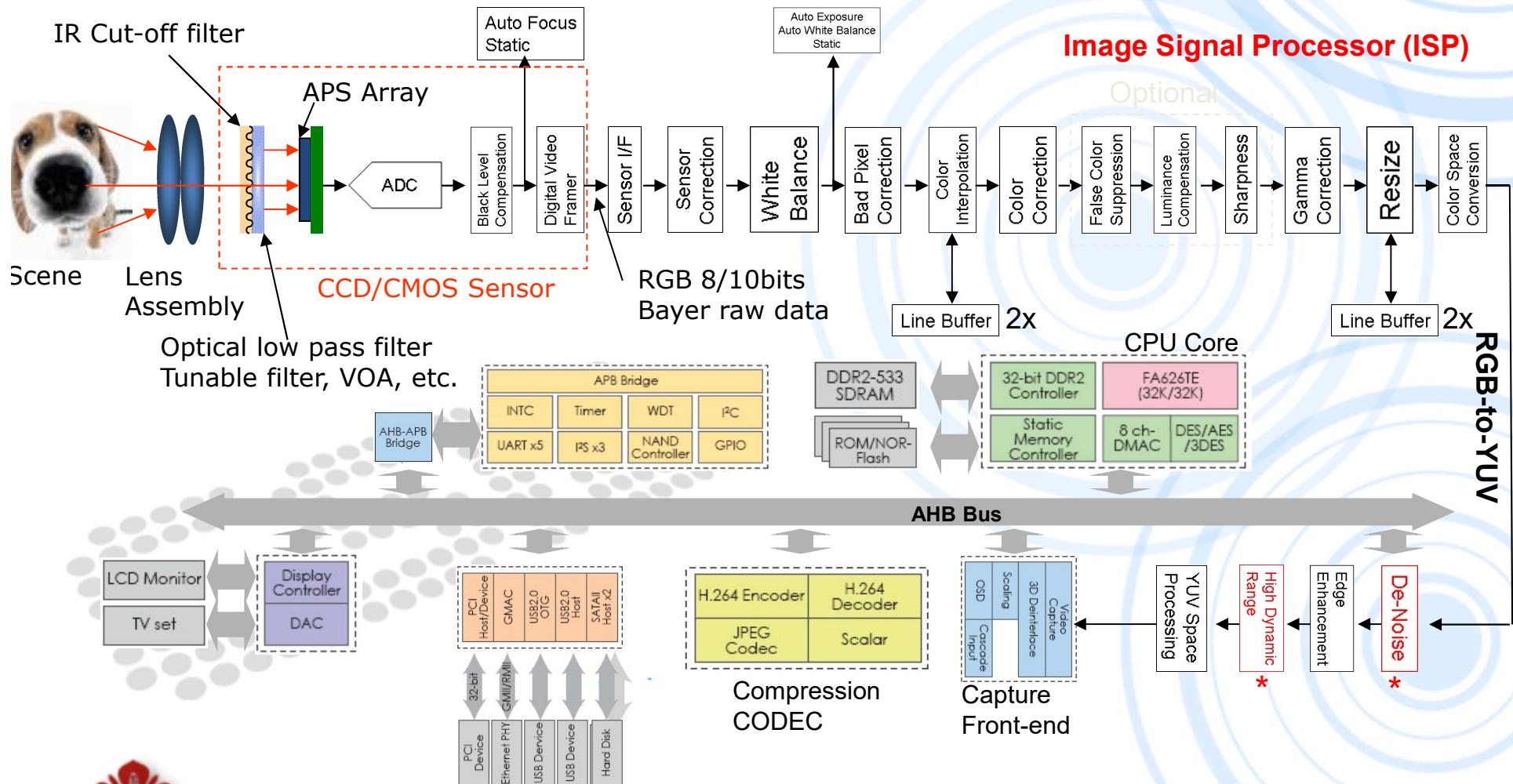
### □ IP CAM Block Diagram:



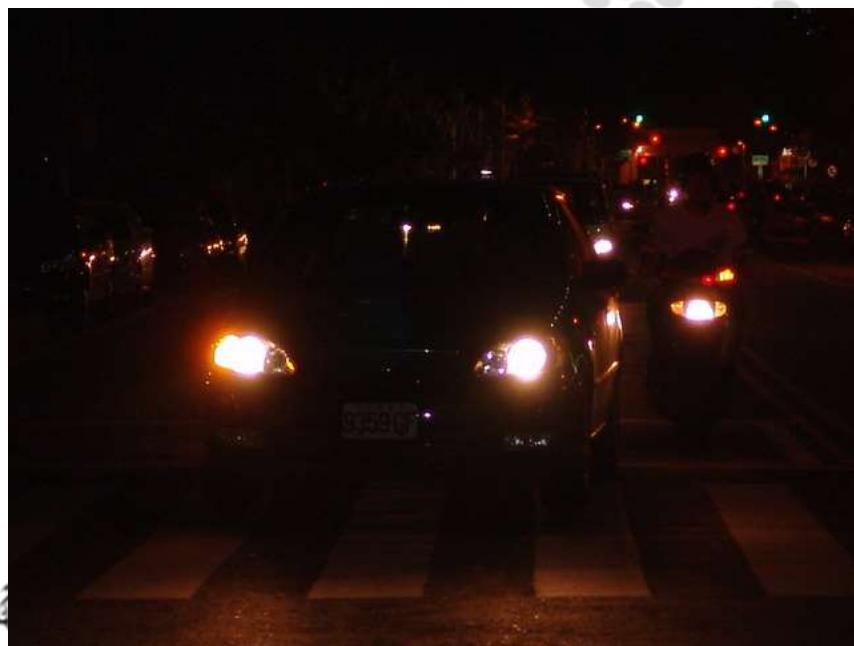
Source: Axis Communications  
國立成功大學

## 2.0.1 Image Signal Processing (ISP): Sensor – IP Camera (2/2)

### IP CAM Function Block Diagram:



## 2.0.1 ISP: High Dynamic Range (HDR)



## 2.0.1 ISP: Stabilization – Fixed Scene Vs. Panning Scene

1)  
Fixed  
Scene  
Stabilization



2)  
Panning  
Scene  
Stabilization



## 2.0.1 ISP: Panorama



## 2.0.2 Face Detection Using AdaBoost Under Various Views

### □ Face detection – Pose estimation



## 2.0.2 Point Detection and Tracking: Shape Extraction Using DCM (Direct Combined Model)

- From Lucas-Kanade optical flow to ASM/AAM to DCM



## 2.0.2 Feature Extraction and Tracking: SIFT



## 2.0.2 Feature Extraction: SIFT - Image Retrieval



change in viewing angle  
+ scale change



• • •  
> 5000  
images



## 2.0.2 Point Tracking and Synthesis:

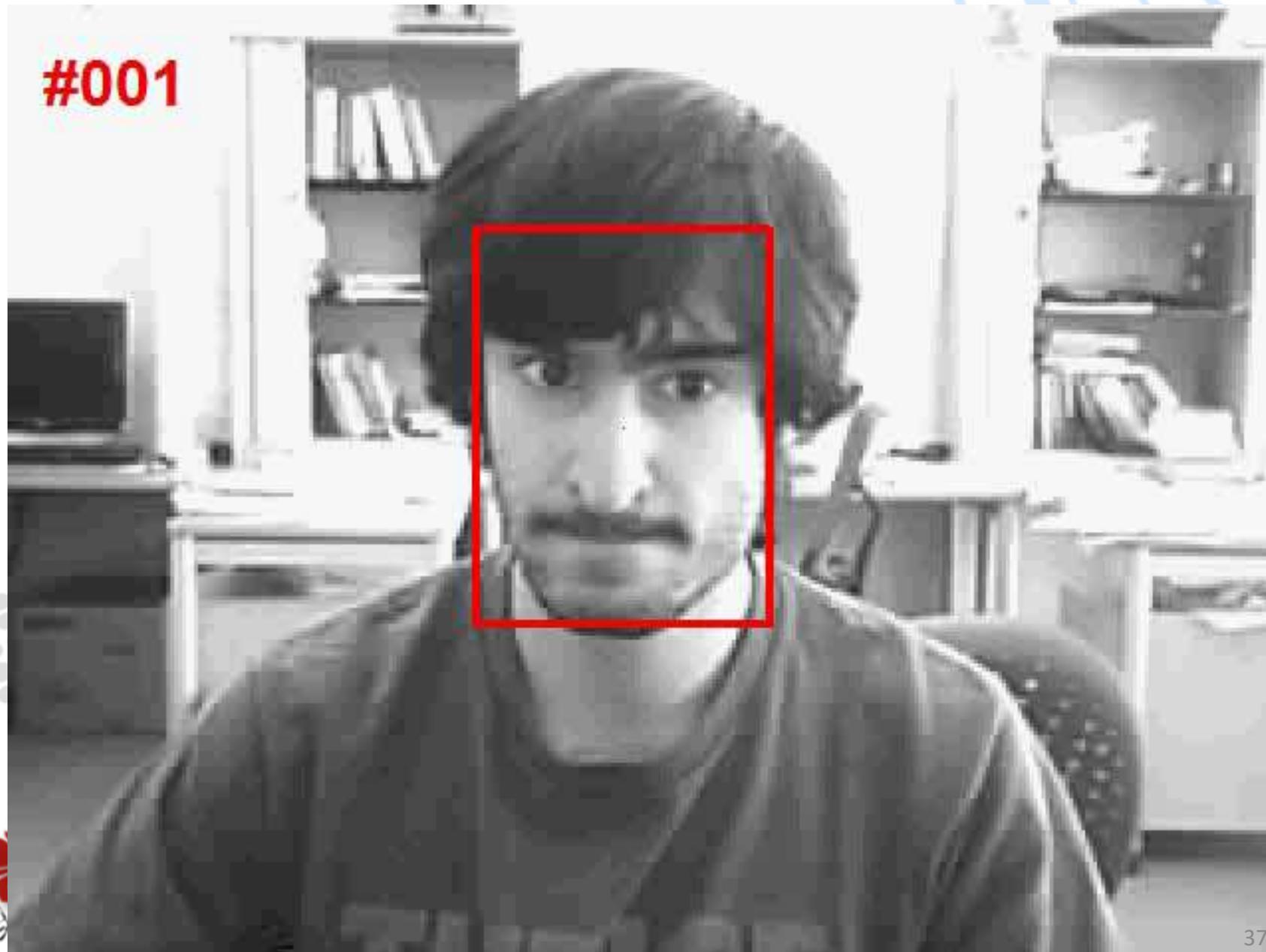


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Robotics Lab

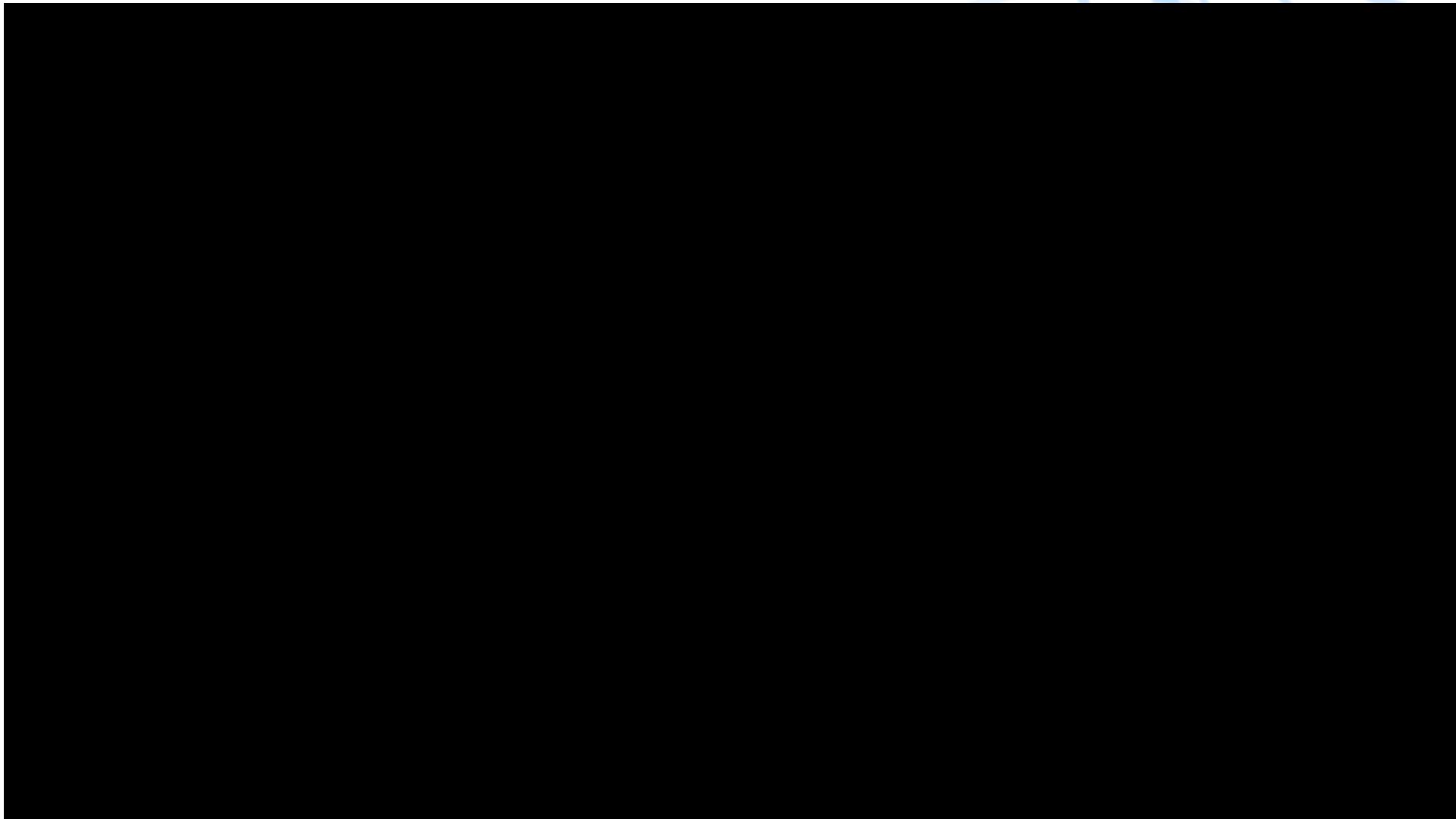
## 2.0.3 Tracking: Moving Vehicle



## 2.0.3 Tracking: Occlusion



## 2.0.3 Feature Tracking and Panorama: Slow Motion in Sports

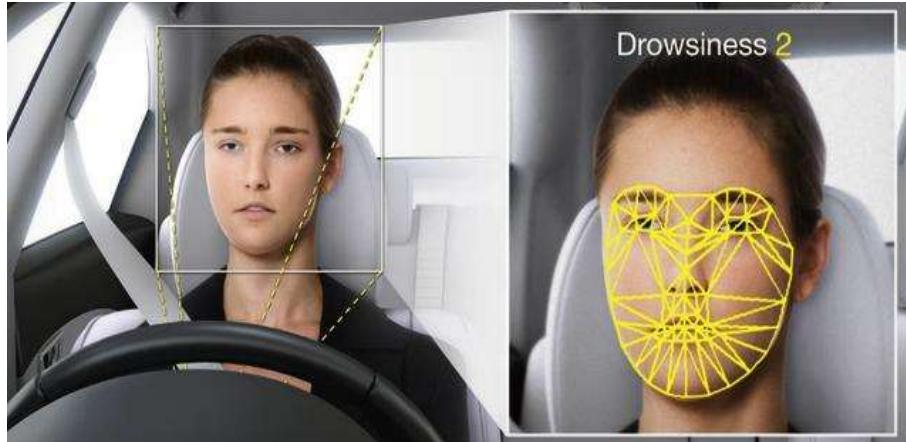


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Robotics Lab

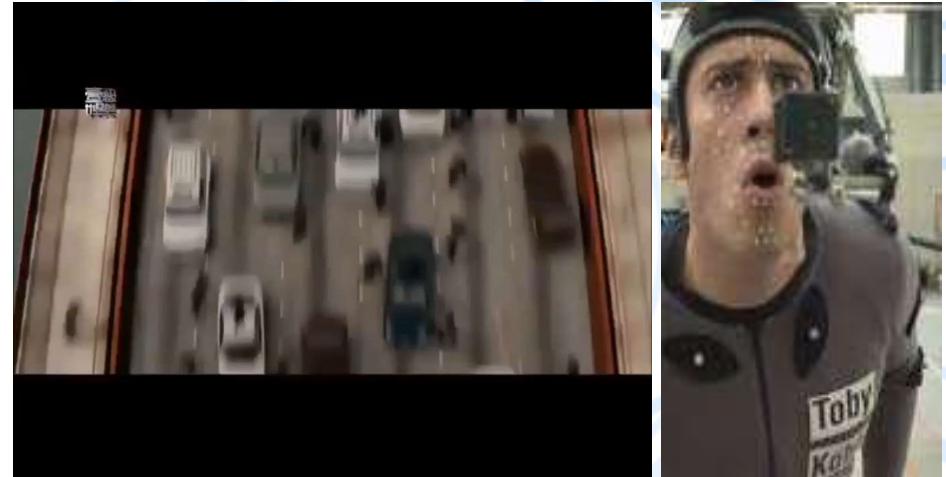
## 2.0.3 Point Tracking and AR: Feature Points and Mesh

- Technology: Facial Feature Point Detection and Tracking

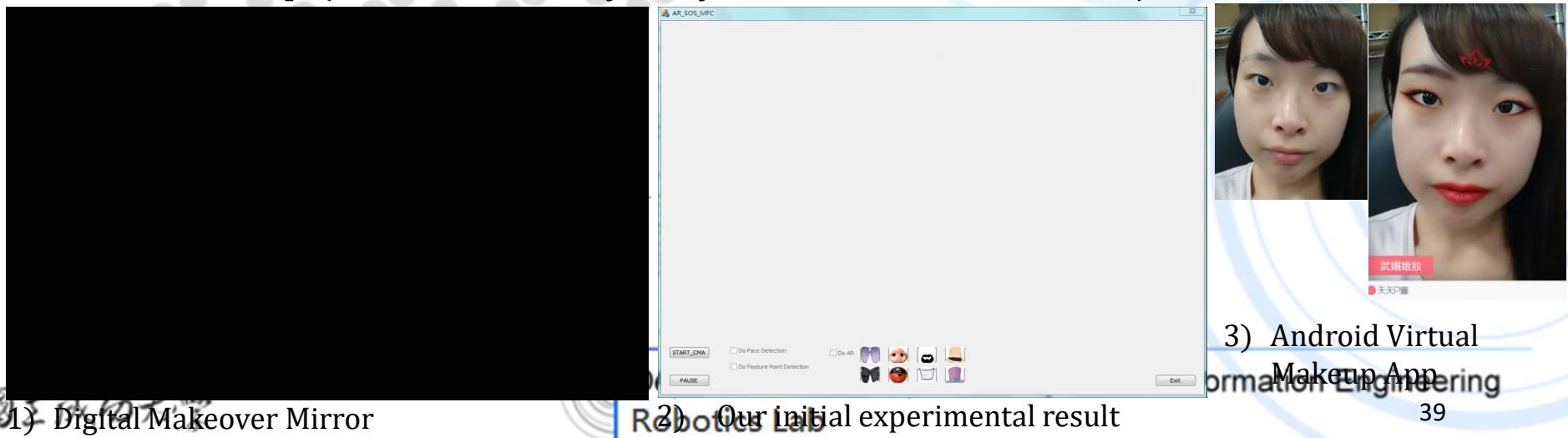
### 1. Drowsy Driving Awareness System (Eye and Mouth)



### 2. Animation of Movie Virtual Effects (Facial contour, eyes, eyebrows, mouth and nose)



### 3. Virtual Makeup (Facial contour, eyes, eyebrows, mouth and nose)

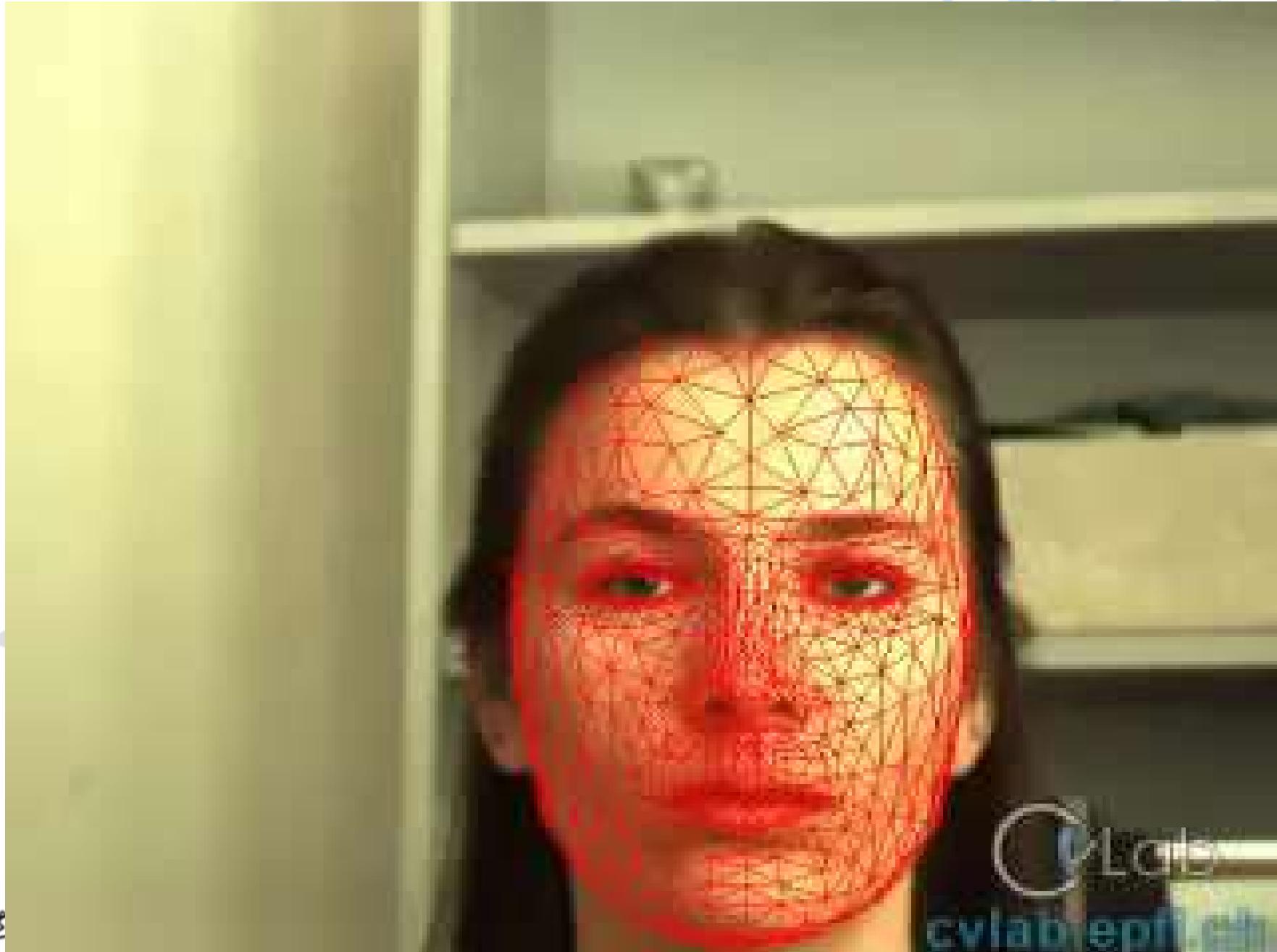


1) Digital Makeover Mirror

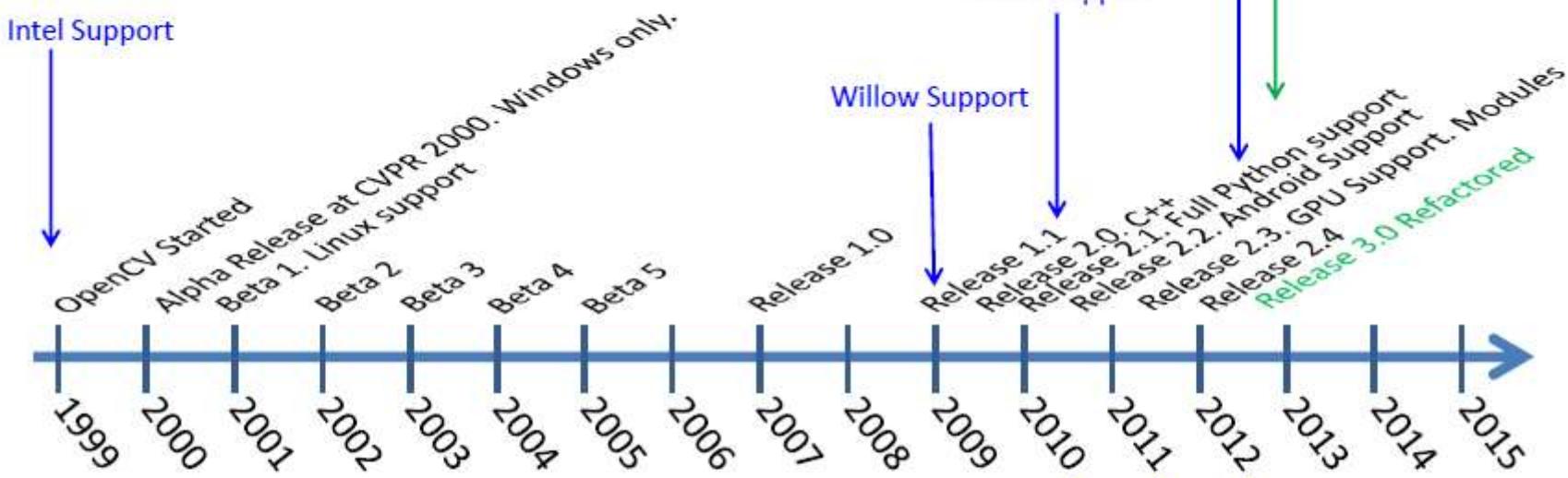
2) Our initial experimental result

3) Android Virtual  
Makeup App

## 2.0.3 Point Tracking and AR: Feature Points and Mesh



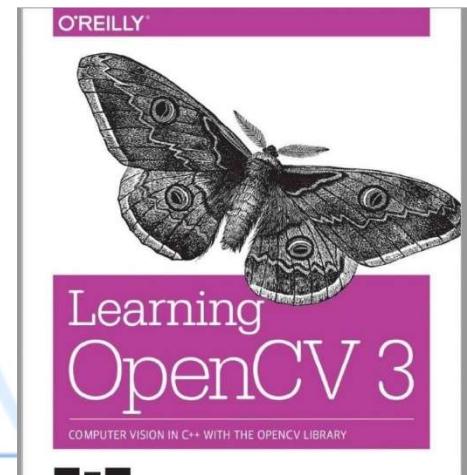
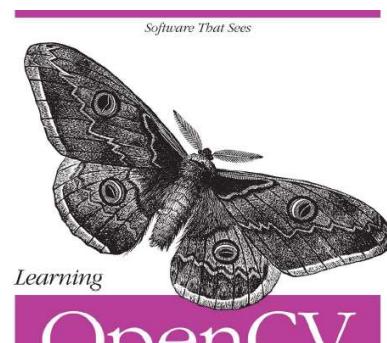
## 2.1 OpenCV: History and Books



Main Current Sponsors:



Google Summer of Code



OpenCV Books V2 in 2008 and V3 in 2016  
by Adrian Kaehler & Gary Bradski





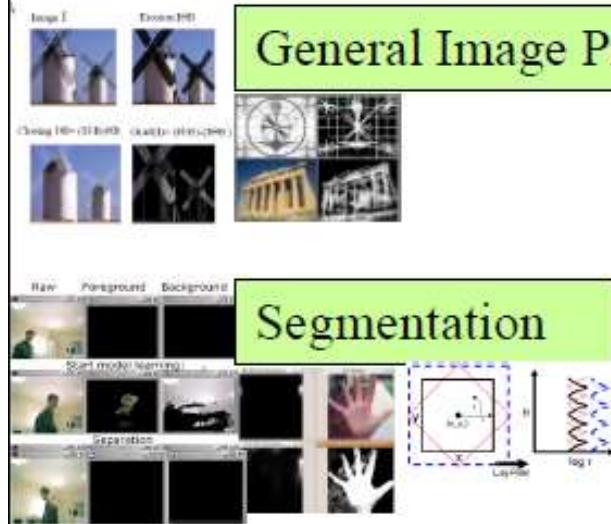
OpenCV

Developer <http://code.opencv.org>; User: <http://opencv.org>

&gt; 2500 algorithms

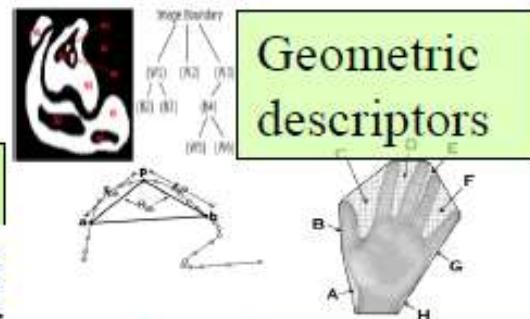


## 2.2 OpenCV Functions:

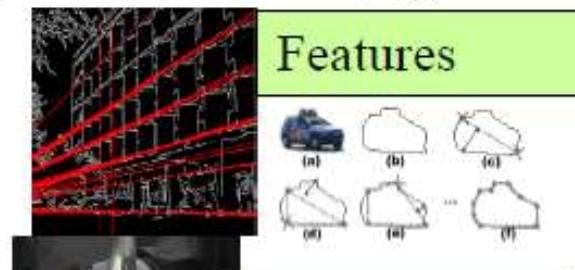


### Segmentation

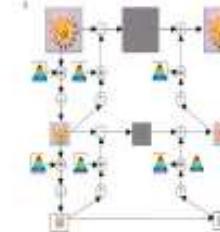
### General Image Processing Functions



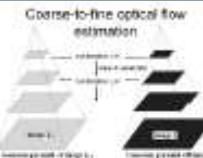
### Geometric descriptors



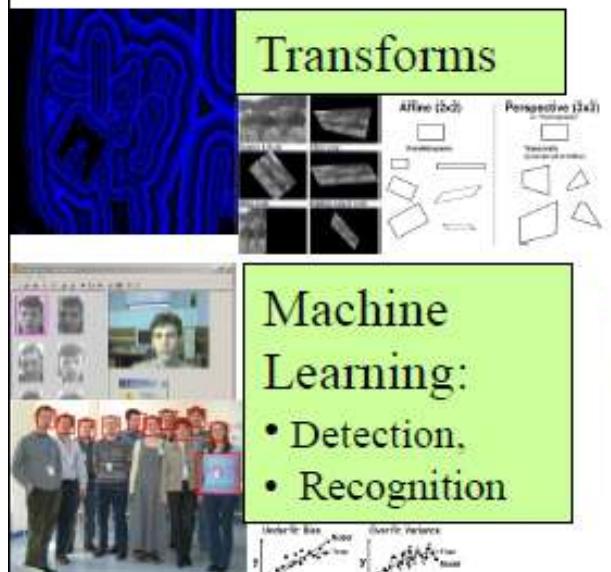
### Features



### Image Pyramids



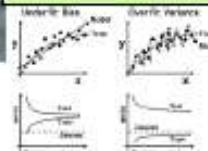
### Camera calibration, Stereo, 3D



### Transforms

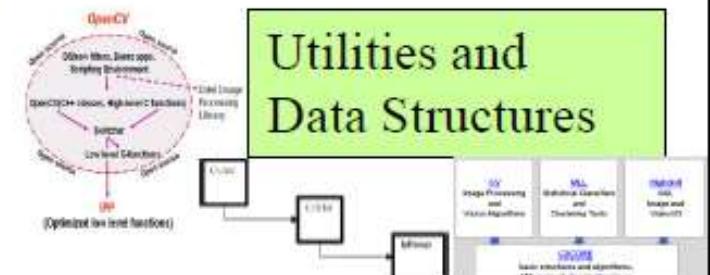
### Machine Learning:

- Detection,
- Recognition

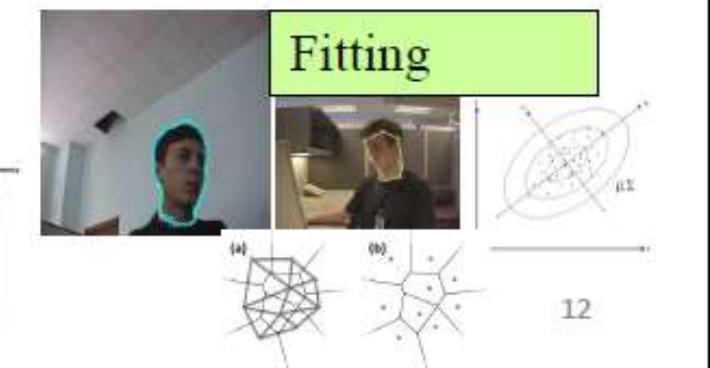


### Matrix Math

Gary Bradski



### Utilities and Data Structures



### Fitting

## 2.3 OpenCV Environments & Platforms, and Architecture & Development

### □ Environment & Platforms

#### ➤ Languages:

- C, C++, C#, Java, Python, Matlab

#### ➤ Platform:

- GPU/Cuda, Android, iOS,



Languages:  
C  
C++  
Python  
CUDA  
JAVA (plans)

3<sup>rd</sup> party libs:  
Eigen  
IPP  
Jasper  
JPEG, PNG  
OpenNI  
QT  
TBB  
VideoInput

Development:  
Maintainers  
Contributors

Modules:  
**Core**  
**ImgProc**  
**HighGUI**  
**GPU**  
ML  
ObjDetect  
Video  
Calib3D  
Features2D  
FLANN

Target archs:  
X86  
X64  
ARM  
CUDA

Technologies:  
CUDA  
SSE  
TBB

Target OS:  
Windows  
Linux  
Mac OS  
Android



QA:  
Buildbot  
Google Tests

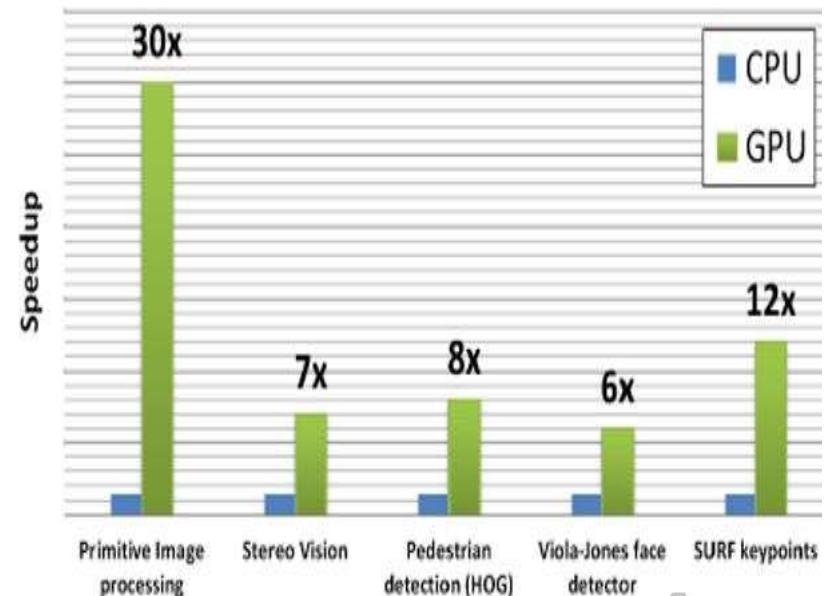
## 2.4 OpenCV GPU Module Performance

Tesla C2050 (Fermi) vs. Core i5-760  
2.8GHz (4 cores, TBB, SSE)

- Average speedup for primitives: **33x**
  - For “good” data (large images are better)
  - Without copying to GPU

What can you get from your computer?

- opencv\samples\gpu\perfomance



**INTRODUCING**  
**NVIDIA DRIVE™ PX**

AUTO-PILOT CAR COMPUTER

Dual Tegra X1 • 12 camera inputs • 1.3 GPix/sec

- 2.3 Teraflops mobile supercomputer
- CUDA programmability
- Deep Neural Network Computer Vision
- Surround Vision

The image shows the NVIDIA DRIVE PX hardware board, which is a green printed circuit board (PCB) featuring two central NVIDIA Tegra X1 SoCs. The board is densely populated with various electronic components, capacitors, and connectors. It has a black metal heat spreader covering the chips. On the right side, there's a black plastic component, likely a M.2 SSD or similar storage device, mounted on the board.

## 2.4 OpenCV GPU Module Performance: Embedded Module

1. [OpenVX](#):
2. [OpenMP](#) (Open Multi-Processing: Parallel Processing):
  - Multi-Cores CPUs, GPUs or DSPs
3. [OpenCL](#) (Open Computing Language):
  - Cross CPU + GPU + DSP + FPGA

- Khronos group - OpenVX:
  - Connecting software to silicon
  - OpenVX is an open, royalty-free standard for cross platform acceleration of computer vision applications.
  - It is designed by the Khronos Group to facilitate portable, optimized and power-efficient processing of methods for vision algorithms.
  - This is aimed for embedded and real-time programs within computer vision and related scenarios. It uses a connected graphics representation of operations.

• khronos 發表電腦視覺API 標準：[OpenVX](#)。在2011年的時候，Khronos 曾經發表過一個名為「Vision」的API 標準，希望可以為電腦視覺（Computer Vision）的處理、定義一套標準的介面，作為硬體加速的抽象層；當時，基本上只是剛開始的階段，並沒有完整的介面出來。2014年10月21日

### OpenVX (Khronos HAL)

