

電腦視覺與應用

Computer Vision and Applications

Lecture-01 Introduction

Tzung-Han Lin

National Taiwan University of Science and Technology
Graduate Institute of Color and Illumination Technology

e-mail: thl@mail.ntust.edu.tw





Course information(CI5336701):

- Computer Vision and Applications
- Place: IB-607
- Time: Mon. PM.9:10~12:10 (M2, M3, M4)

Instructor: 林宗翰 (Tzung-Han Lin)

- E-mail: thl@mail.ntust.edu.tw
- Office: IB1037 (10F)
- Web: <http://homepage.ntust.edu.tw/thl/>
- Office hour: Mon. 13:00~15:00 (regular), or by appointment.
- Ext: 3717. (phone: 0227303717)
- TA: 楊智 (Zhi Yang) email: d11022502@mail.ntust.edu.tw or zemptice@gmail.com



Course information(CS4805301):

- Practice of Computer Vision and Applications
- Place: TR616
- Time: Thu. PM.4:30~6:10 (R9, R10)

Instructor: 林宗翰 (Tzung-Han Lin)

- E-mail: thl@mail.ntust.edu.tw
- TA: 楊智 (Zhi Yang) email: d11022502@mail.ntust.edu.tw or zemtice@gmail.com



首頁 【林宗翰個人網頁】位置：首頁

- 網站功能導覽
- [首頁/Home](#)
- [成員/Member](#)
- [成果/Achievement](#)
- 連結/Link
- [實驗室動態/Latest](#)
- [實驗室網頁/Lab page](#)
- [色彩所臉書/Facebook](#)
- [色彩所網頁/Homepage](#)

((((歡迎您的光臨)))
您是第29949位訪客！



姓名：林宗翰 (Tzunghan Lin)
系所：色彩與照明科技研究所
職稱：教授
個人辦公室：IB1037 (國際大樓十樓)
研究實驗室：[Color Imaging 3D Lab](#)
電子郵件：thl@mail.ntust.edu.tw
聯絡電話：(02)2730-3717

學歷：
[國立台灣大學 機械工程學博士](#)

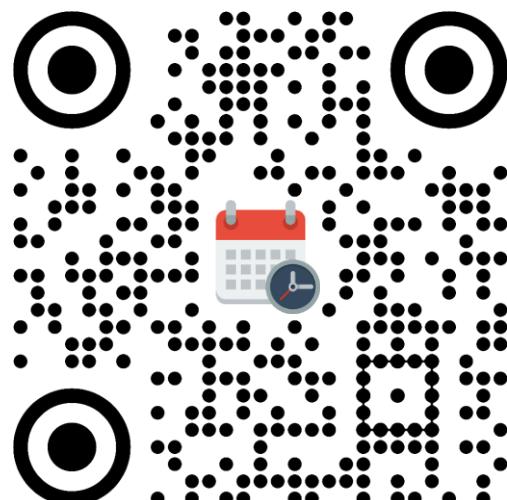
經歷：
臺灣科技大學 色彩與照明科技研究所(教授), 2020.8.~
臺灣科技大學 色彩與照明科技研究所(副教授), 2015.8~2020.7.
臺灣科技大學 色彩與照明科技研究所(助理教授), 2011.8~2015.7.
鈺創科技(顧問) 2014, 2015.
工業技術研究院(ITRI) 電子與光電研究所(EOL)(工程師/資深工程師) 2007.1~2011.7.
[Carnegie Mellon University, Pittsburgh, USA](#) (Visiting Scholar) 2007, 2008.

教授課程：
[授課內容/Regular Lectures](#)

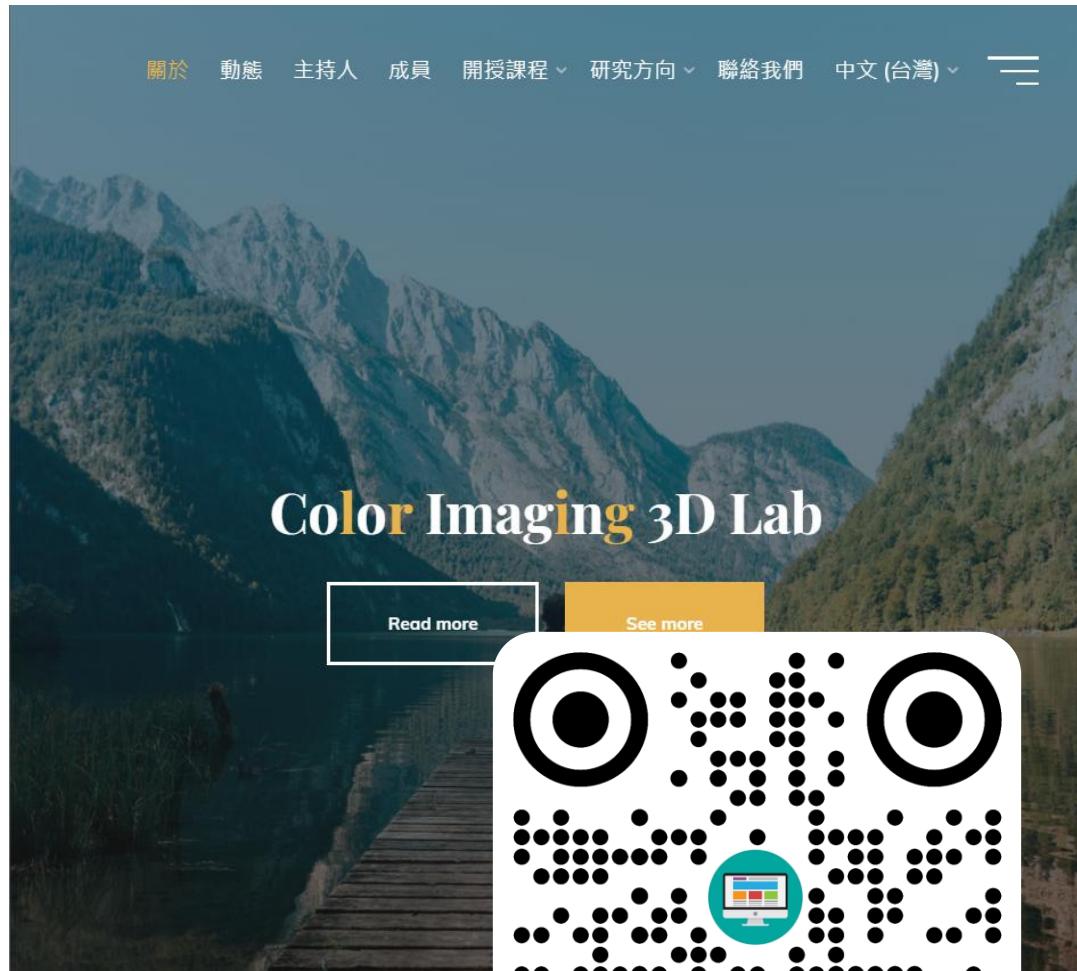
研究領域：
[研究內容/Research Works](#)

- 我的行事曆(My schedule, UTC+8)

Today		Mon	Tue	Wed	Thu
Feb 1		2	3		
2pm busy	5pm busy	6am busy 2pm busy 5:30pm busy			
8	9	4pm busy	10		



Homepage

<http://homepage.ntust.edu.tw/thl/><http://ci3d.ntust.edu.tw>

Lab Page



Course outline

This course will discuss about the principle and technology of “Computer Vision” research field. Applications on Stereo / Multi-views / Augmented Reality are also revealed, and this course outline includes,

1. Pinhole camera,
2. Projective 2D geometry,
3. Camera Models,
4. Projective 3D geometry,
5. Camera Calibration,
6. Epipolar geometry,
7. Multiview and 3D reconstruction,
8. Applications on stereo vision,
9. Applications on augmented reality.



Course material

1). Slides (9~10 sections).

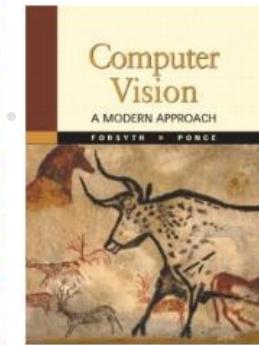
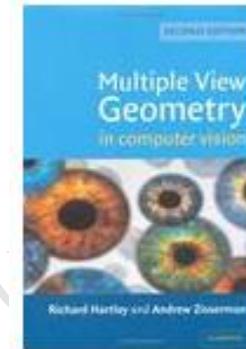
Textbook:

2). “**Multiple View Geometry in Computer Vision,**”

Richard Hartley and Andrew Zisserman, 2nd Edition Cambridge University Press. 2004.

(ISBN: 0521540518)

In Sec.2~5,6, Sec.7~11, Sec.13~15.



3). “**Computer Vision, A Modern Approach,**” David A. Forsyth and Jean Ponce, Prentice Hall.

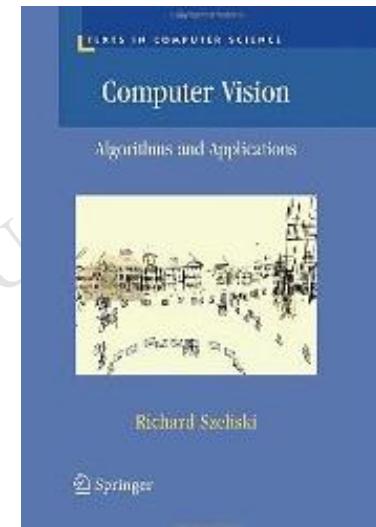
In Sec.1, 2, 3, 10~13. (main), Sec.14~15 (select).



Course material

Miscellaneous materials

1. Selected Papers
2. OpenCV & Matlab (practice)





Grade of final mark

- Participation (10%)
- 3 to 4 homework assignments (40%)
- Midterm project (25%)
- Final project (25%)



成績等第說明

■ 關於成績等第與分佈

A+：達成學習目標，且表現優異

A：達成學習目標

A-：雖達成學習目標，但需再精進

B+：達成部分目標，且品質佳

B：達成部分目標

B-：雖達成部分目標，但需要精進

C+：達成最低目標

C：雖達成最低目標，但需精進

C-：達成最低目標，但有重大缺失

D：雖未達最低目標，但可再研修

E：未達最低目標，不核予成績

碩博士級及格線

學士級及格線

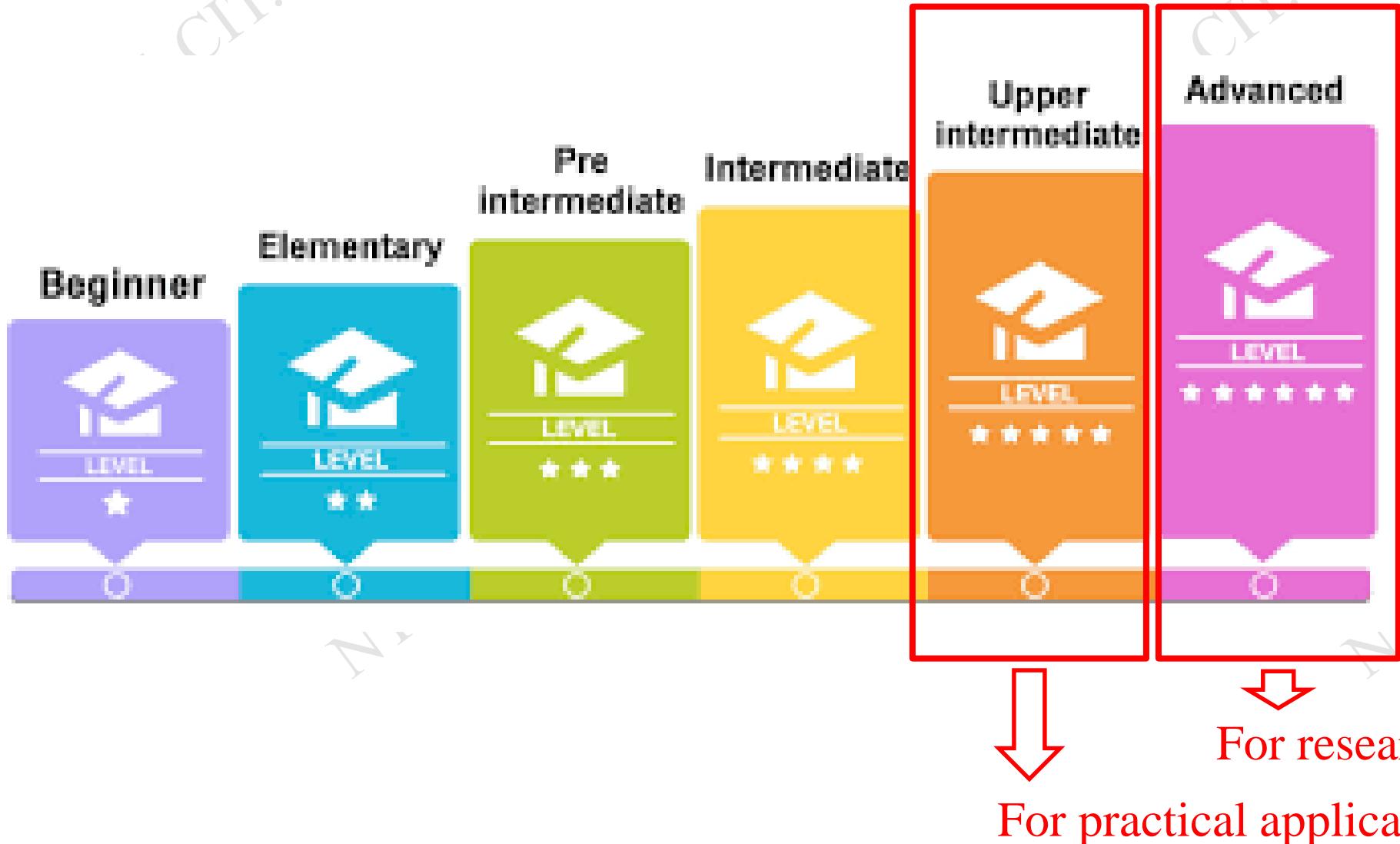
等第制	百分制	GP									
A+	95	4.0	B+	78	3.3	C+	68	2.3	D	55	1.0
A	87	4.0	B	75	3.0	C	65	2.0	E	49	0.0
A-	82	3.7	B-	71	2.7	C-	61	1.7			



Grade distribution in previous five years



Definition of course level





Lecture comment from students

(2021 Spring)

我認為這門課的教學目的為何?
理解 3D 物件成像原理
Computer vision is an important aspect of our life nowadays. I think it allows us to know certain ways of understanding the use of image processing.
我覺得這門課最好的部分:
老師講解得很仔細，作業內容讓學生可以更透徹理解上課內容
藉由作業可以馬上檢驗自己每一階段的課程到底有沒有聽懂，非常好
I think the use of Computer vision gives a new way of thinking and using the vision application for our life.
對本課程其他具體建議:
I would love to have extra time for the course due to we face a lot of problem due to online class.

1. 根據這門課程的學習經驗，您會不會推薦這位老師給其他同學?	會	不會	沒意見
	21	1	1

老師的講解很清楚，針對學生的提問會給予適切的回覆，有助於學習成效的提升
學完這堂課感覺很充實，老師的教學化繁為簡很容易聽得懂看起來很難的東西
I would love to recommend this course, it will be a beneficial course who want to work in the field of computer vision and applications.
可以學到程式背後更詳細的數學理論。
本身做立體視覺研究，老師上課內容解釋清楚，講義整理非常完整。很多基礎知識該懂得都可學會，雖然有些很難又用不到，但從中寫作業並實作讓我獲益良多。
和我之前修過的電腦視覺課程有很大的不同，老師在數值運算的部分講得非常仔細，能夠深刻的了解原理以及如何實現。
不過因為老師講得非常仔細，內容感覺比較少，像是SLAM、CNN等內容希望也能涵蓋在課程中，可能作為補充或是Reading assignment之類的



Lecture comment from students

(2020 Spring)

我認為這門課的教學目的為何?

使學生了解電腦視覺以及其應用

讓學生了解電腦視覺的技巧與應用

理解3D 立體成像原理

學會3D模型 圖片空間轉換求得實體大小

了解電腦視覺相關應用

我覺得這門課最好的部分：

課程內容編排得宜，由淺入深。

很多細節都有討論到，值得花時間上課。

透過作業將老師課程的內容做應用。

能夠了解到別堂課無法學習到的電腦視覺的知識，而且還能透過程式實作中學習如何解決可能會遇到的問題

詳細講解講義內容，內容範圍廣泛

中英文雙語授課

對本課程其他具體建議：

希望老師可以增加用中文解說的時間，因為我似乎在那短短的幾十分鐘學的比整堂上課還多。

五、其他具體評語或建議

The course is great!

老師對於分派的作業下很多苦心，將教學內容融入至作業之中進行實際應用。
對於學生提出問題會詳細回答。

1. 上課內容：由淺入深，內容連貫
2. 教學：老師的英文發音不是很好懂(也有可能是我聽力爛)，因此我大多是先自己看投影片，看不懂才聽課
3. 投影片：非常詳細，比如矩陣乘法是整個寫出來，而不像教科書用簡短的符號表示，這對初學者很有幫助
4. 作業：寫程式作業能幫助理解上課內容，也能熟悉opencv

這門課可以學習到許多關於電腦視覺的知識與觀念，老師也分享許多在應用時需要注意的地方及細節，很用心的出作業和撰寫上課的講義，讓我們能在做作業的過程中學到如何進行合理的假設來解決問題，是一門能學習到許多東西的課程。

教學細心，作業內容與上課相關性高，有助於提升對課程了解

做電腦視覺相關研究的學生修這門課可以得到很多收穫。上課時老師將理論講得很詳細，有時會補充業界實務的經驗。這門課沒有考試，只有老師設計的Project，不同於過去學習只為了應付考試，而是透過完成Project思考上課學習到的知識，我認為這樣有實際應用的上課方式，讓我可以靈活運用在課程中學到的知識。

我是第一次寫C++，我覺得會一點程式能力就可以修習這門課。看得出老師在這領域的專業能力以及上課比其他系的老師認真，也會適時提示作業的想法，只可惜這學期只有16週。另外對這領域沒興趣的同學可能會覺得無聊和痛苦。



Lecture comment from students

(2019 Spring)

我認為這門課的教學目的為何？
了解影像處理原理及實作
使學生能了解並實作出電腦視覺相關應用之程式方法
學習
了解相機影像應用與2D3D位置推估之原理與實作練習
對於3D、圖像的處理及應用
我覺得這門課最好的部分：
業界師資淺談及作業實用性質高
能夠有實作，不僅止於理論探討
課中老師清楚地說明學理，課後助教很能解決作業問題
目前覺得是作業的部分，藉由作業能夠再複習老師所講，老師授課的時候也講解清楚
老師講得很清楚很詳細
深入了解

五、其他具體評語或建議

非常推薦給同樣做視覺相關研究的學生選修這門課，這堂課的內容非常有用，作業也都很貼切真實案例，有認真上課的話同學收穫一定很多。

講課清楚

謝謝老師

老師上課的時候會很仔細地解講每一個公式，讓同學能清楚明白每一個公式的由來及化檢過程。

對於對於影像處理和電腦視覺收獲良多，老師上課也講的很清楚，不過需要有點基礎修才能跟得上

感謝老師這學期的教學，收穫良多。

老師真得棒

授課內容很實務，且老師除了理論授予外也有自身的coding經驗，而且會註明說哪些方法是老師認為還可以繼續研究以及哪些是已經發展完全，或是以目前的我們是不適合的，用導引的方式再輔助我們學習的方向，還會分享以他的觀點來看未來電腦視覺的發展趨勢，整體來說是一位實務經驗非常豐富且教學很詳細很完整的老師！



Lecture comment from students

(2018 Spring)

amazing

老師的教材投影片若能在頁碼處加入章節，在切換參考章節投影片可以協助學生快速掌握老師切換到哪一章節的投影片去做參考。

認真教學，清楚呈現範例讓學生可自行檢查程式。選課週可說明負擔大讓人有心理準備

林老師的圖學及電腦視覺皆為欲從事此領域的人必選修之課，原理講解十分透徹，作業也融合理論與時事，達到做中學學中做的成果，但難易度非同小可，若無經驗須斟酌選修！

我認為這門課的教學目的為何？

了解影像處理原理及實作

使學生能了解並實作出電腦視覺相關應用之程式方法

學習

了解相機影像應用與2D3D位置推估之原理與實作練習

對於3D、圖像的處理及應用

我覺得這門課最好的部分：

業界師資淺談及作業實用性質高

能夠有實作，不僅止於理論探討

課中老師清楚地說明學理，課後助教很能解決作業問題

目前覺得是作業的部分，藉由作業能夠再複習老師所講，老師授課的時候也講解清楚

老師講得很清楚很詳細

深入了解



Lecture comment from students

(2017 Spring)

106(二) CI5336701 電腦視覺與應用
Computer vision and applications

1. 目前覺得是作業的部分，藉由作業能夠再複習老師所講，老師授課的時候也講解清楚
2. 老師講得很清楚很詳細
3. 在本學期色彩所課程中，本課最有機會應用於博士研究
4. amazing
5. 認真教學，清楚呈現範例讓學生可自行檢查程式。選課週可說明負擔大讓人有心理準備。
6. 林老師的圖學及電腦視覺皆為欲從事此領域的人必選修之課，原理講解十分透徹，作業也融合理論與時事，達到做中學學中做的成果，但難易度非同小可，若無經驗須斟酌選修！



Course agenda (tentative)

Week	Date	Event	Lecture Agenda (tentative)	Assignment
1	2022/2/14		Introduction	
2	2022/2/21		pin-hole camera model	
3	2022/2/28		[Cancelled, National Holiday]	
4	2022/3/7		Visual Hull case study	Homework#1 Assignment
5	2022/3/14		projective 2D geometry	
6	2022/3/21		Estimation for 2D Projective Transformations	Homework#2 Assignment
7	2022/3/28		Projective 3D geometry	
8	2022/4/4		[Cancelled, National Holiday]	Midterm Project Assignment
9	2022/4/11	Offical Midterm Exam Week	Two-views geometry	
10	2022/4/18		Two-views geometry/case study (or Cancelled) [TBD]	Homework#3 Assignment
11	2022/4/25		Camera Calibration	
12	2022/5/2		Camera Calibration / 3D reconstruction (vision base)	Homework#4 Assignment
13	2022/5/9		3D reconstruction (vision base)	
14	2022/5/16		Feature Detection and Matching	Final Project Assignment
15	2022/5/23		Argumented Reality Application	
16	2022/5/30	Final Exam Week	[Cancelled]	



Pre-requisite skills of this course

To join this course, two skills are strongly recommended,

1. Basic matrix calculation

(either “Linear algebra” or “Engineering Mathematics”)

2. Programming (for homework and algorithm verification)

(either “python”, “C/C++” or “Matlab”)



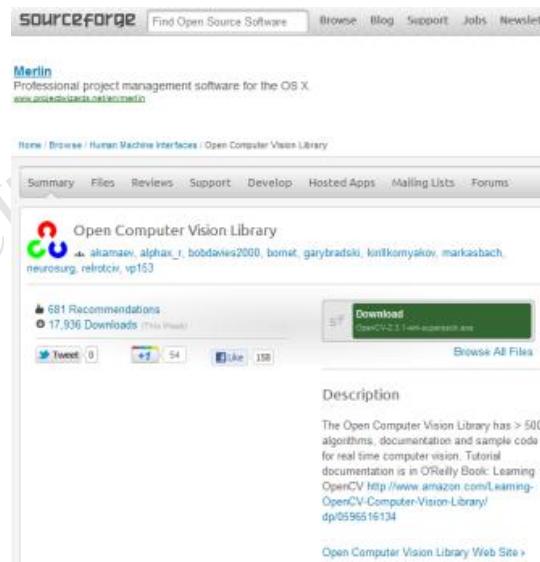
Course further objective

1. Ability to define a “Computer Vision” problem, then solve it.
2. Ability to submit a conference paper in this field.



Tools and implementation

- We are realizing and developing “computer vision” topics, instead of “learning openCV”.
- openCV may assist you to speed up your practical period.



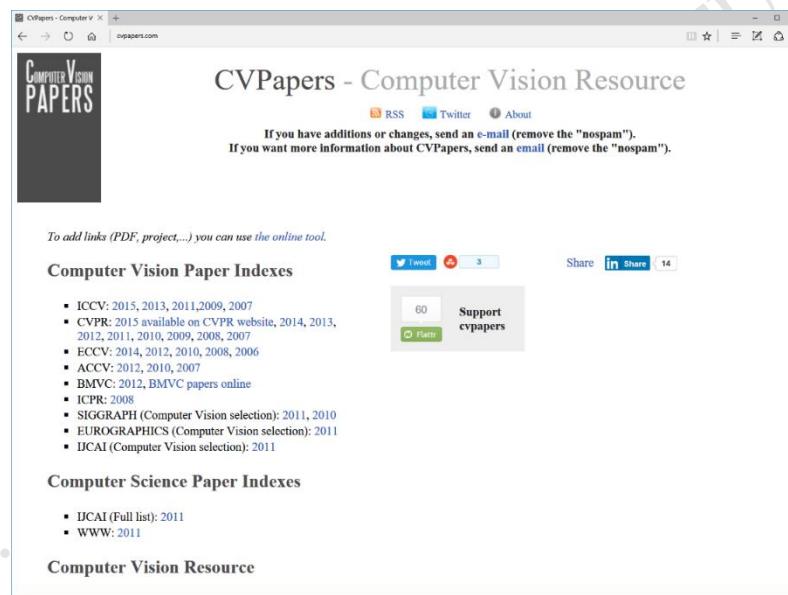
<http://sourceforge.net/projects/opencvlibrary/>

http://xanthippi.ceid.upatras.gr/people/evangelidis/matlab_opencv/



Premier conference in this field

- CVPR: Computer Vision and Pattern Recognition, IEEE Conference on.



- ACM SIGGRAPH (optional)



Beyond image processing & Computational photography ...

1. Single view
 - recognition, object detection,
 - stitching (multi-images)
 - tracking, AR (plus time)
2. Two views
 - depth perception, stereo, robotics
 - synthesis
3. Multi views
 - 3D structure
 - image based rendering
 - synthesis



Transformations (planar mapping)



Captured image



synthesized image



synthesized image



Captured image



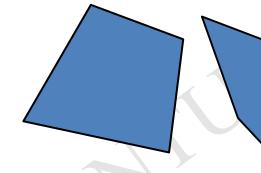
synthesized image



Transformations (planar mapping)

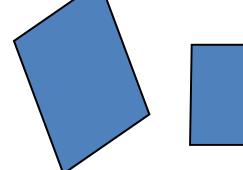
Projective
8dof

$$\begin{bmatrix} h_{11} & h_{12} & h_{13} \\ h_{21} & h_{22} & h_{23} \\ h_{31} & h_{32} & h_{33} \end{bmatrix}$$



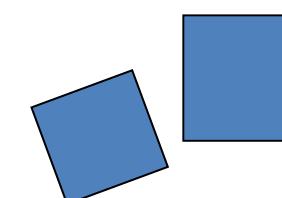
Affine
6dof

$$\begin{bmatrix} a_{11} & a_{12} & t_x \\ a_{21} & a_{22} & t_y \\ 0 & 0 & 1 \end{bmatrix}$$



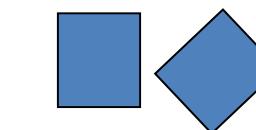
Similarity
4dof

$$\begin{bmatrix} sr_{11} & sr_{12} & t_x \\ sr_{21} & sr_{22} & t_y \\ 0 & 0 & 1 \end{bmatrix}$$



Euclidean
3dof

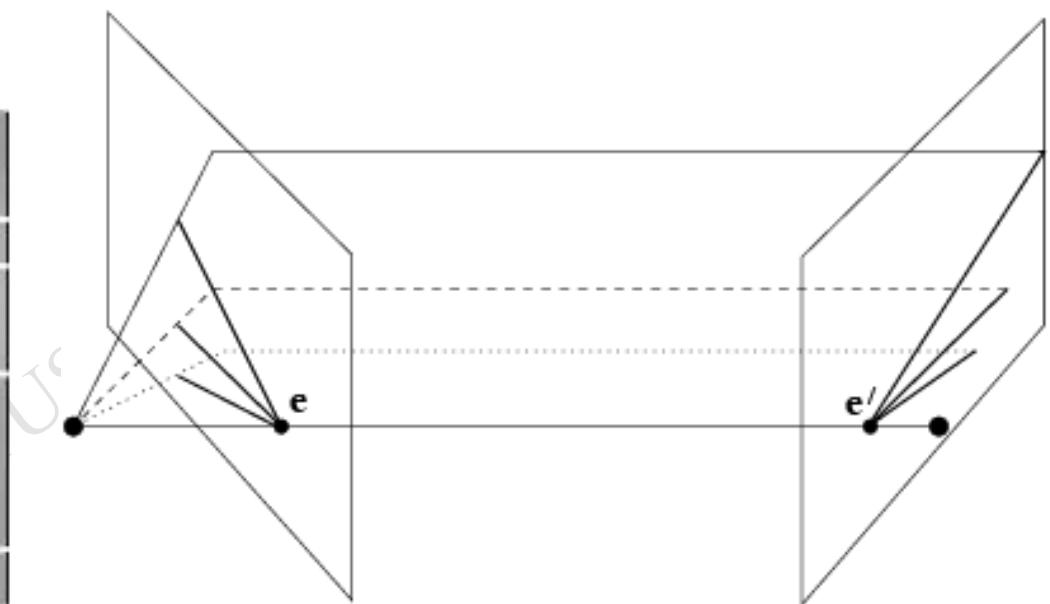
$$\begin{bmatrix} r_{11} & r_{12} & t_x \\ r_{21} & r_{22} & t_y \\ 0 & 0 & 1 \end{bmatrix}$$





Two view geometry: Epipolar geometry

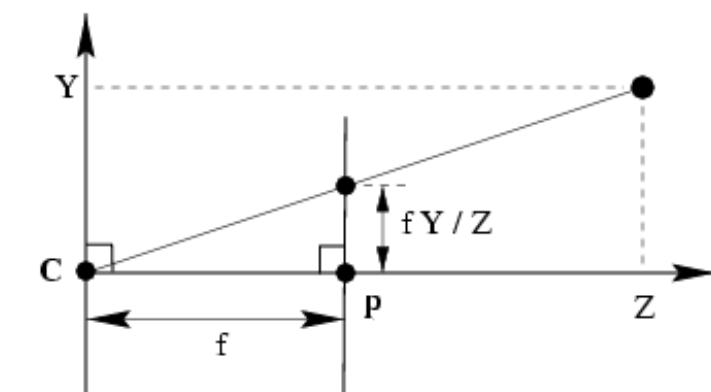
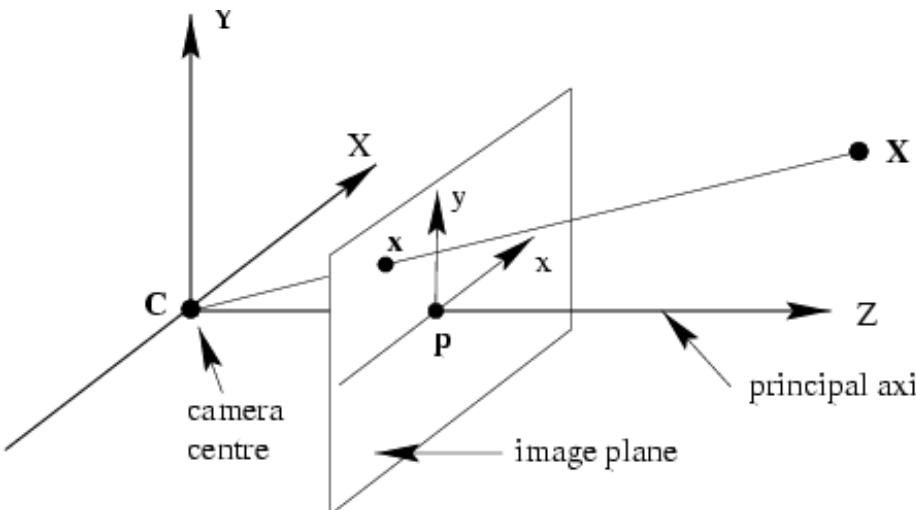
- Picture from book: Multiple View Geometry in Computer Vision





Camera models

- Picture from book: Multiple View Geometry in Computer Vision



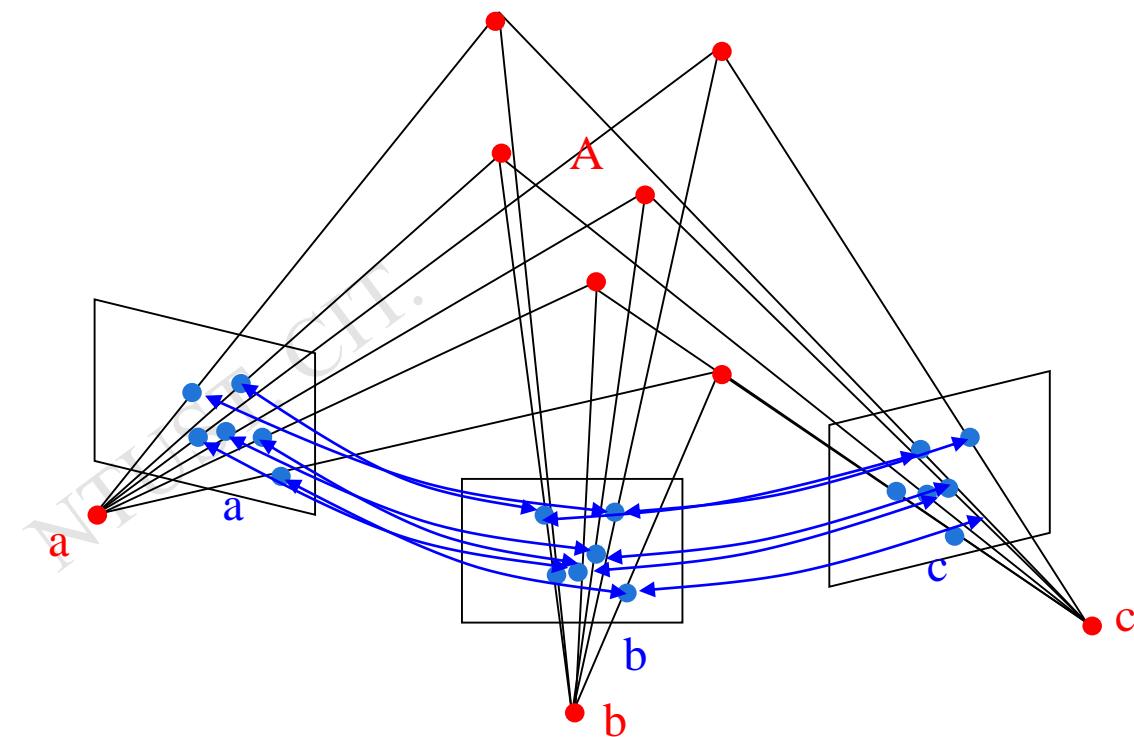
$$\lambda \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = \begin{bmatrix} f & p_x & 1 \\ f & p_y & 1 \\ 0^T_3 & 1 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix}$$

or $\lambda x = P.X$



Camera models

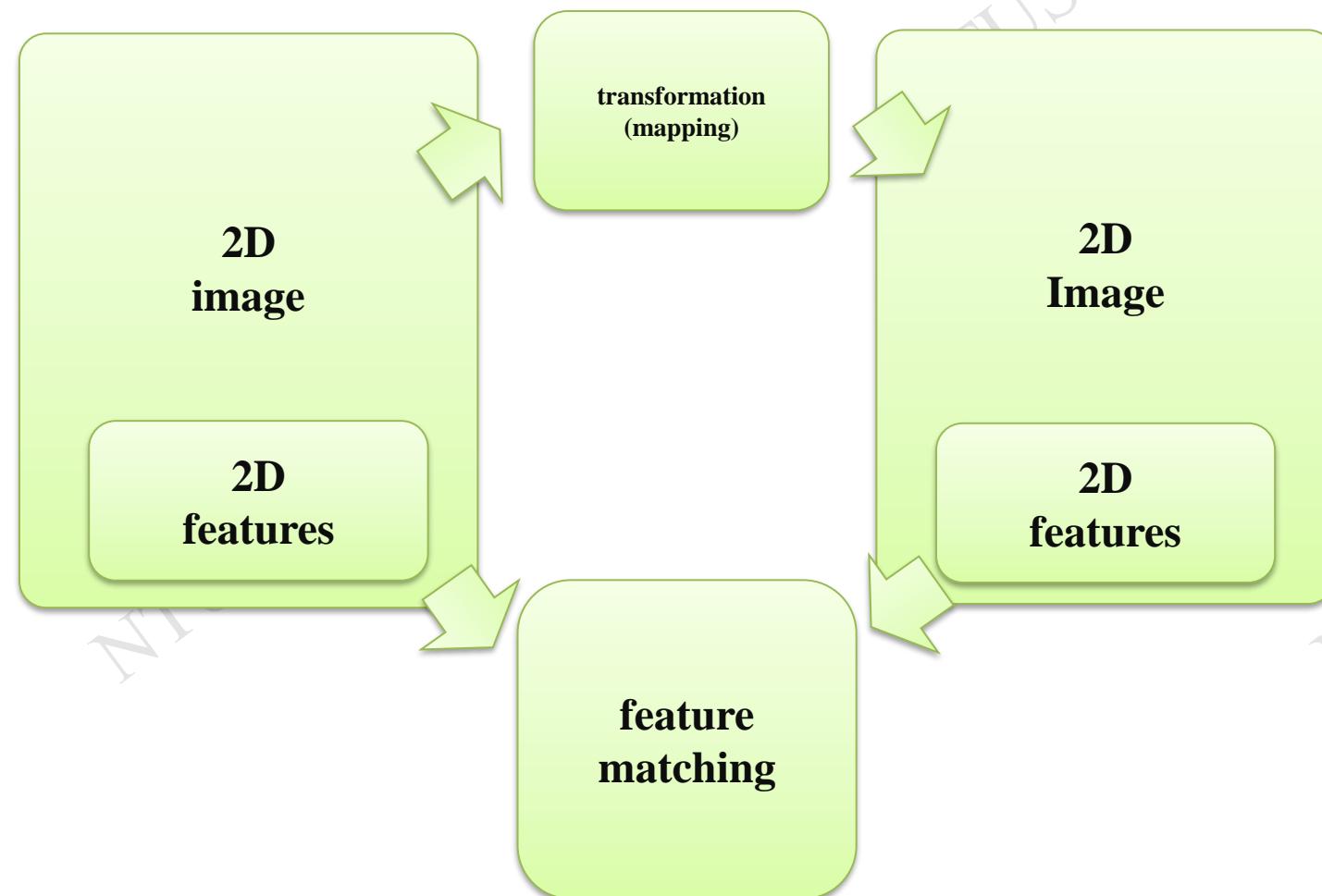
- 3D→2D (projection)
- 2D→3D (reconstruction)





Application and pipeline

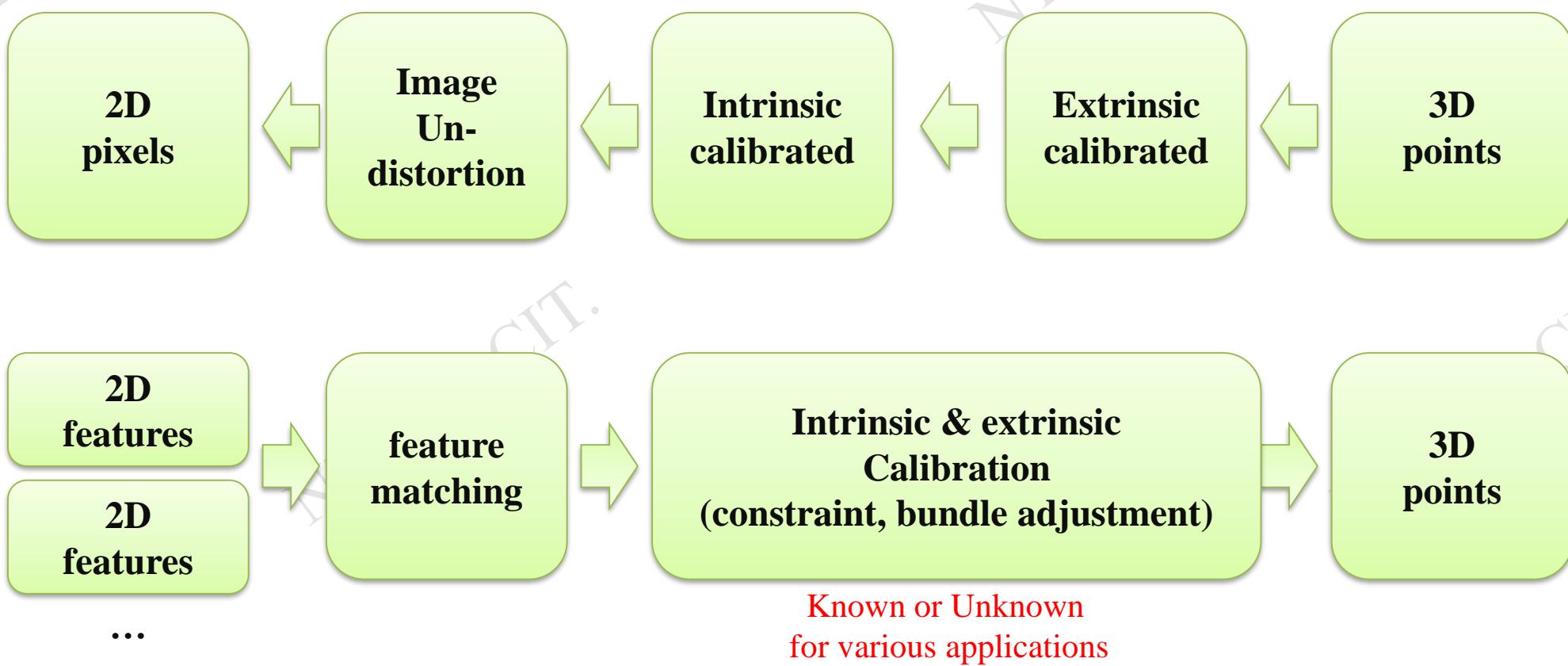
- Top-down & bottom-up applications





Application and pipeline

■ Top-down & bottom-up applications





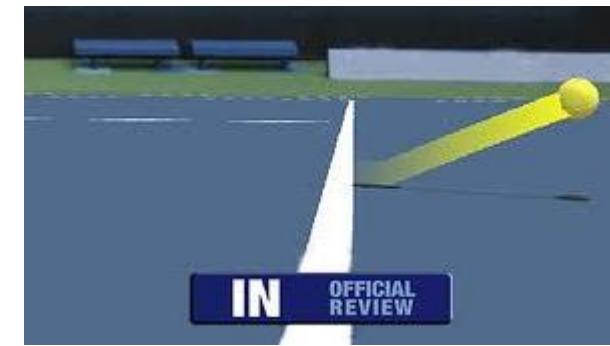
Standard operating procedure (SOP)

1. Define your problem
 - Input? Output?
 - Constraints ? physical limits ?
2. Make an assumption (optional)
3. Estimate your completeness/performance
4. Select or develop your tools/algorithms
5. Verify/test and adjust your method (again and again)



Computer vision application

- Superimpose “3D” info. onto video clips.





Computer vision application—cont.

- Multiple camera-view synthesis





Computer vision application—cont.

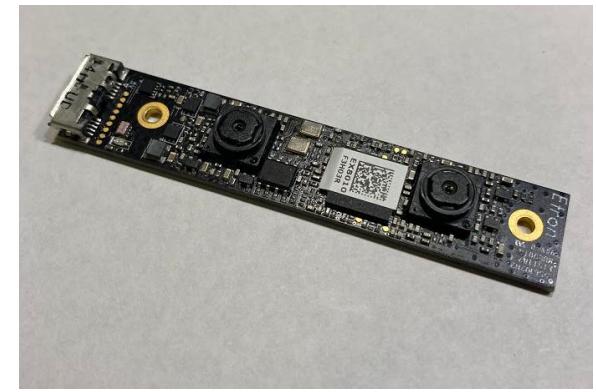
■ Stereoscopic camera



depth info.



3D reconstruction
(Pointgrey/FLIR product)



Stereo camera (with depth)



Microsoft/Apple Kinect (interaction)



depth map



Structure Light Sensor



Computer vision application—cont.

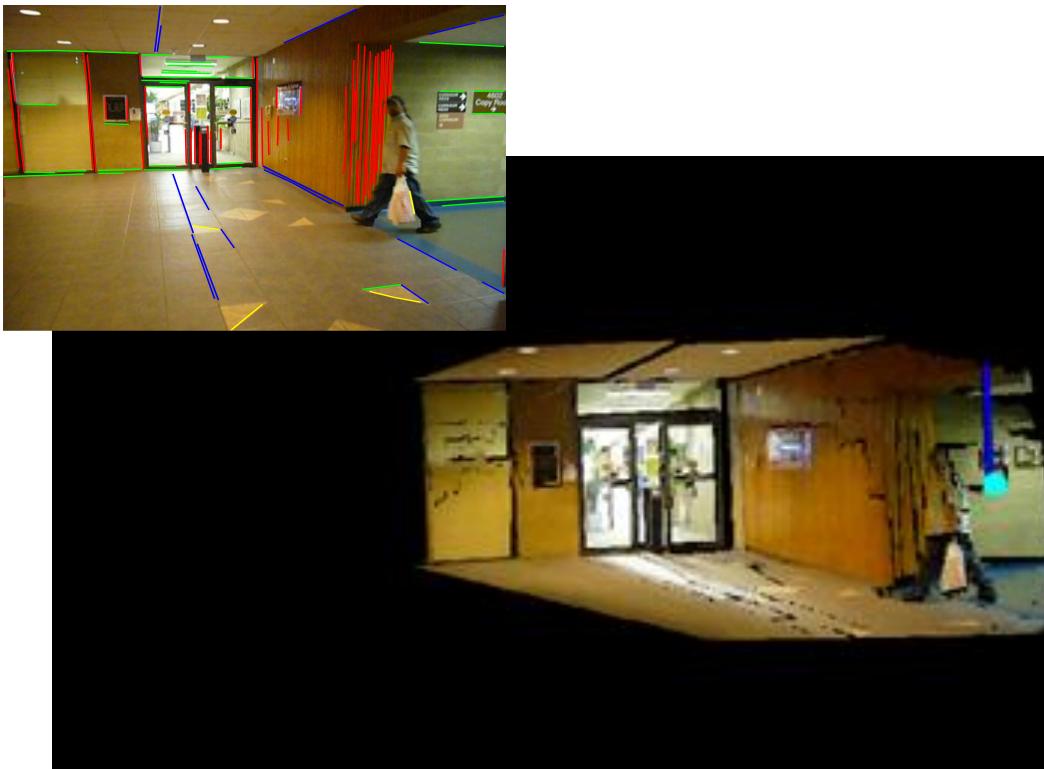
- Conventional problem : Object detection and tracking





Computer vision application—cont.

- 3D reconstruction from single image
- 2D to 3D issue



DEPTH PROPAGATION

Our Depth Propagation technology allows you to extend a single or few key frame depth map to an entire video, creating the depth map for each frame on the basis of the source depth map.

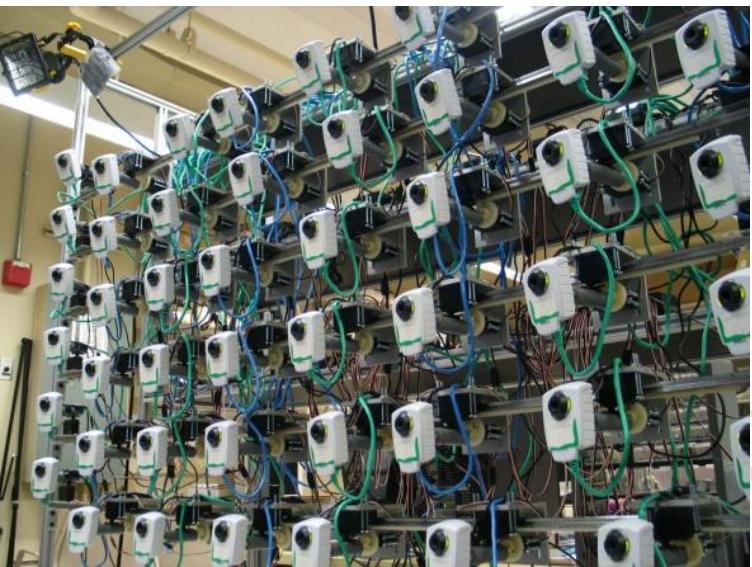
DEPTH PROPAGATION
[read more...](#)





Computer vision application—cont.

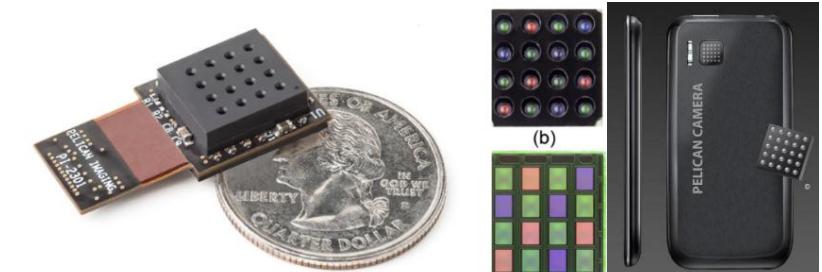
- Image based rendering
- View synthesis



Picture from Prof. TH Chen

<https://light.co/>

<https://www.breezesys.com/products/>

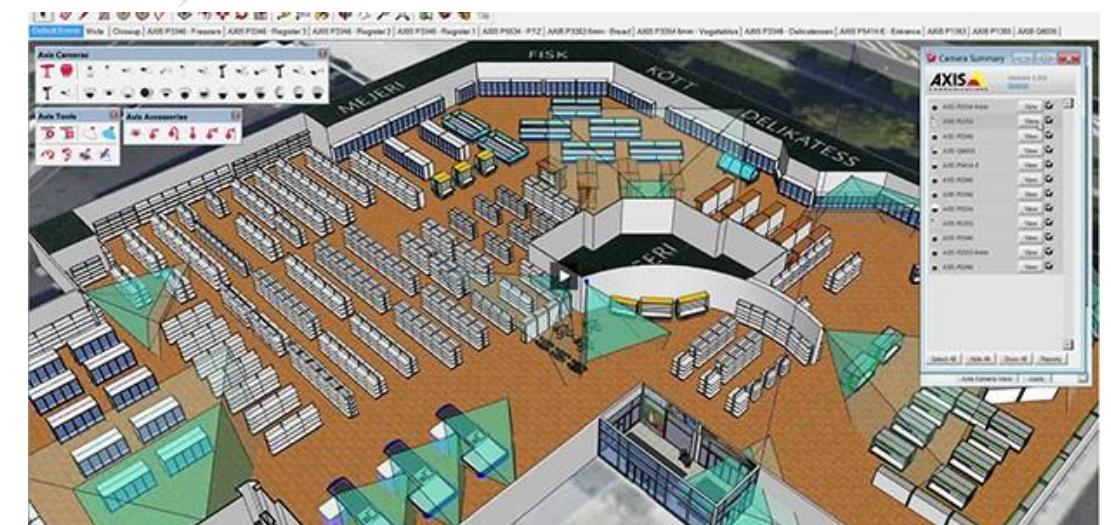
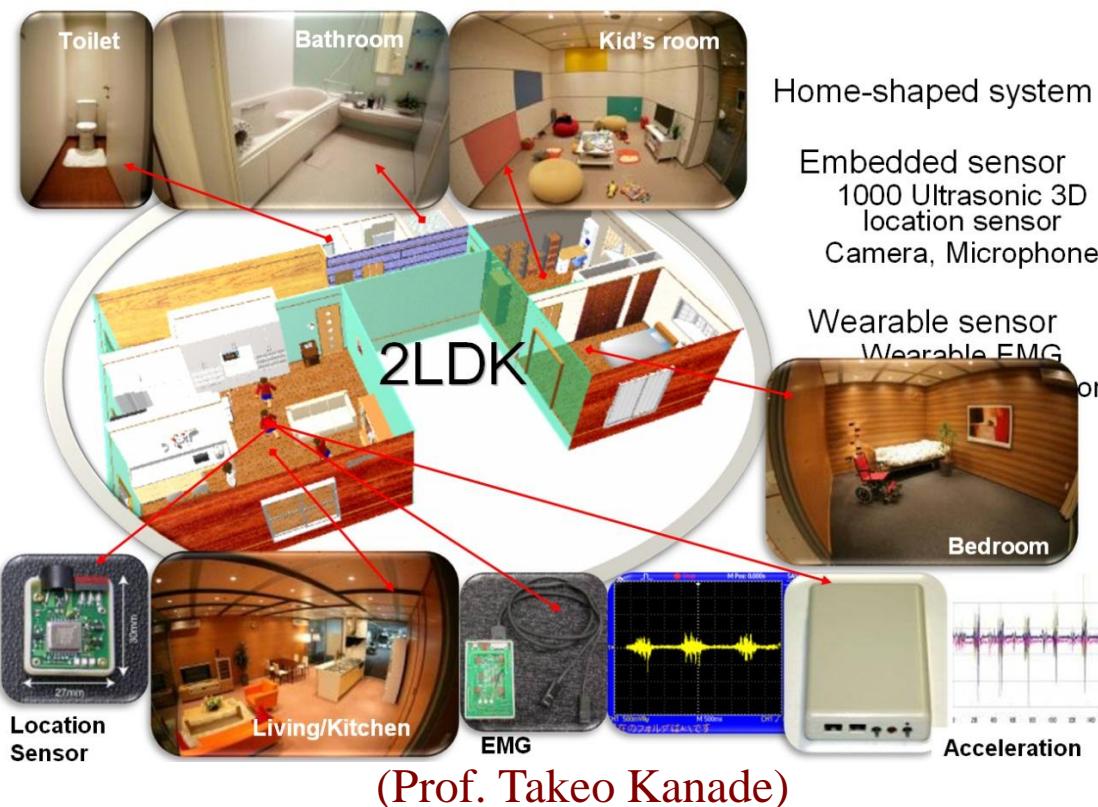


Light-field composite image



Computer vision application—cont.

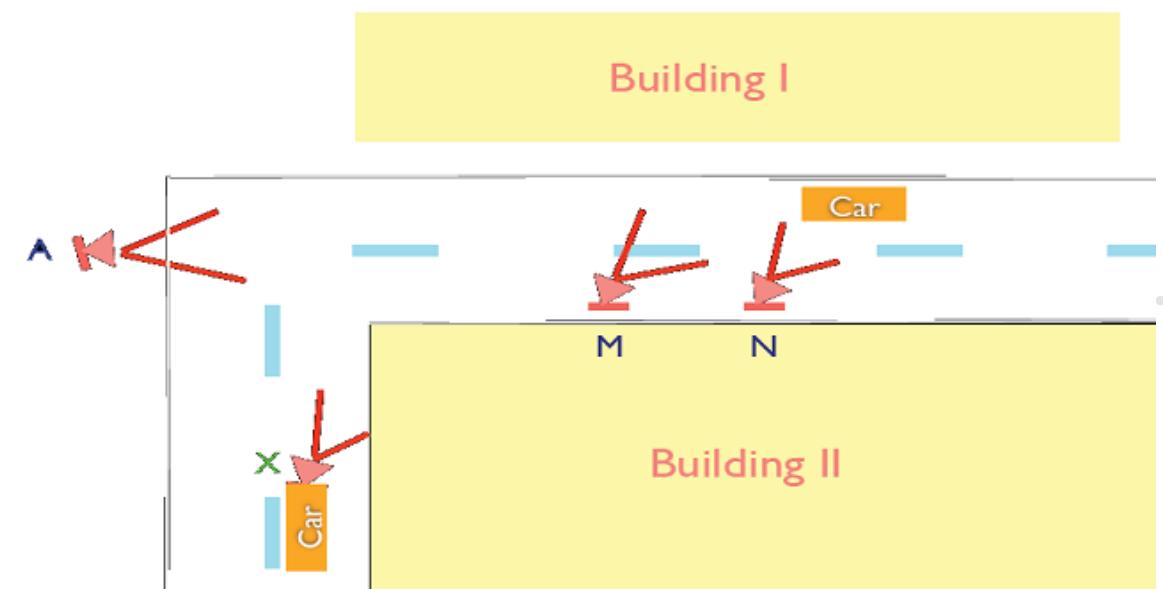
■ Video surveillance: multiple camera array





Computer vision application—cont.

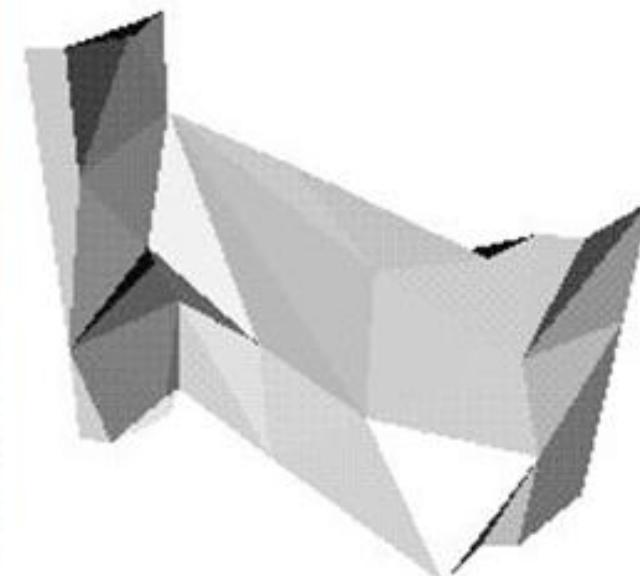
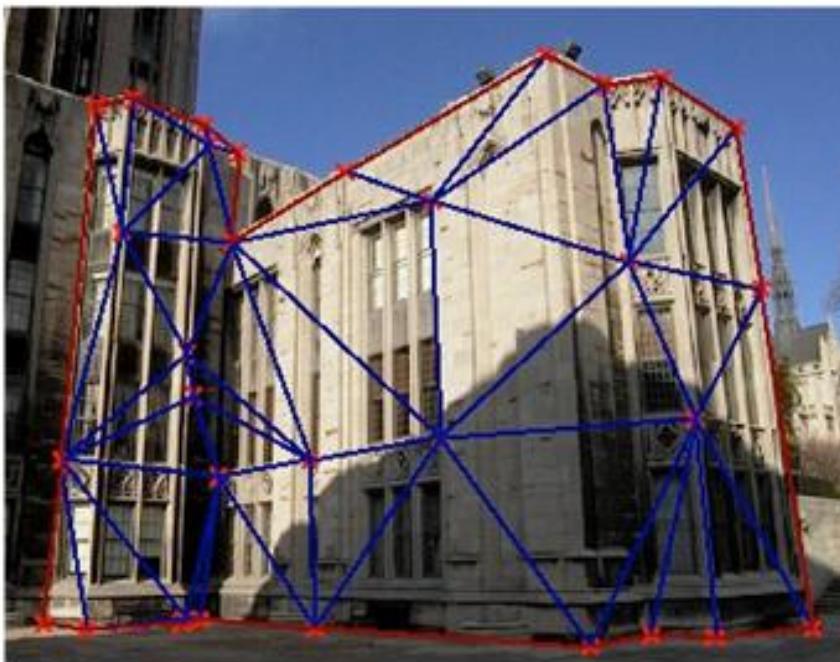
- Safety driving
- Multiple camera synthesis





Computer vision application—cont.

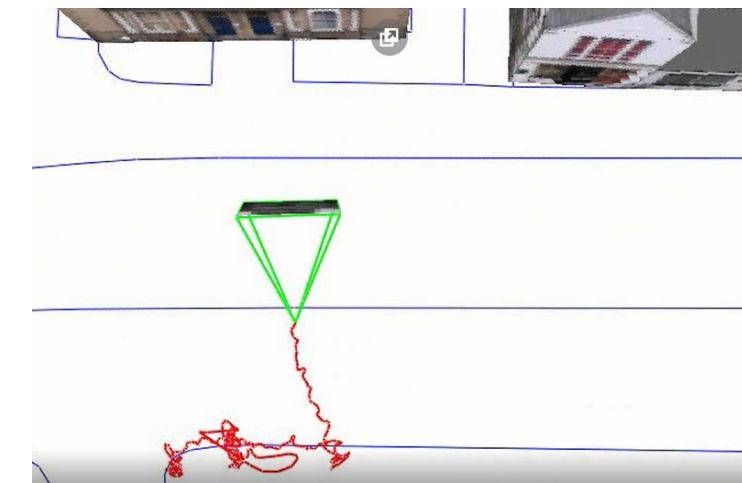
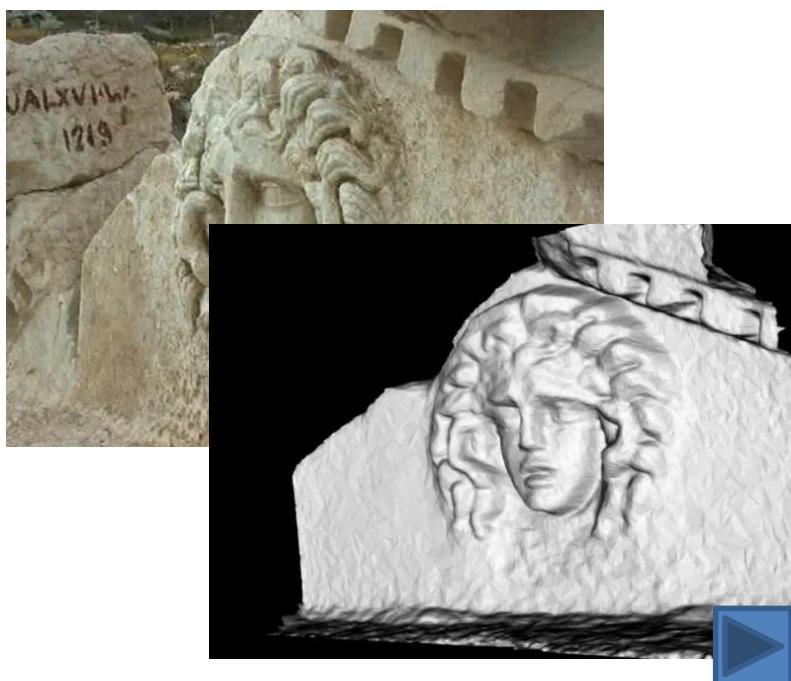
■ Multiple view 3D reconstruction





Computer vision application—cont.

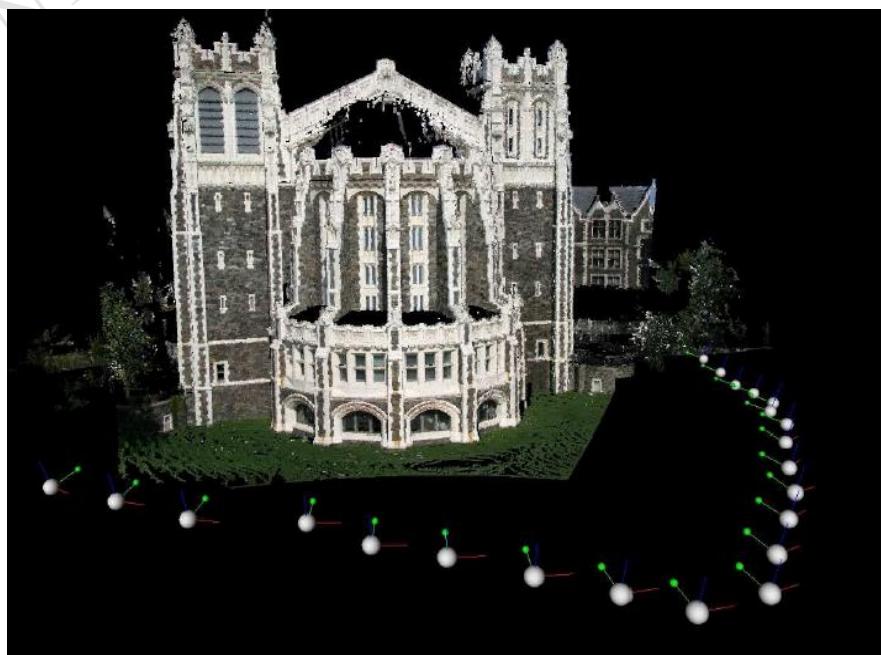
- Structure from motion
- 3D reconstruction
- Localization



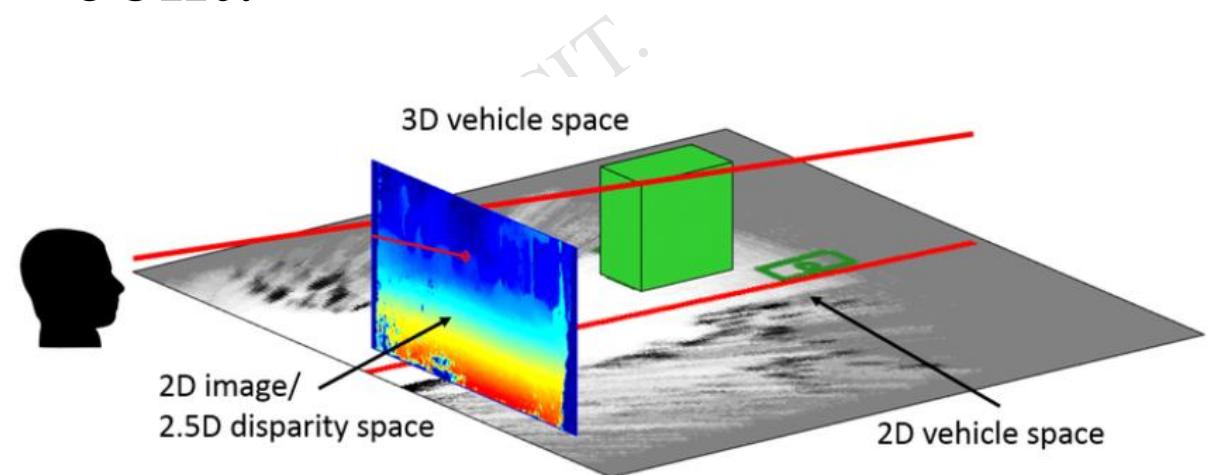


Computer vision application—cont.

■ Data fusion & image registration



Textured model



L. Liu and I. Stamos, "Automatic 3D to 2D registration for the photorealistic rendering of urban scenes," *Proc. IEEE Comput. Soc. Conf. Comput. Vis. Pattern Recognit.*, vol. 2, pp. 137–143, 2005.

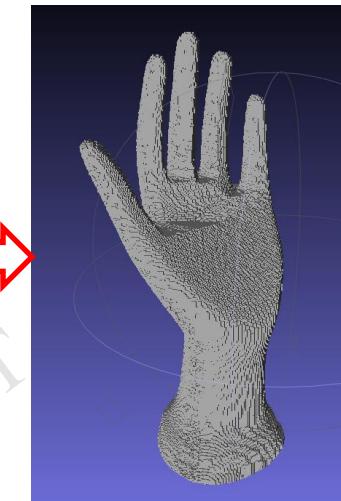
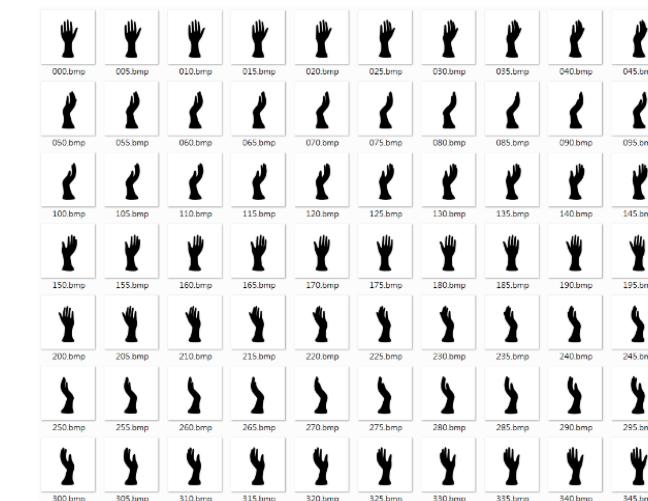
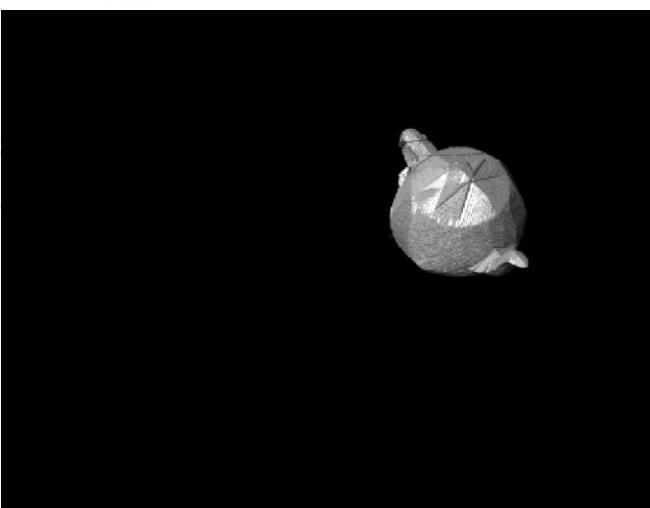
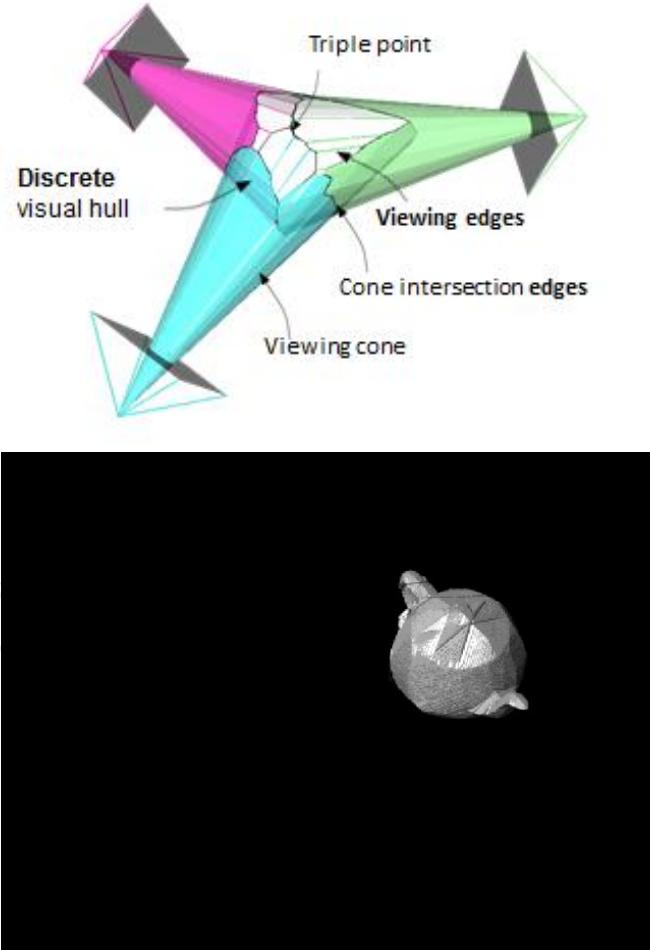
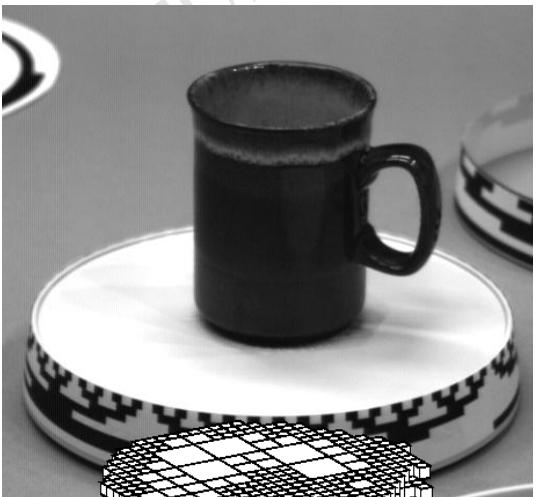
Schwehr , Driver's Gaze Prediction in Dynamic Automotive Scenes, 2017

<https://www.springwise.com/innovation/mobility/futurus-AR-windscreen>



Computer vision application—cont.

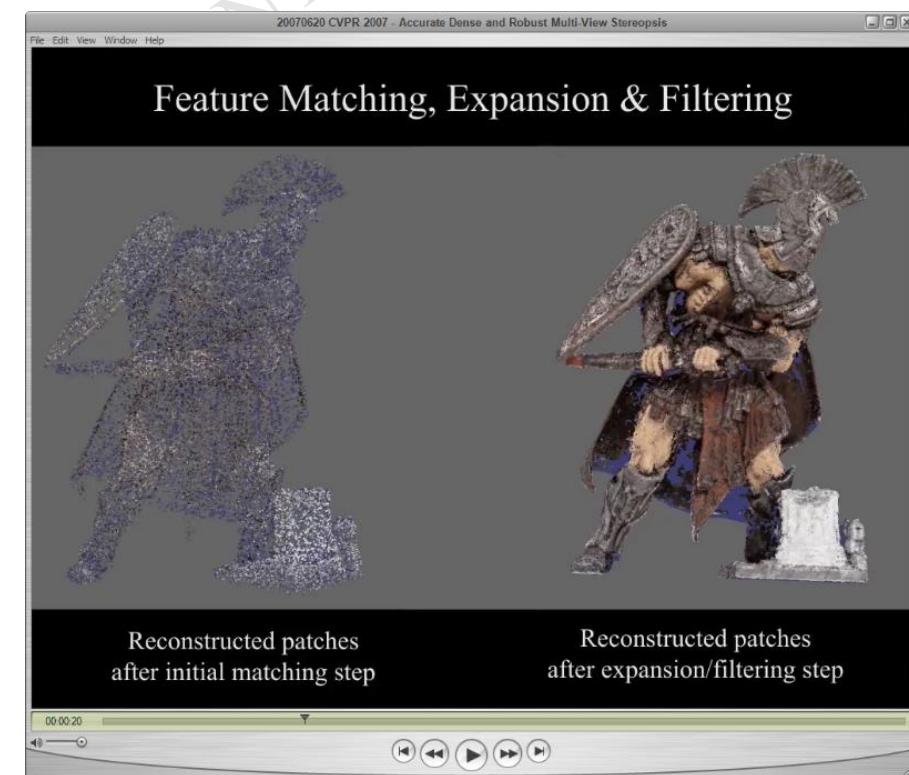
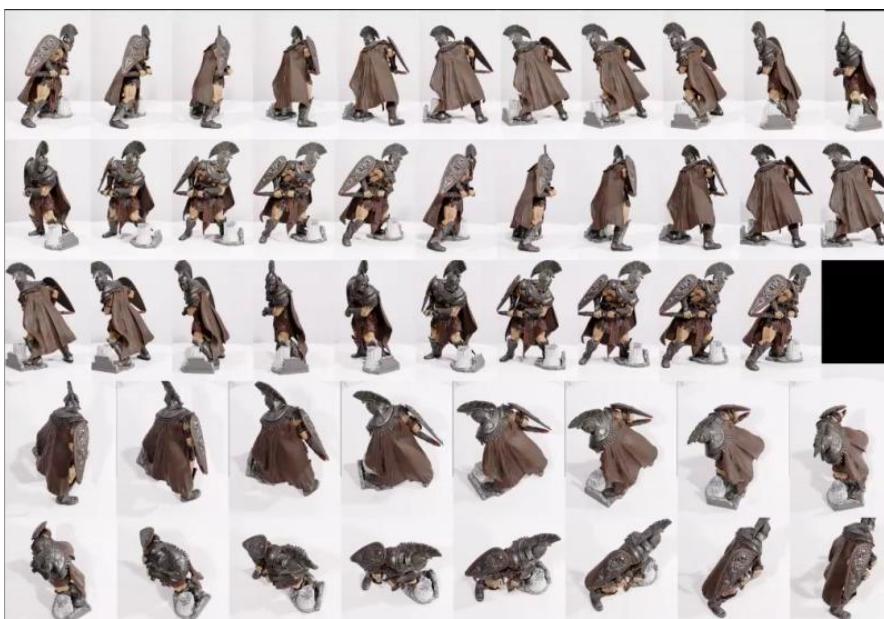
■ Visual hull





Computer vision application—cont.

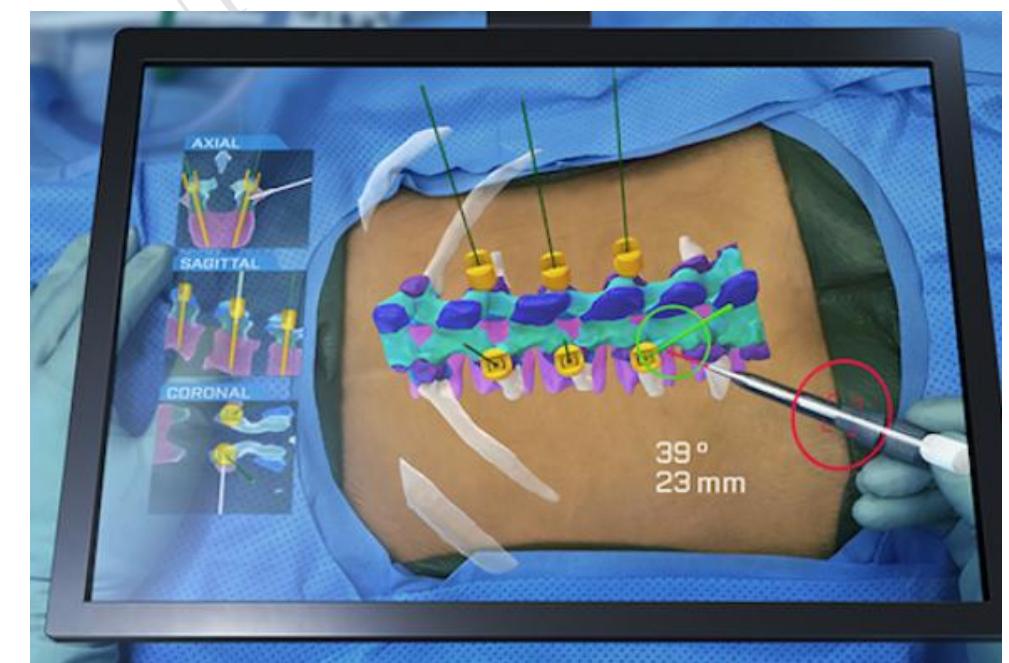
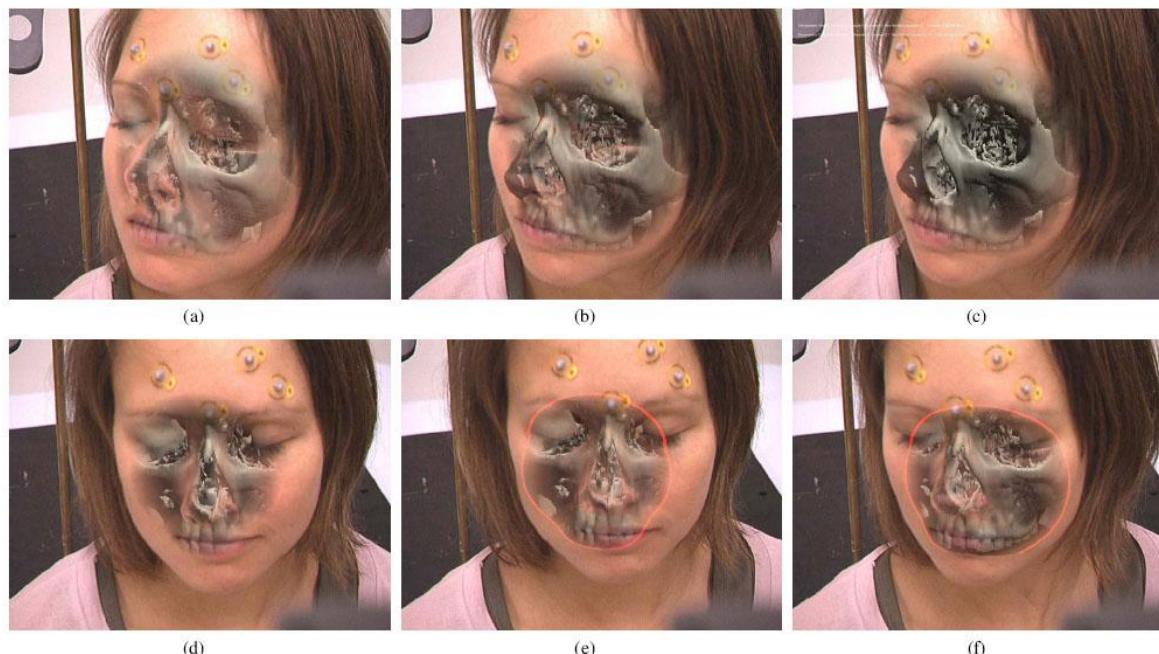
- Multi-view + stereo + photo consistency





Computer vision application—cont.

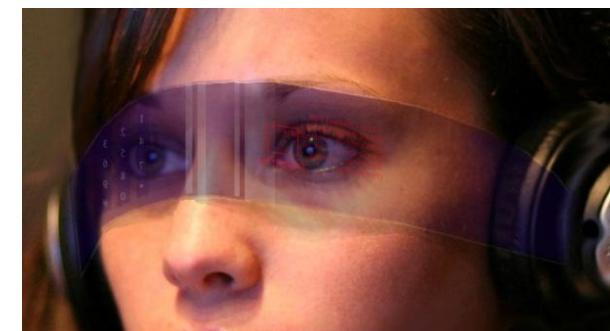
■ Augmented Reality in surgery





Computer vision application—cont.

- AR, Mobile computing
- PS3/PS4 game



<https://www.youtube.com/watch?v=YZvxIjdyII>

<https://www.youtube.com/watch?v=V9jRAzVS0Xg>



Computer vision application—cont.

■ Visual Effect

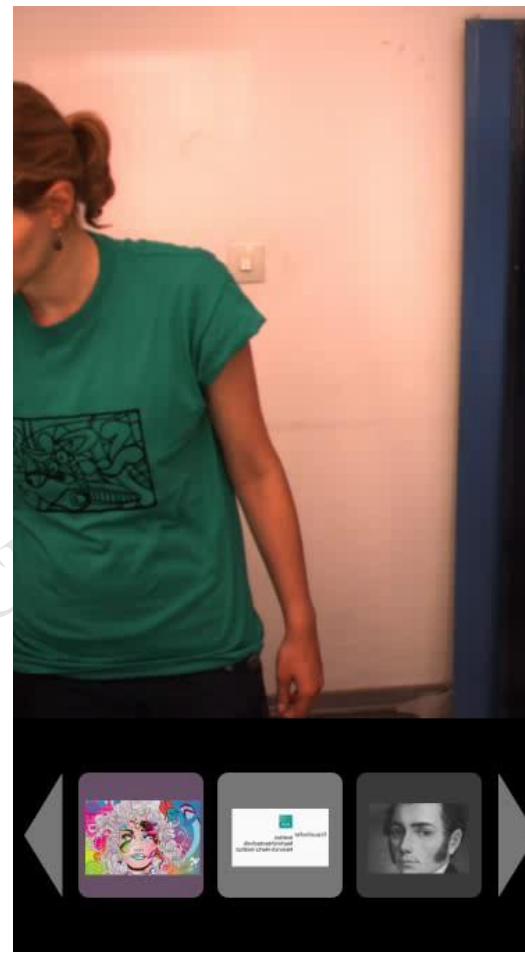




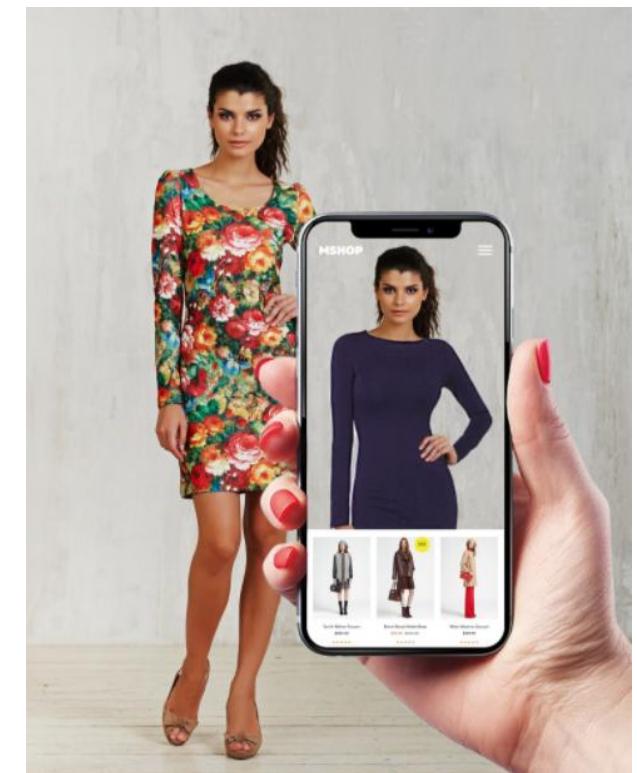
Computer vision application—cont.



[virtual dressing]



[ICIP 2008]





色彩與照明科技研究所
Graduate Institute of
Color and Illumination Technology

