電腦視覺與應用
Computer Vision and Applications

Lecture-01 Introduction

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TAIWAN TECH National Taiwan University of Science and Technology

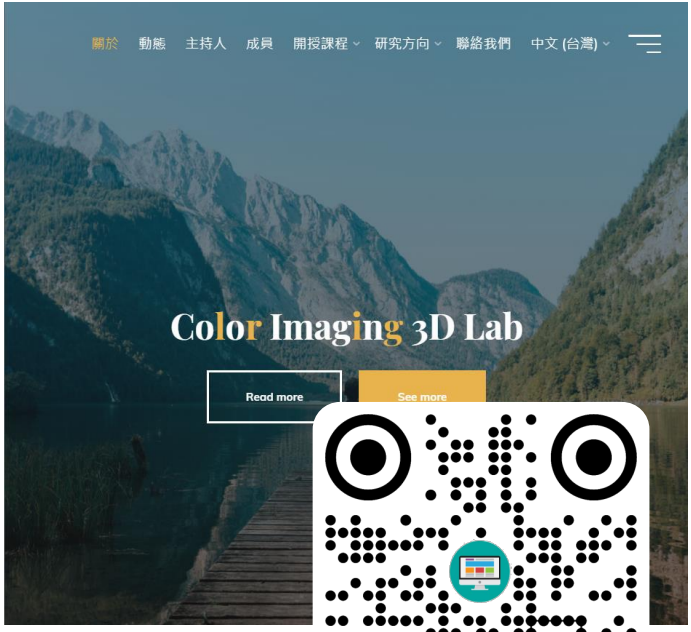
CIT 色彩與照明科技研究所 Graduate Institute of Color and Illumination Technology

Course information:

- Computer Vision and Applications (CI5336701)
- Place: IB-607
- Time: Mon. Am.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: Tue. 10:00~12:00 (regular), or by appointment.
- Ext: 3717. (phone: 0227303717)
- TA: NA

Homepage



Lab Page

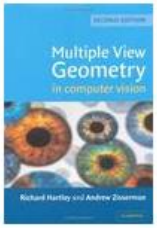
http://homepage.ntust.edu.tw/thl/
http://ci3d.ntust.edu.tw

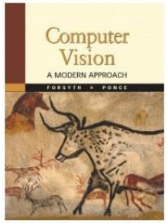
Course outline

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.

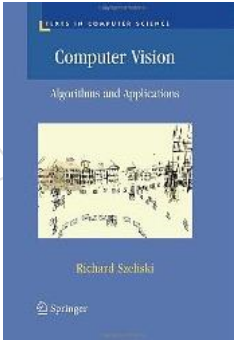
3). "**Computer Vision, A Modern Approach**," David A. Forsyth and Jean Ponce, Prentice Hall.

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 (35%)
- Midterm project (25%)
- Final project (30%)

成績等第說明

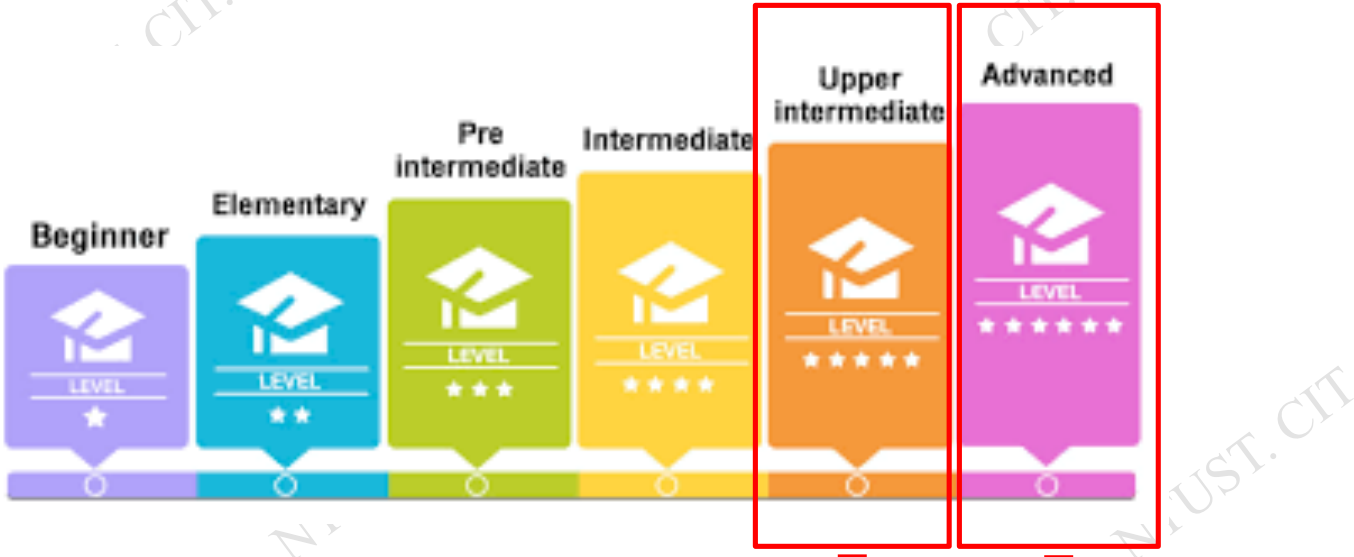
■ 關於成績等第與分佈

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 ——— 碩博士級及格線
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 ——— 學士級及格線
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

等第制	百分制	GP	等第制	百分制	GP	等第制	百分制	GP	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

(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爲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!

Pros. of this lecture

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！
105(二)	CI5336701	電腦視覺與應用 Computer vision and applications	1. 老師教學非常用心，除了上課內容非常豐富外，對於業界的動態也不吝分享，對於對這領域的學弟妹真的推薦用心聽課，收益良多。 2. 教得很詳細很棒，但課程偏難，不知道教授有沒有考慮上課架個錄影機，讓同學可以回家反覆看慢慢吸收 3. 真的很棒! 4. 教導同學進入電腦視覺的領域，從基礎的開始，範例作業都出的很用心，不是想難倒同學。 5. 老師的教材準備得非常用心，作業也很用心的出。

Course agenda (tentative)

Week	Date	Event	Lecture Agenda (tentative)	Assigment
1	2021/2/22		Introduction	
2	2021/3/1		[Holiday & Lecture cancelled]	
3	2021/3/8		pin-hole camera model	
4	2021/3/15		Visual Hull case study	Homework#1 Assignment
5	2021/3/22		projective 2D geometry	
6	2021/3/29		Estimation for 2D Projective Transformations	Homework#2 Assignment
7	2021/4/5		[Holiday & Lecture cancelled]	
8	2021/4/12		Projective 3D geometry	Midterm Project Assignment
9	2021/4/19	Midterm Exam Weel	No lecture but Open hours	
10	2021/4/26		Two-views geometry	Midterm Project Due
11	2021/5/3		Two-views geometry / case study	Homework#3 Assignment
12	2021/5/10		Camera Calibration	
13	2021/5/17		Camera Calibration / 3D reconstruction (vision base)	Homework#4 Assignment
14	2021/5/24		3D reconstruction (vision base)	
15	2021/5/31		Feature Detection and Matching	Final Project Assignment
16	2021/6/7		Argumented Reality Application	
17	2021/6/14		[Holiday & Lecture cancelled]	
18	2021/6/21	Final Exam Week	No lecture but Open hours	Final Project Due

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”)

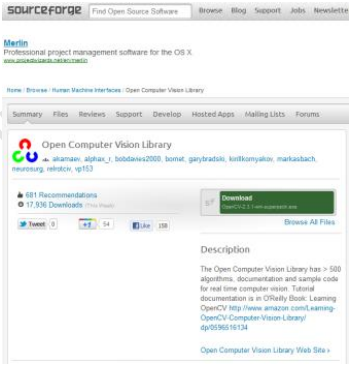
Couse further objective

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)

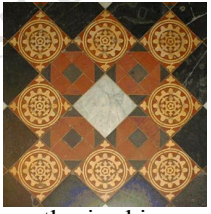
Beyond image processing & Computational photography …

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

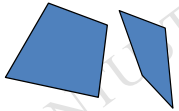
Captured image

synthesized image

Transformations (planar mapping)

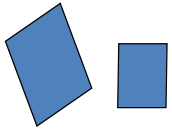
Projective 8dof

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



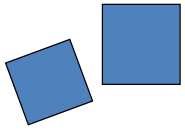
Affine 6dof

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



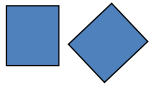
Similarity 4dof

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



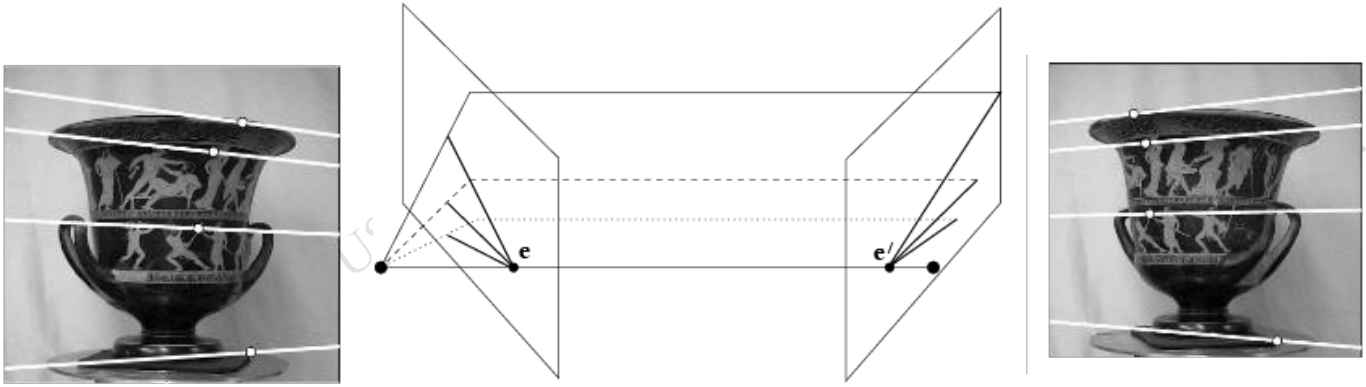
Euclidean 3dof

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



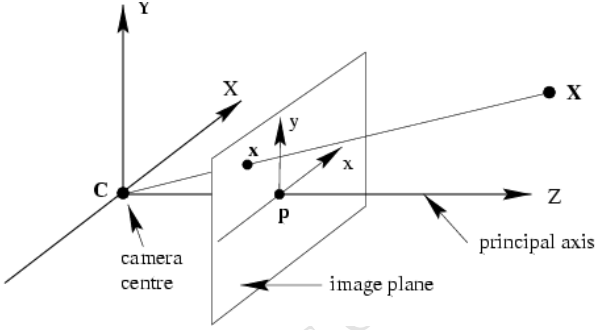
Two view geometry: Epipolar geometry

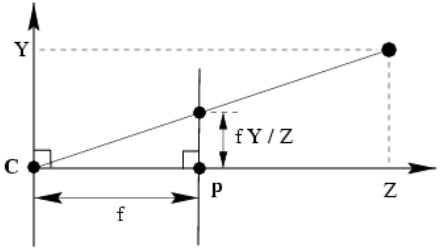
- Picture from book: Multiple View Geometry in Computer Vision



Camera models

- Picture from book: Multiple View Geometry in Computer Vision

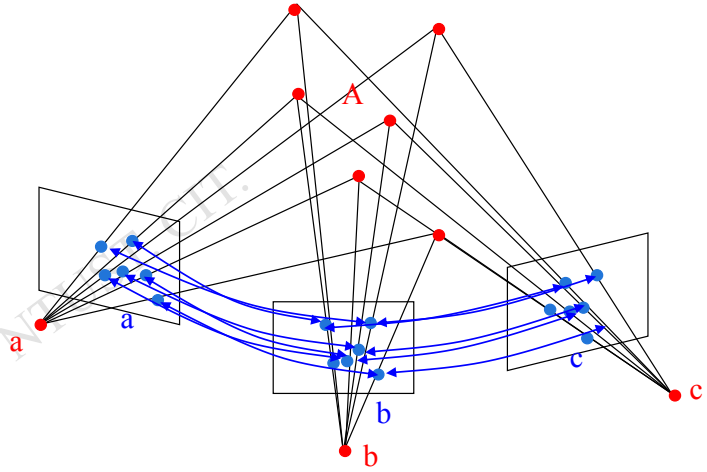




$$\lambda \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = \begin{bmatrix} f & & p_x \\ & f & p_y \\ & & 1 \end{bmatrix} \begin{bmatrix} 1 & & \\ & 1 & \\ & & 1 \end{bmatrix} \begin{bmatrix} \mathbf{R} & \mathrm{t} \\ 0_3^{\mathsf{T}} & 1 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix} \quad \text{or} \quad \lambda \mathrm{x} = \mathbf{P}.\mathrm{X}$$

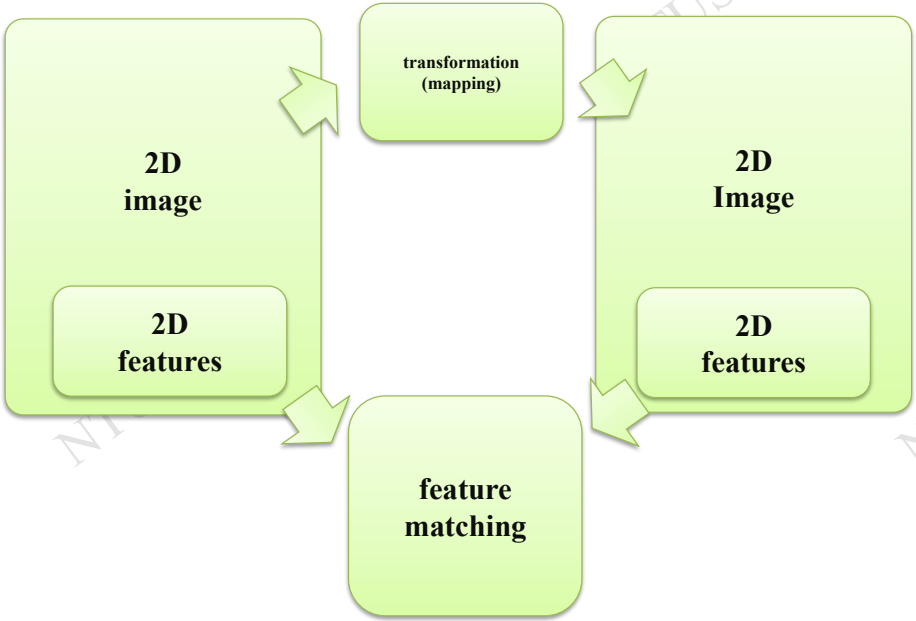
Camera models

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



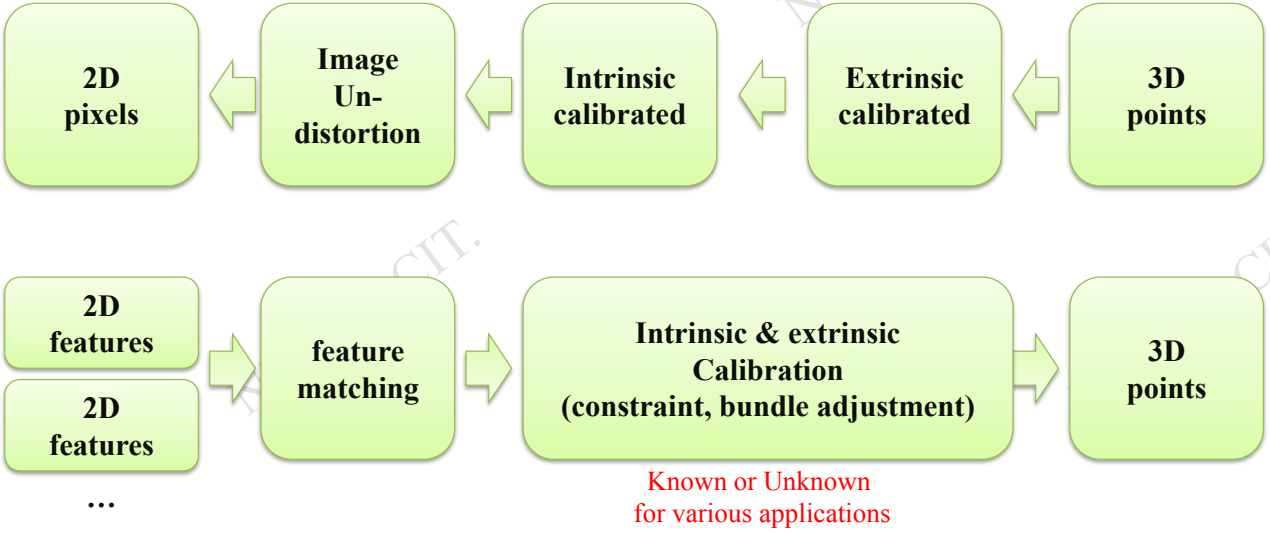
Application and pipeline

- 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)

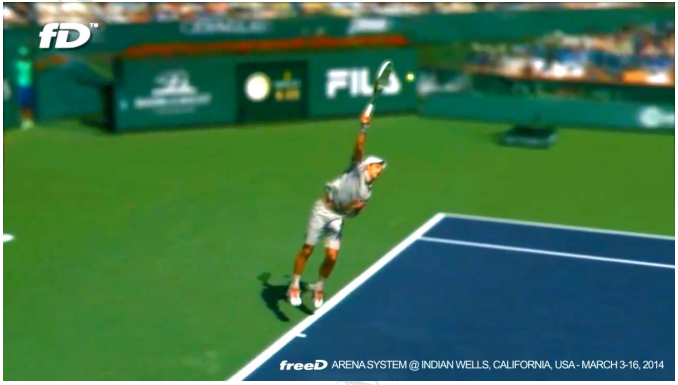
Computer vision application

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

http://www.sportvision.com/video.html

Computer vision application—cont.

- Multiple camera-view synthesis



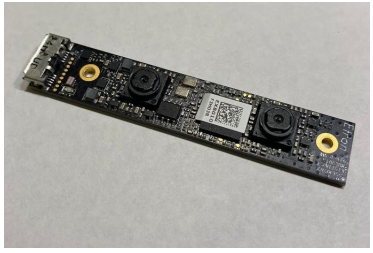
Video from Free-D company, http://replay-technologies.com/

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

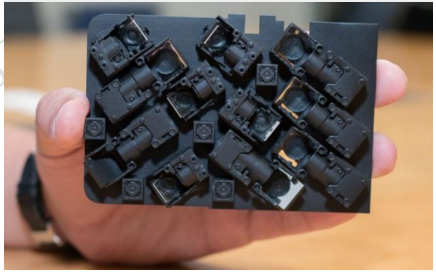
Computer vision application—cont.

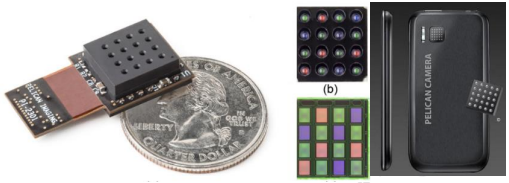
- 3D reconstruction from single image
- 2D to 3D issue

Picture from Prof. Takeo Kanade
https://www.yuvsoft.com

Computer vision application—cont.

- Image based rendering
- View synthesis

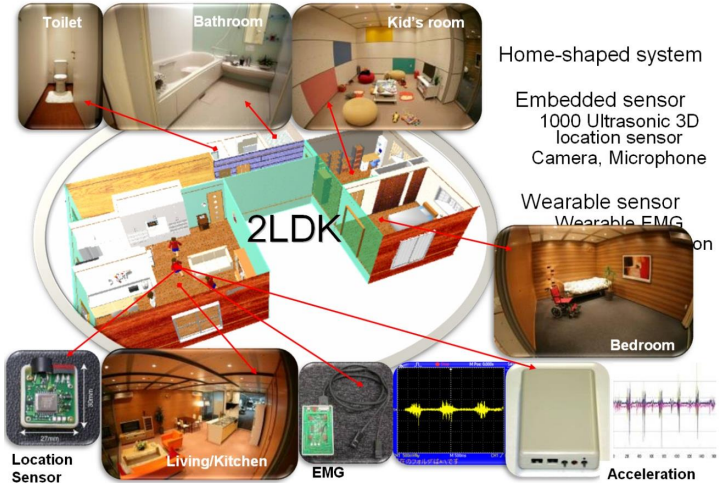




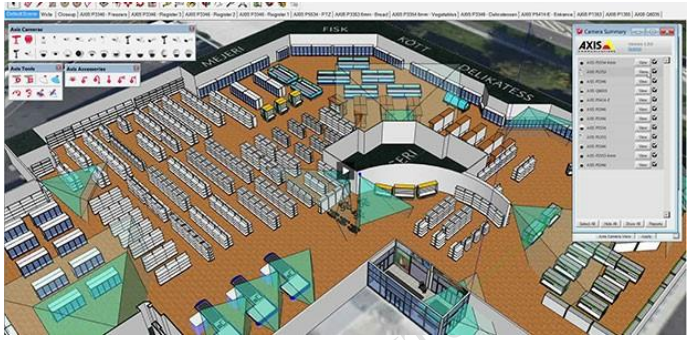
Picture from Prof. TH Chen
https://light.co/
https://www.breezesys.com/products/

Computer vision application—cont.

- Video surveillance: multiple camera array



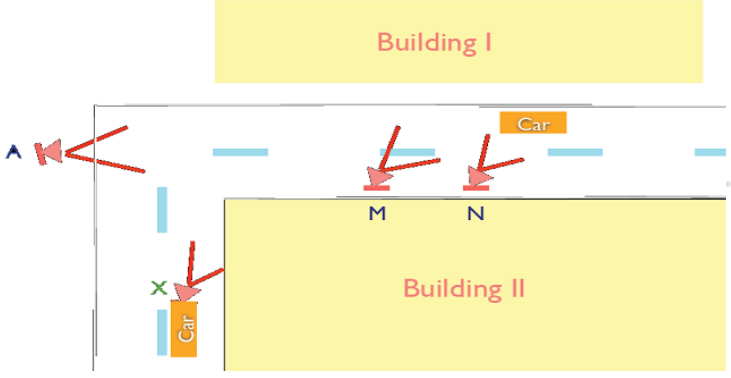
(Prof. Takeo Kanade)



https://thesecuritylion.wordpress.com/2014/02/25/axis-communications-introduces-interactive-camera-visualisations-tool-for-sketchup-3d-cad-software/

Computer vision application—cont.

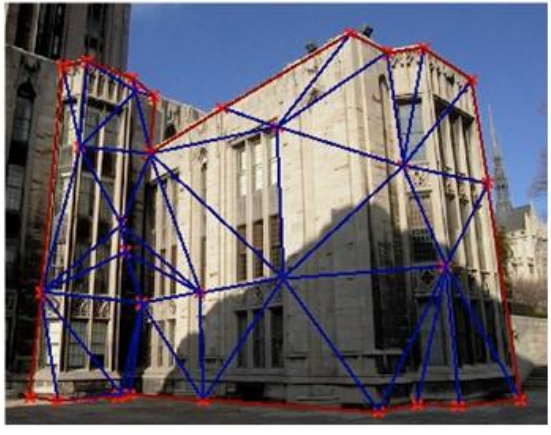
- Safety driving
- Multiple camera synthesis

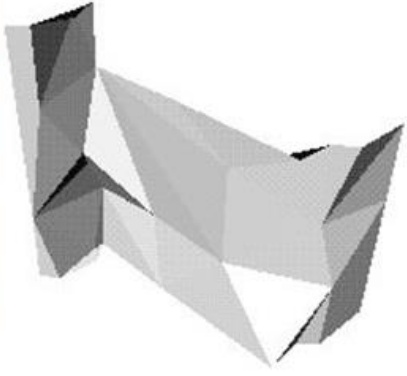


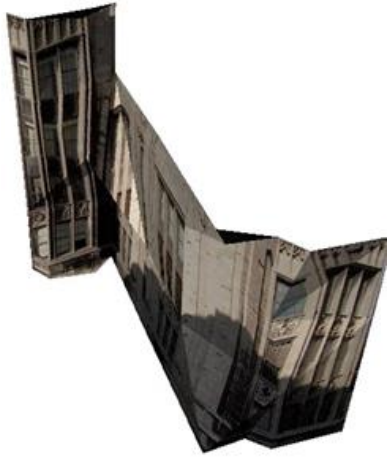
Picture from Prof. Takeo Kanade

Computer vision application—cont.

- Multiple view 3D reconstruction



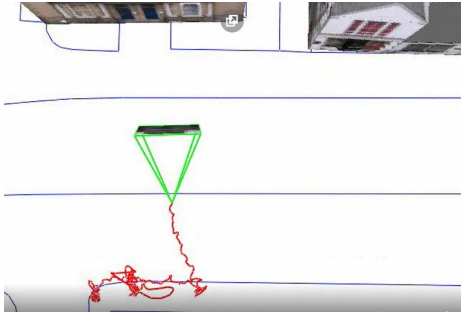




Picture from Prof. Takeo Kanade

Computer vision application—cont.

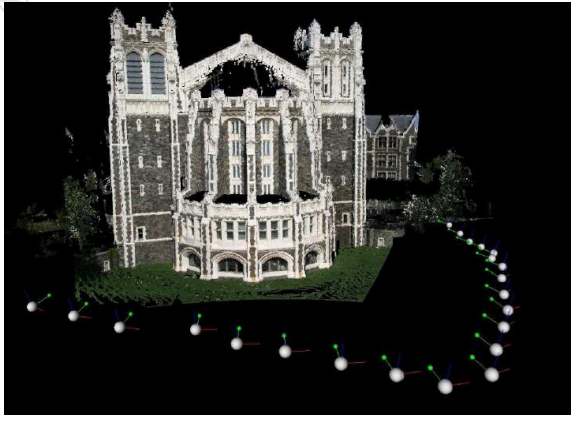
- Structure from motion
- 3D reconstruction
- Localization



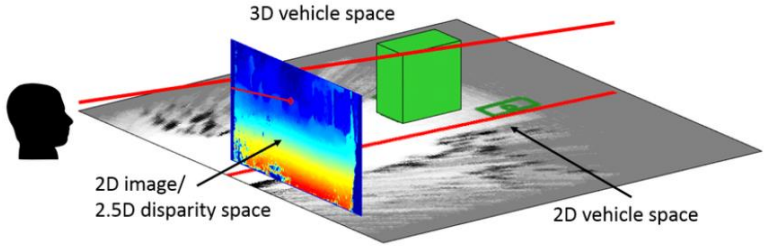
M. Pollefeys, L. Van Gool, M. Vergauwen, F. Verbiest, K. Cornelis, J. Tops, and R. Koch, "Visual modeling with a hand-held camera," *Int. J. Comput. Vis.*, vol. 59, no. 3, pp. 207–232, Sep. 2004.
K. Kolev, P. Tanskanen, P. Speciale, and M. Pollefeys, "Turning Mobile Phones into 3D Scanners," IEEE Int. Conf. Comput. Vis. Pattern Recognit., pp. 3946–3953, Jun. 2014.

Computer vision application—cont.

- Data fusion & image registration



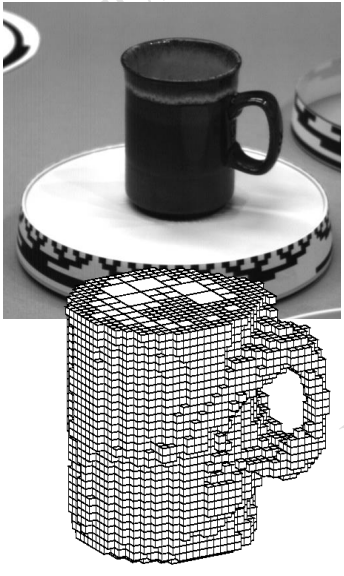
Textured model

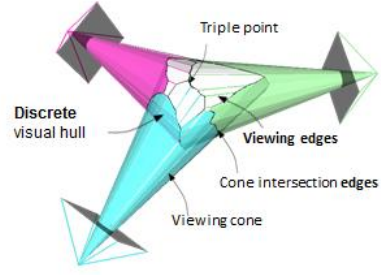


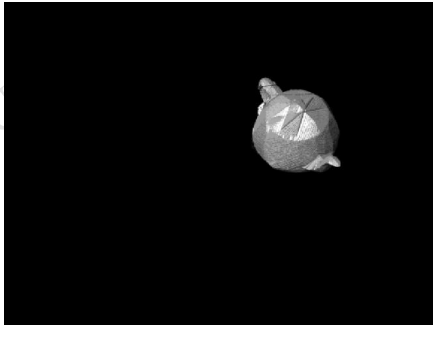
L. Liu and I. Stamos, "Automatic 3D to 2D registration for the photorealistic rendering of urban scenes," *Proc. IEEE Comput. Soc. Conf. Comput. Vis. Pattern Recognit.*, vol. 2, pp. 137–143, 2005.
Schwehr , Driver's Gaze Prediction in Dynamic Automotive Scenes, 2017
https://www.springwise.com/innovation/mobility/futurus-AR-windscreen

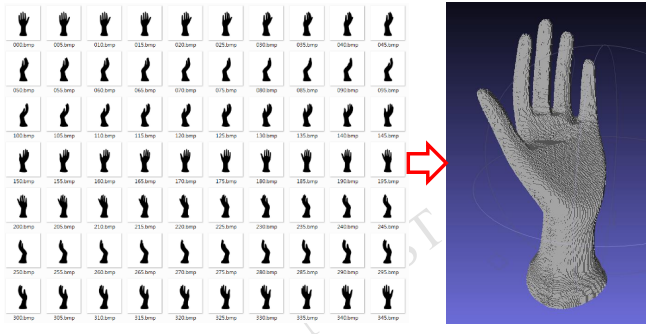
Computer vision application—cont.

- Visual hull



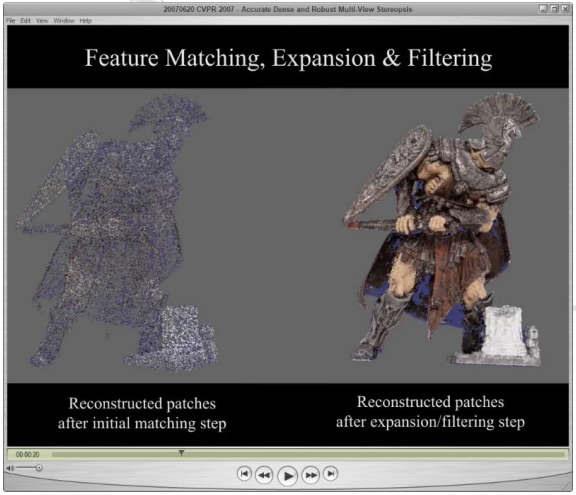






Computer vision application—cont.

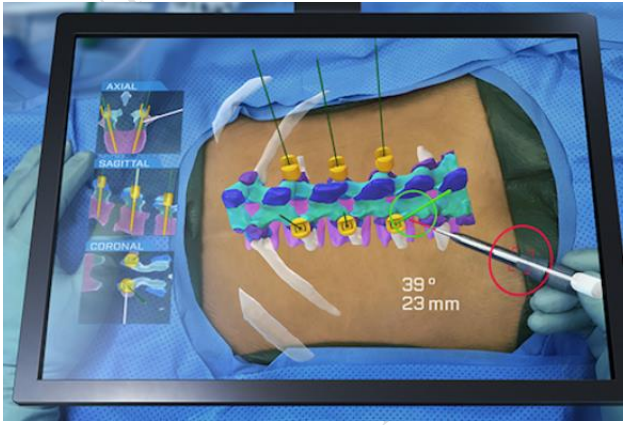
- Multi-view + stereo + photo consistency



Y. Furukawa and J. Ponce, "Accurate, dense, and robust multiview stereopsis," in *IEEE International Conference on Computer Vision and Pattern Recognition*, 2007, vol. 32, no. 8, pp. 1362–1376.

Computer vision application—cont.

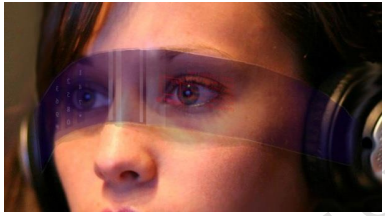
- Augmented Reality in surgery



TUM—Prof. Dr. Nassir Navab
https://www.design-engineering.com/digital-platform-utilizes-augmented-reality-for-spinal-surgery-1004032538/

Computer vision application—cont.

- AR, Mobile computing
- PS3/PS4 game



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

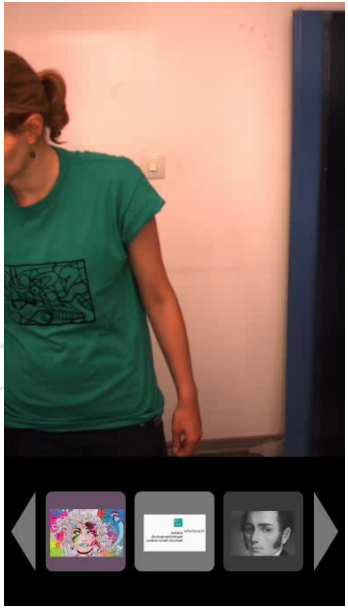
Computer vision application—cont.

- Visual Effect

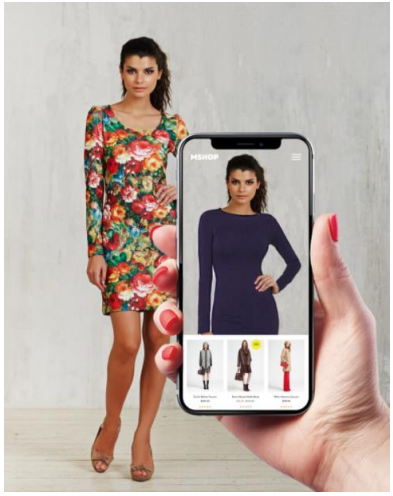
https://www.youtube.com/watch?v=clnozSXyF4k
https://www.youtube.com/watch?v=WhN1STep_zk&feature=player_detailpage

Computer vision application—cont.

[virtual dressing]



[ICIP 2008]



A. Hilsmann and P. Eisert, “Optical flow based tracking and retexturing of garments,” in *IEEE International Conference on Image Processing*, 2008, pp. 845–848.

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Color and Illumination Technology

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