電腦視覺與應用
Computer Vision and Applications

Lecture-01 Introduction

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

Course information:

- 電腦視覺與應用(CI5336701) Computer Vision and Applications

- Place: IB611
- Time: Fri. Am.9:20~12:10 (F2, F3, F4)

Instructor：林宗翰 (Tzung-Han Lin)

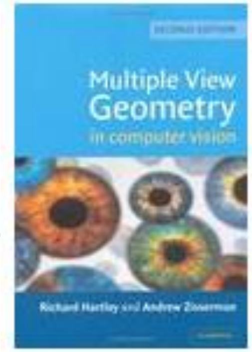
- E-mail: thl@mail.ntust.edu.tw
- Office: IB1037, 國際大樓10F
- Web: http://homepage.ntust.edu.tw/thl/
- Office hour: Wed. 13:30~15:30 (regular), or by appointment.
- Ext: 3717.   (phone: 0227303717)
- TA(暫訂): 劉宇倫 (d10322501@mail.ntust.edu.tw)

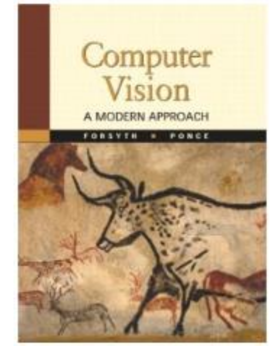
Course outline

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.

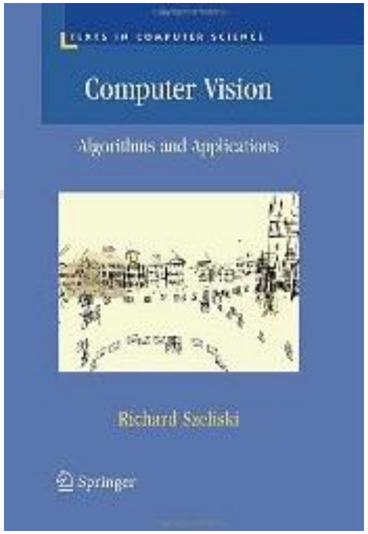
3). "**Computer Vision, A Modern Approach**," David A. Forsyth and Jean Ponce, Prentice Hall.

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

Course material

Miscellaneous materials

1. Selected Papers
2. OpenCV &Matlab (practice)
3. ARToolkit (optoional)



Grade of final mark

- Participation (10%)
- 2 to 4 homework assignments (35%)
- Midterm project (25%)
- Final project (30%)

歷年成績分佈

- 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			

歷年成績分佈

課程正面回饋意見

年度	課號	課程中英文名稱	正面意見彙整
104(二)	CI5336701	電腦視覺與應用 Computer vision and applications	1. 了解電腦視覺的理論與應用 2. 有實作應用，讓人更加了解電腦視覺 3. 論文可能會用到 4. 實際操作讓人有感 5. 老師教學認真，且考慮到每個同學程度不同，在上課講解及作業都有做更詳細的引導
103(二)	CI5336701	電腦視覺與應用 Computer vision and applications	1. 內容實際 2. 相關領域與概念概述，實作應用 3. 老師有與業界交流，所以很清楚如何將三維技術應用在產業，這點很對學生很有幫助。 4. 老師會將學術應用在產業，感覺超強也超帥。 5. FANTASTIC
102(二)	CI5336701	電腦視覺與應用 Computer vision and applications	1. 理論與實作並用
101(二)	CI5336701	電腦視覺與應用 Computer vision and applications	1. Good 2. 老師教的超棒，私下問私下問題也樂於解答！ 3. 上課學到很多,老師課餘也很願意為學生解惑,超棒的老師! 4. 希望老師未來能夠繼續開課，真的收穫良多，謝謝您 5. VERY GOOD
100(二)	CI5336701	電腦視覺與應用 Computer vision and applications	1. 理論和範例互相說明

Course agenda (tentative)

週次	日期	事項	課程進度(暫訂)	預定事項
1	2017/2/24		Introduction	
2	2017/3/3		pin-hole camera model Introduction to OpenCV (supplemenal material)	
3	2017/3/10		Visual Hull case study	Homework#1 Assignment
4	2017/3/17		projective 2D geometry	
5	2017/3/24		projective 2D geometry	Homework#2 Assignment
6	2017/3/31		Estimation for 2D Projective Transformations	
7	2017/4/7		Projective 3D geometry	Midterm Assignment
8	2017/4/14		Two-views geometry	
9	2017/4/21	期中考週	Two-views geometry	
10	2017/4/28		Midterm Exam	
11	2017/5/5		Two-views geometry / case study	Homework#3 Assignment
12	2017/5/12		Camera Calibration	
13	2017/5/19		Camera Calibration / 3D reconstruction (vision base)	Homework#4 Assignment
14	2017/5/26		3D reconstruction (vision base)	
15	2017/6/2		Feature Detection and Matching	Final Project Assignment
16	2017/6/9		Argumented Reality Application	
17	2017/6/16	停課		
18	2017/6/23	期末考週	Final Project Due	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 “C/C++” or “Matlab”)

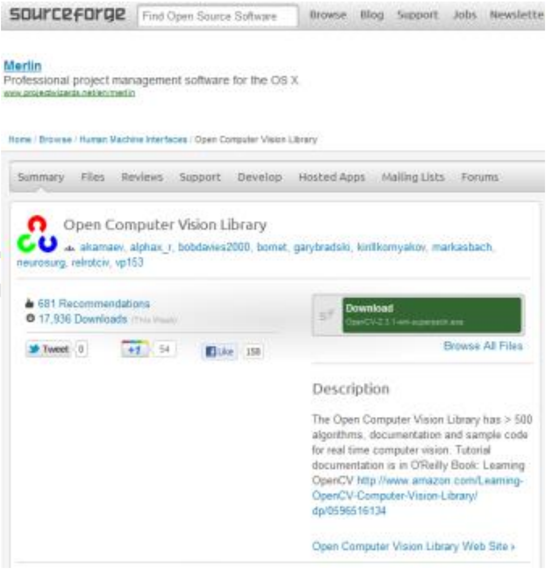
Couse further objective

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.

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

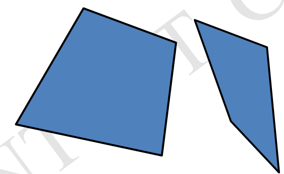

Captured image


synthesized image

Transformations (planar mapping)

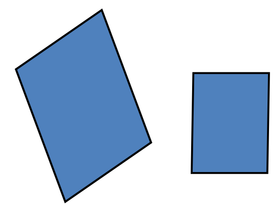
Projective
8dof

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



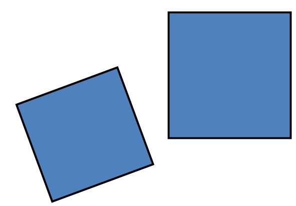
Affine
6dof

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



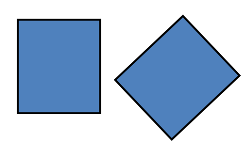
Similarity
4dof

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



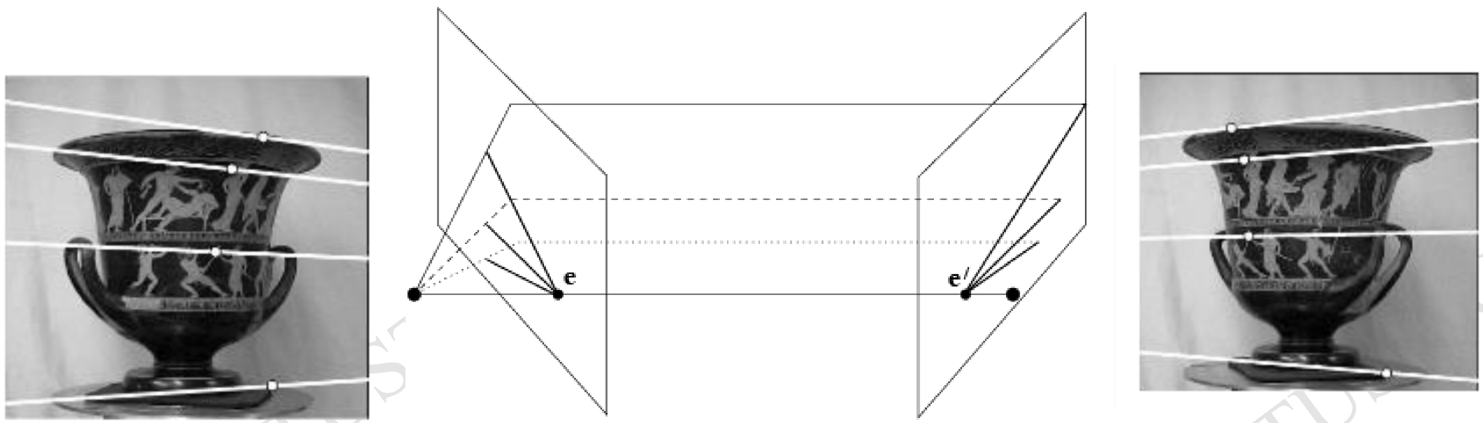
Euclidean
3dof

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



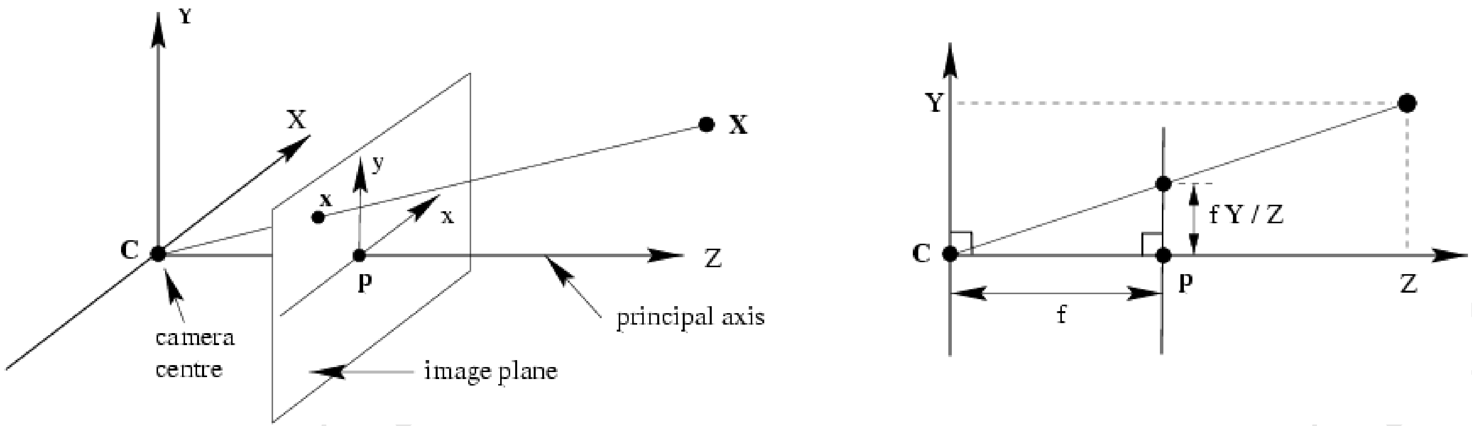
Two view geometry: Epipolar geometry

- Picture from book: Multiple View Geometry in Computer Vision



Camera models

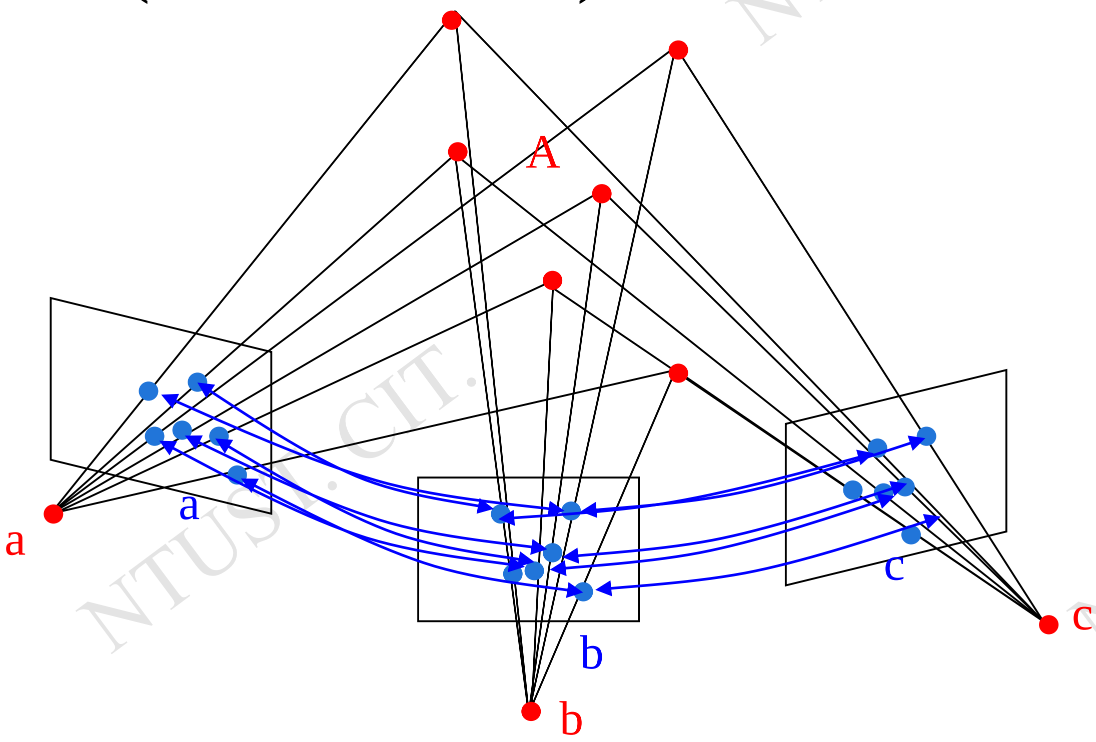
- Picture from book: Multiple View Geometry in Computer Vision



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

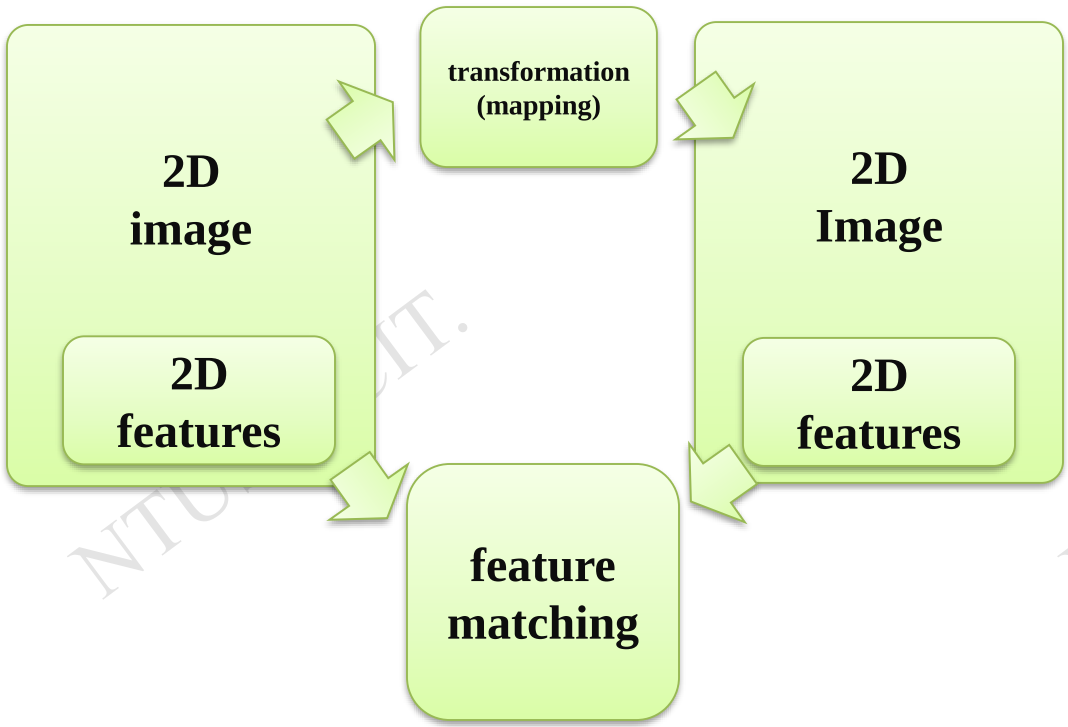
Camera models

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



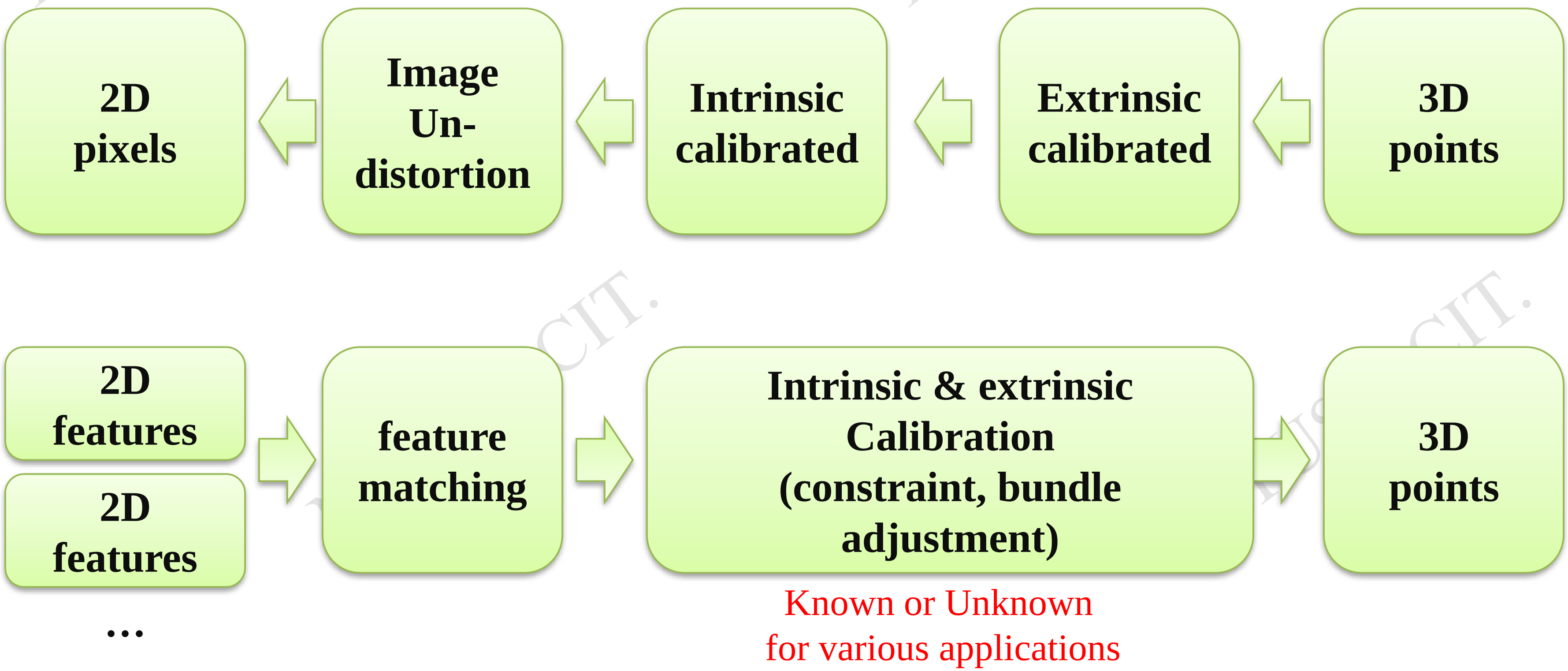
Application and pile line

- Top-down & bottom-up applications



Application and pile line

- Top-down & bottom-up applications

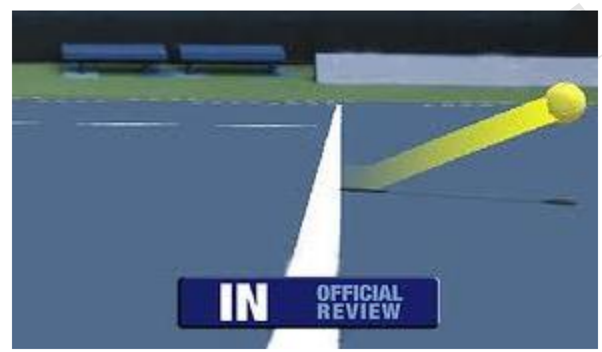


Standard operating procedure (SOP)

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

- Add “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/

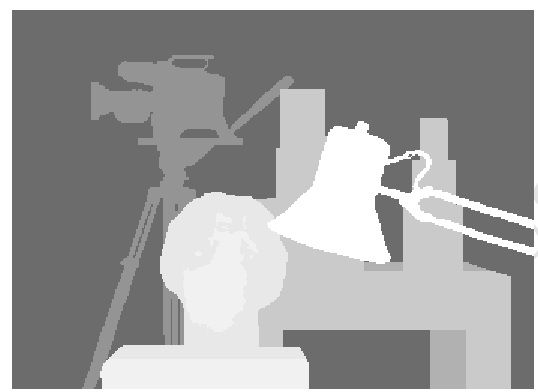
Computer vision application—cont.

- Stereoscopic camera

depth info.

3D reconstruction
(pointgrey product)

Microsoft/Apple Kinect (interaction)



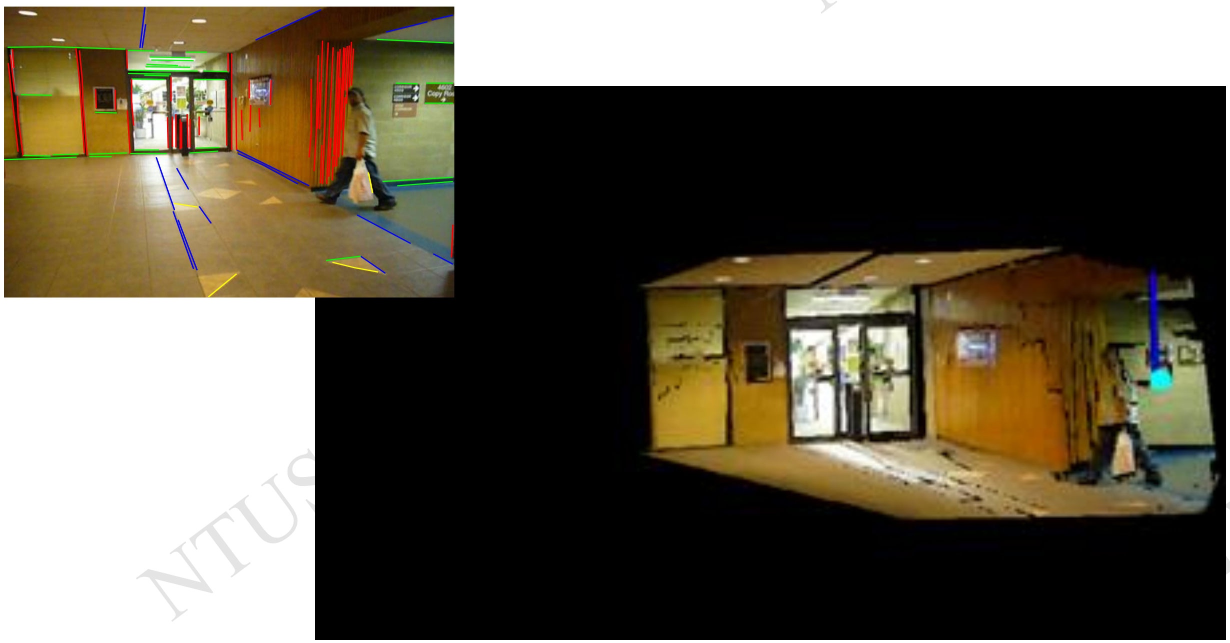
depth map

Computer vision application—cont.

- Conventional problem : Object detection and tracking

Computer vision application—cont.

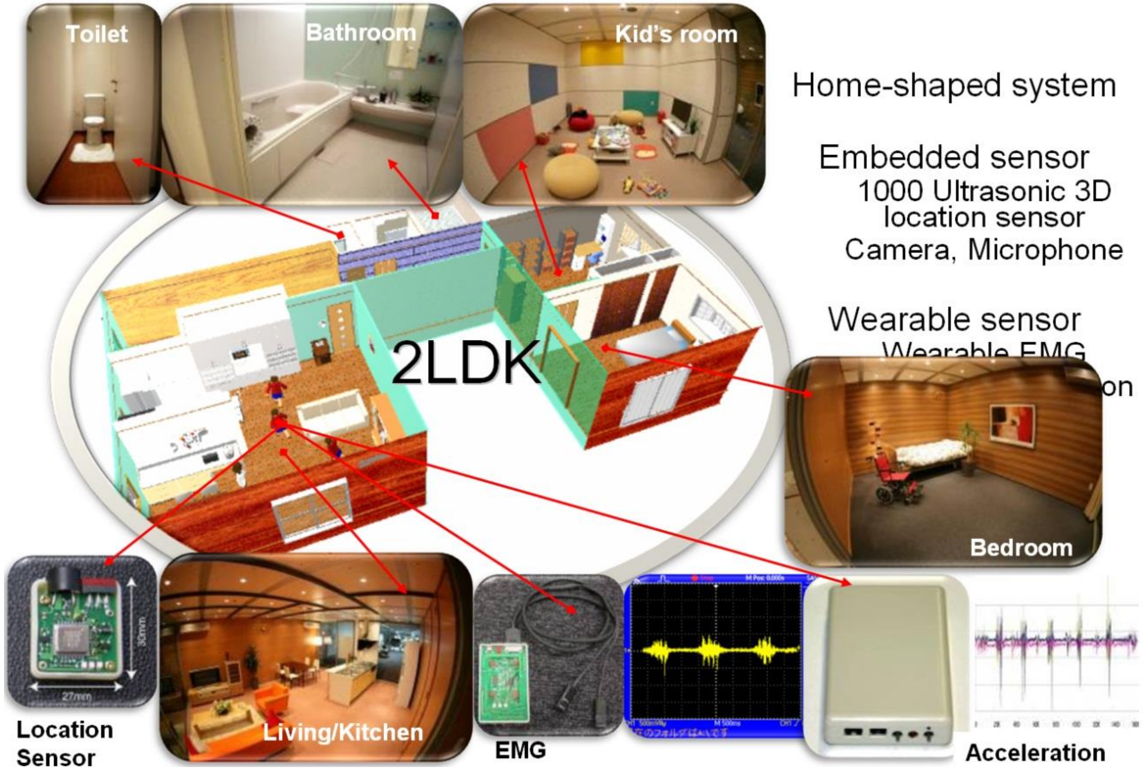
- 3D reconstruction from single image
- 2D to 3D



Picture from Prof. Takeo Kanade

Computer vision application—cont.

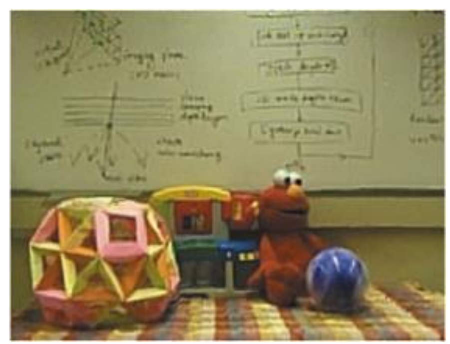
- Video surveillance: multiple camera array

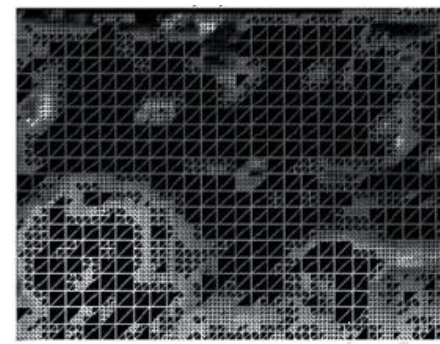


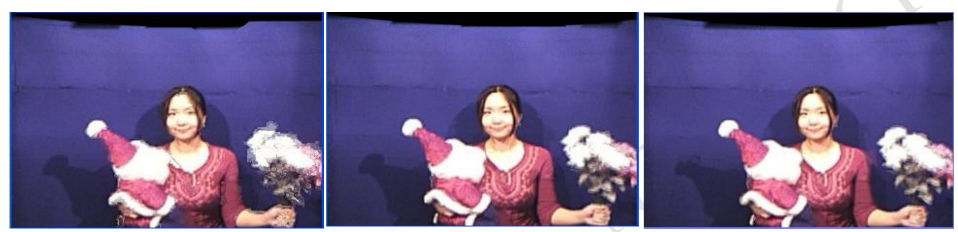
(Prof. Takeo Kanade)

Computer vision application—cont.

- Image based rendering
- View synthesis



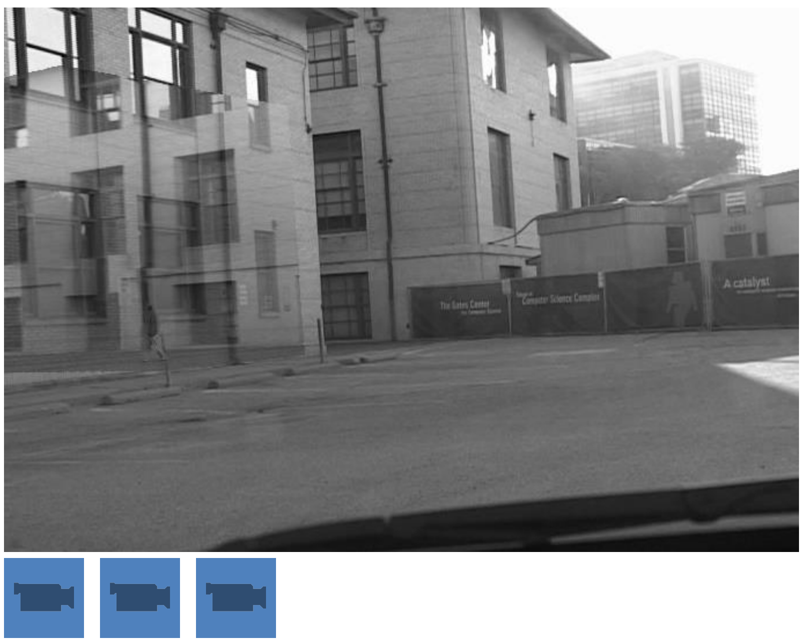


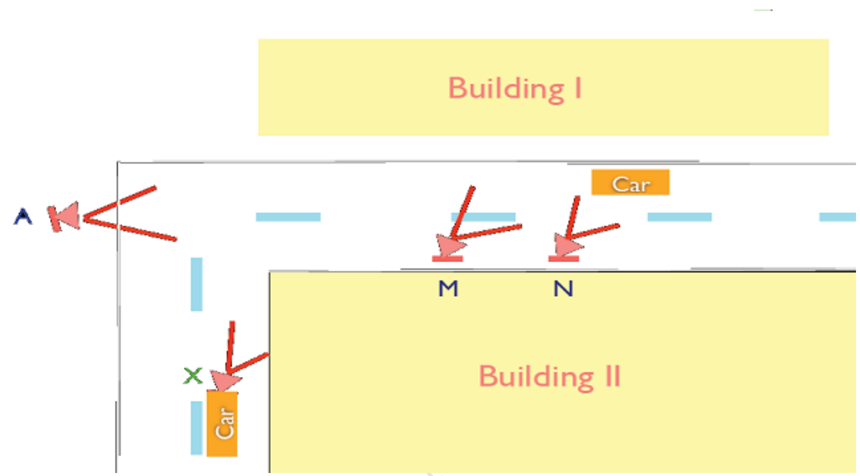


4x4 12x12 24x24

Computer vision application—cont.

- Safety driving
- Multiple camera synthesis

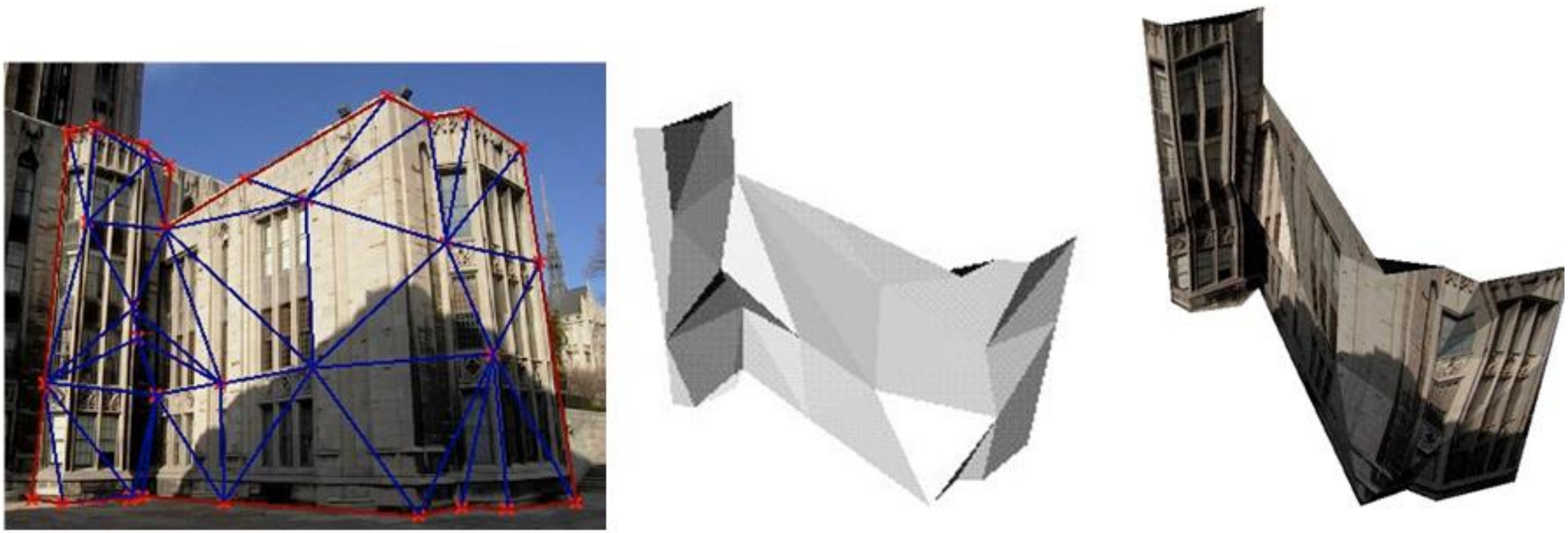




Picture from Prof. Takeo Kanade

Computer vision application—cont.

- Multiple view 3D reconstruction



Picture from Prof. Takeo Kanade

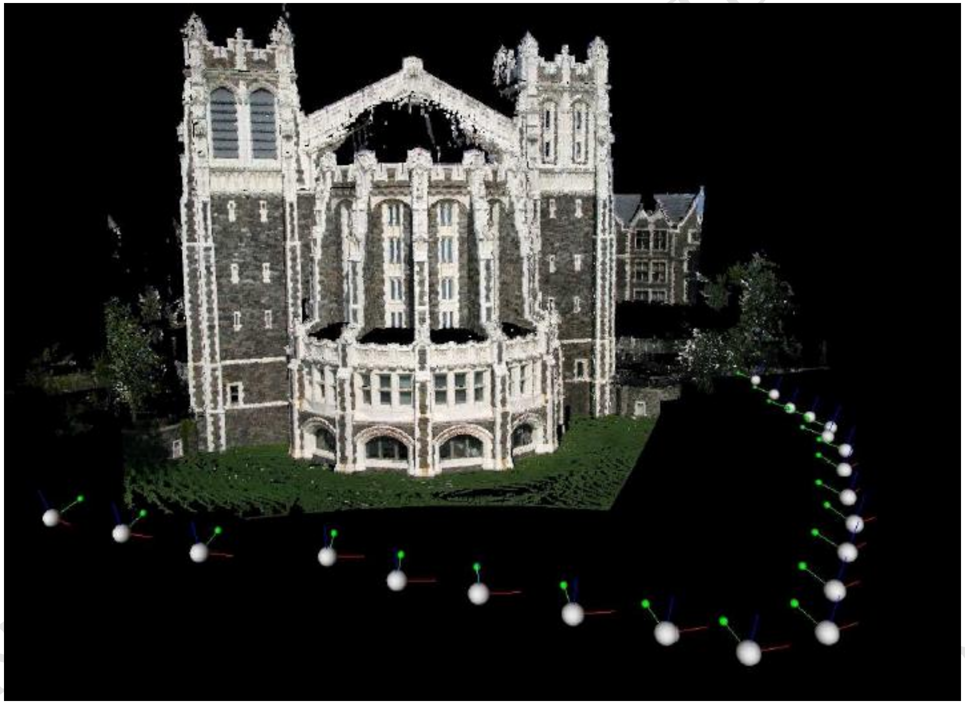
Computer vision application—cont.

- Structure from motion
- 3D reconstruction

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

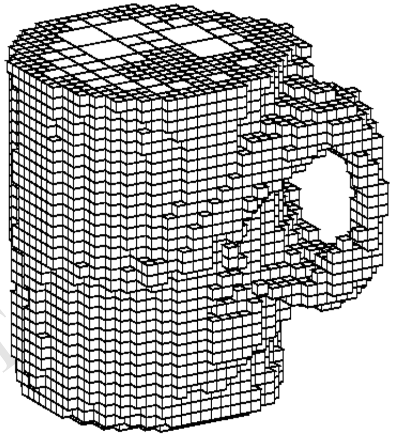


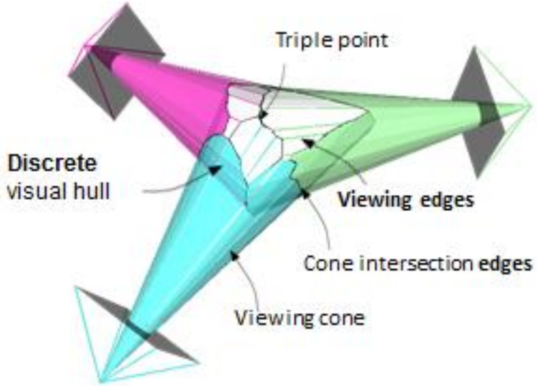
Textured model

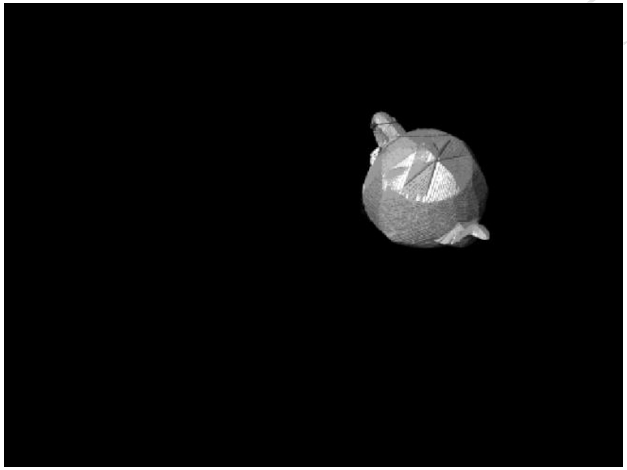
L. Liu and I. Stamos, "Automatic 3D to 2D registration for the photorealistic rendering of urban scenes," *Proc. IEEE Comput. Soc. Conf. Comput. Vis. Pattern Recognit.*, vol. 2, pp. 137–143, 2005.

Computer vision application—cont.

- Visual hull

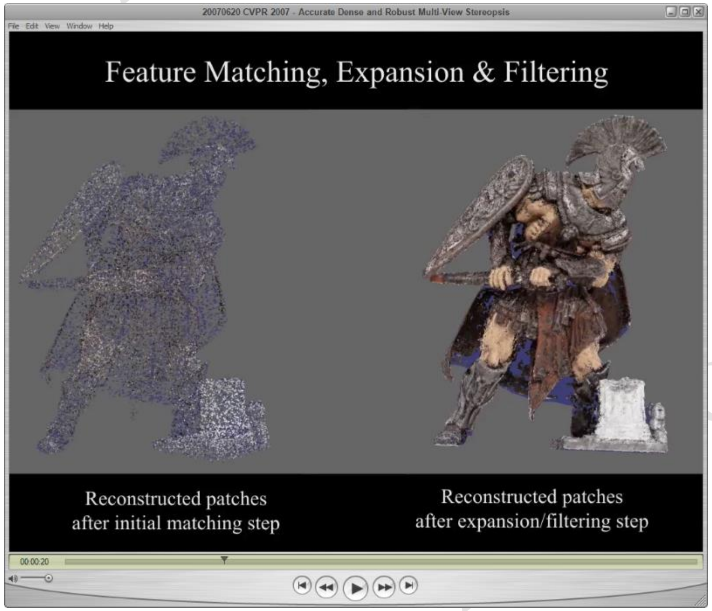






Computer vision application—cont.

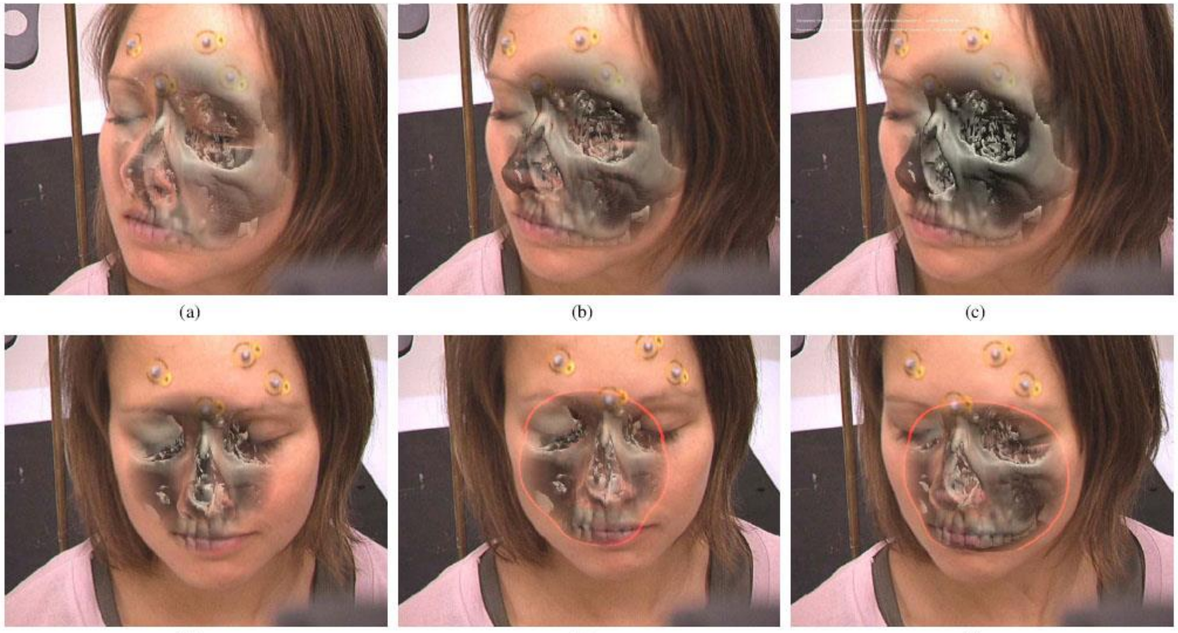
- Multi-view + stereo + photo consistency



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.

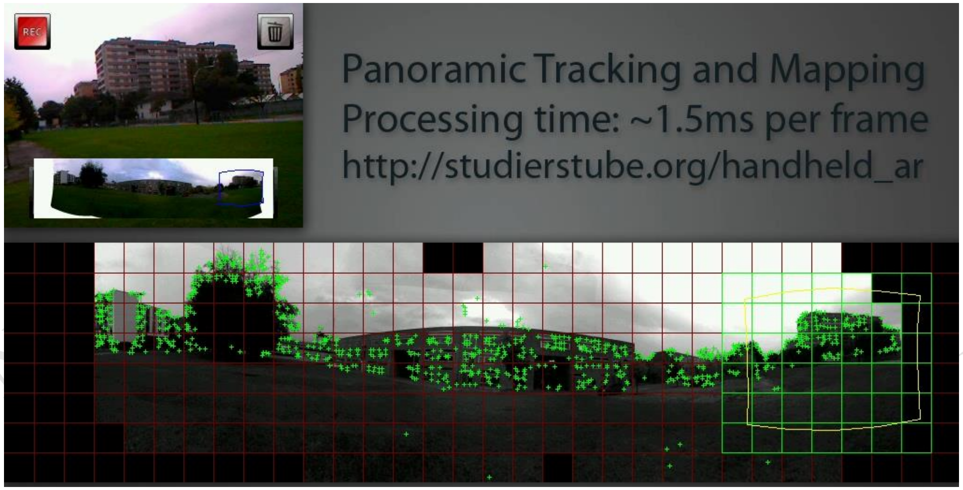
- Augmented Reality on surgery



(a) (b) (c) (d) (e) (f)

Computer vision application—cont.

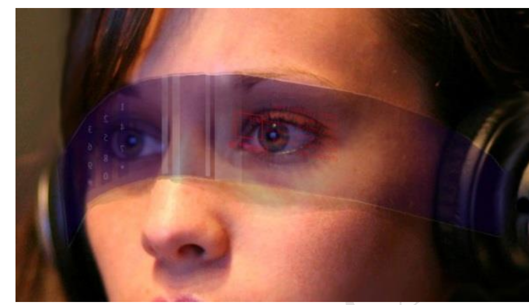
- Panorama / image stitching



http://www.cs.bath.ac.uk/brown/autostitch/autostitch.html

Computer vision application—cont.

- AR, Mobile computing
- PS3/PS4 game



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

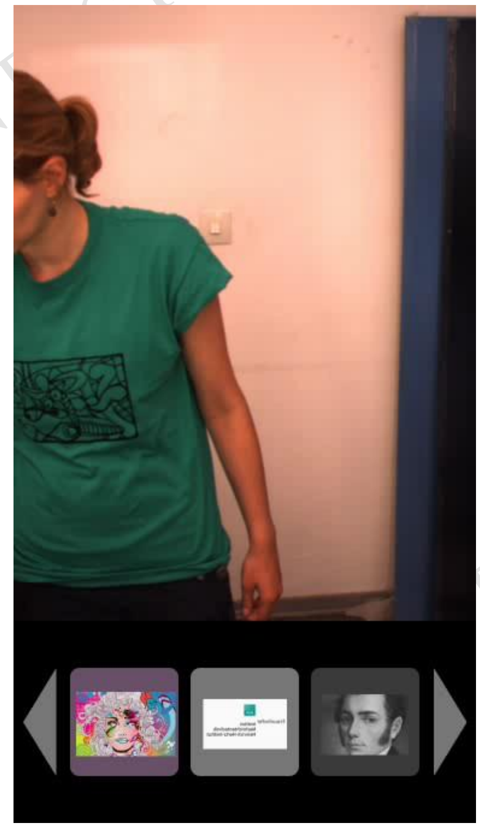
Computer vision application—cont.

- 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.

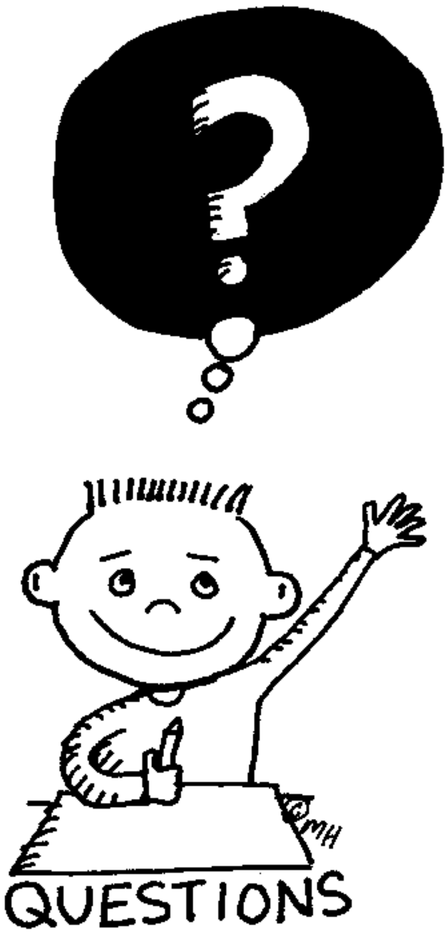


Figure from : http://www.gabankruptcylawyersnetwork.com/files/2014/08/question.gif