Computer Vision

No. 1
What is the Computer Vision?

Instructor

- Katsushi Ikeuchi
- Takeshi Oishi
- Masataka Kagesawa
- Rei Kawakami
- Yasuhide Okamoto
- Shintaro Ono
- Bo Zheng

Pointers

- 03-5452-6242
- cvl-sec@cvl.iis.u-tokyo.ac.jp
- 東京都目黒区駒場４－６－１
  東大生研　Ee405

Pre-requisite

- This course mainly reads recent research papers on computer vision
- If you have not taken one of the followings:
  - Grad: 学際情報学基礎IV　（学際情報学府）
  - UnGrad: コンピュータビジョン（理学部情報科学）

  I strongly discourage you to take this course

Evaluation

- attendance 50%
- Report 50%

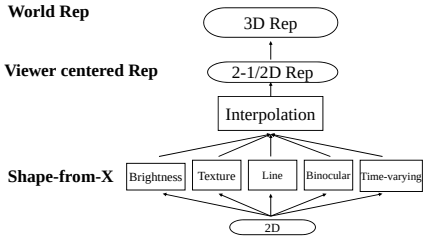
Class document

- Report submission:
  cvl-class-2012w@cvl.iis.u-tokyo.ac.jp
- Hand-out
  http://www.cvl.iis.u-tokyo.ac.jp/class/grad

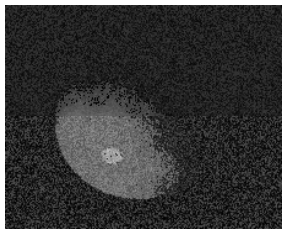
Computer Vision (CV)

- To make a computer to recognize the 3D world as we do
- To generate 3D representations from 2D images

Marr's Paradigm

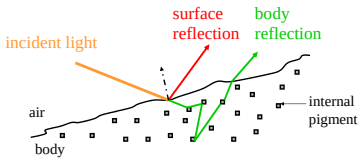


Shape-from-Shading



Surface and body reflection

- Surface reflection and body reflection



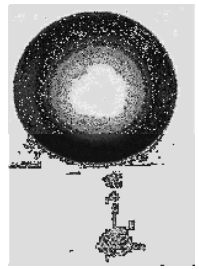
surface reflection=gloss,highlights very directional(specular)
body reflection =object color all direction(diffuse)
plastic, paint have both
metal has only surface reflection

Model for body reflection

Diffuse---scatters in all directions
common approximation:
equal in all directions
"lambertian"Lambertian's cosine law
"perfectly diffuse reflector"
reflectance=constant * geometric factor
f(i,e,g) = Kb * cos i
why cos i ?

angle of incidence affects "density" of illumination.(irradiance)

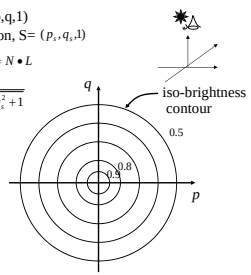
irradiance=light/area
light=1
area=1/cos i
irradiance = cos i



Calculating a reflection map (Lambertian)

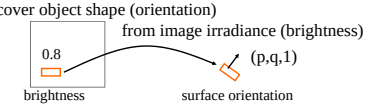
- for each(p,q), N=(p,q,1)
- light source direction, S= $(p_s,q_s,1)$

$$R(p,q,p_s,q_s)=\cos i = N \bullet L$$
$$=\frac{p\cdot p_s+q\cdot q_s+1}{\sqrt{p^2+q^2+1}\sqrt{p_s^2+q_s^2+1}}$$
$$(p_s,q_s)=(0,0)$$
$$R(p,q)=\frac{1}{\sqrt{p^2+q^2+1}}$$

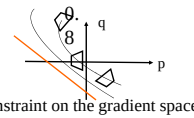


Shape-from-shading

recover object shape (orientation)
from image irradiance (brightness)



E(x,y)=R(p,q) -- image irradiance equation



gives one constraint on the gradient space at each pixel
--- > ill-posed problem (cannot solve !!!!!)

Shape-from-shading

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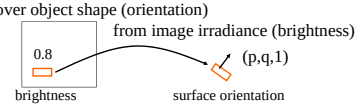

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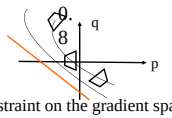

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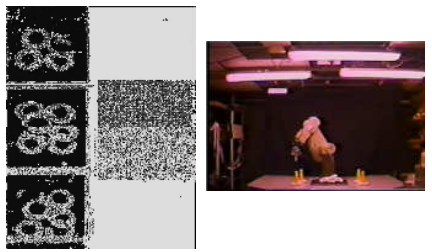


Relaxation method

3. Set up a minimization problem.

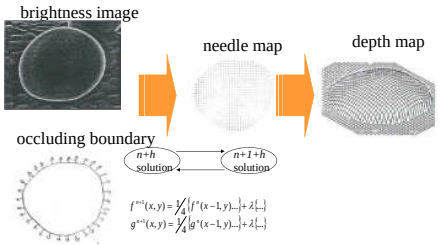
$$E = \iint (E(x,y) - R(f(x,y), g(x,y)))^2 + \lambda \left\{ \left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial y}\right)^2 + \left(\frac{\partial g}{\partial x}\right)^2 + \left(\frac{\partial g}{\partial y}\right)^2 \right\} dxdy \rightarrow \min$$

4. Using the calculus of variations get iterative formula.

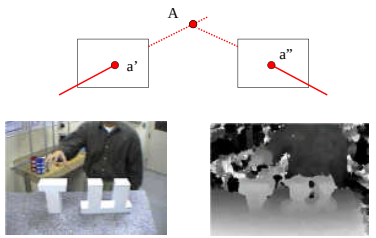
$$f^{n+1}(x,y) = \tfrac{1}{4}\{f^n(x+1,y) + f^n(x-1,y) + f^n(x,y+1) + f^n(x,y-1)\} + \lambda\{E(x,y) - R(f^n(x,y), g^n(x,y))\}$$

$$g^{n+1}(x,y) = \tfrac{1}{4}\{g^n(x+1,y) + g^n(x-1,y) + g^n(x,y+1) + g^n(x,y-1)\} + \lambda\{E(x,y) - R(f^n(x,y), g^n(x,y))\}$$

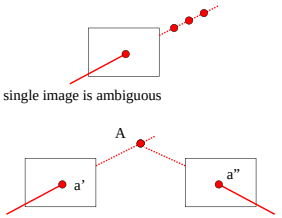
Ikeuchi & Horn 81



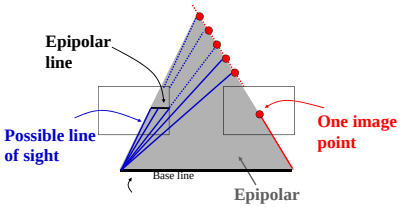
Binocular Stereo



Binocular stereo



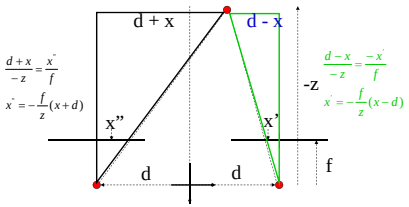
Epipolar line constraints



Corresponding points lie on the Epipolar lines

Epipolar line constratints

Basic binocular stereo equation



$\frac{d+x}{-z} = \frac{x''}{f}$ $\quad x'' = -\frac{f}{z}(x+d)$

$\frac{d-x}{-z} = \frac{-x'}{f}$ $\quad x' = -\frac{f}{z}(x-d)$

$x'' - x' = -\frac{f}{z}(x+d-x+d) = -\frac{f}{z}2d$

z=-2df/(x"-x')

x"-x': disparity

2d : base line length

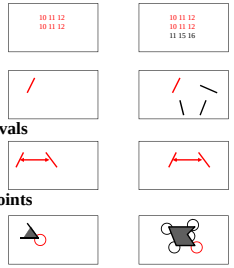
Features for matching

a. brightness

b. edges

c. edge intervals

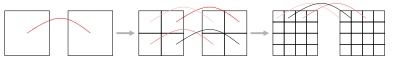
d. interest points



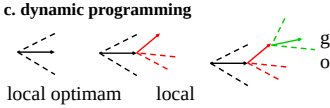
Strategies for matching

a. relaxation

b. coarse to fine



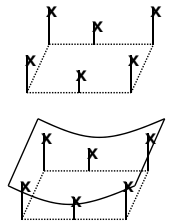
c. dynamic programming



$f(x_1, x_2, x_3) = f_1(x_1) + f_2(x_1, x_2) + f_3(x_2, x_3)$

Interpolation

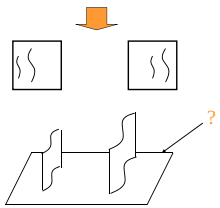
Surface Interpolation



Purpose of surface interpolation 1

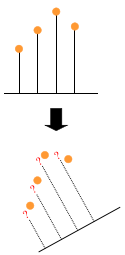
(Computer Vision)

Binocular Stereo



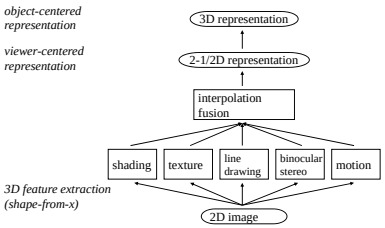
Purpose of surface interpolation 2

(Graphics)



Purpose of surface interpolation 3

(Psychology and computer vision)

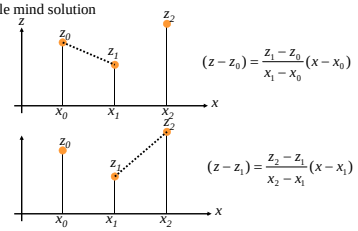


Purpose of surface interpolation 4

(Psychology)

Method 1

simple mind solution



$$(z - z_0) = \frac{z_1 - z_0}{x_1 - x_0}(x - x_0)$$

$$(z - z_1) = \frac{z_2 - z_1}{x_2 - x_1}(x - x_1)$$

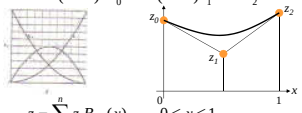
Problem:

orientation discontinuity at x_1

Method 2

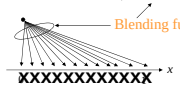
Bezier curve

3 points $z = (1-x)^2 z_0 + 2x(1-x)z_1 + x^2 z_2$



$$z = \sum_{i=0}^{n} z_i B_{i,n}(x) \qquad 0 \le x \le 1$$

$$B_{i,n}(x) = {}_nC_i u^i (1-u)^{n-i}$$



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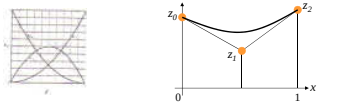
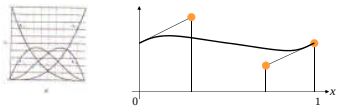
Example of Bezier curve

3 points $z = (1-x)^2 z_0 + 2x(1-x)z_1 + x^2 z_2$



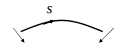
4 points $z = (1-x)^3 z_0 + 3x(1-x)^2 z_1 + 3x^2(1-x)z_2 + x^3 z_3$



Least energy curve (Snake)

- To find a curve which minimizes

1) internal energy --- bending

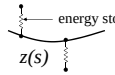


$$E_{internal} = \int_0^S bending - energy(s)ds$$

2) external energy --- intensity

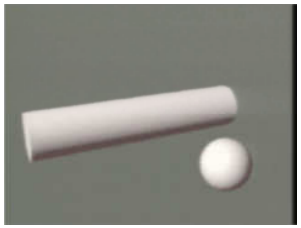
$$E_{external} = \int_0^S I(s)ds$$

3) constraint energy --- boundary

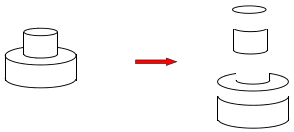


$$E_{constraint} = k(z(s) - z_0)^2$$

Falling Rug



Object Representation

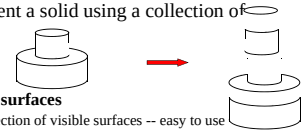


Classification of representation

- **Surface based representation**
  - represented as a collection of surfaces
    - » curvature primal sketch
    - » extended gaussian image
    - » aspect graph
    - » b-rep (winged-edge)
    - » well-tessellated surface
- **Function based representation**
  - represented as a function and its parameters
    - » generalized cylinder
    - » superquadric
    - » symmetry seeking
    - » spherical attribute image
- **Volumetric based representation**
  - represented as a collection of primitive solids
    - » constructive solid geometry
    - » occupancy graph
    - » oct-tree

Surface based representation

- Represent a solid using a collection of surfaces

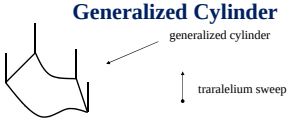


- **which surfaces**
  - * collection of visible surfaces -- easy to use
  - * collection of all surfaces -- easy to maintain
- **what is a reasonable definition**
  - * orientation discontinuity -- if range data is available, one of the most common definitions
  - * Gaussian curvature and mean curvature represent a solid using a collection of surfaces
  - * color (brightness) -- view dependent only

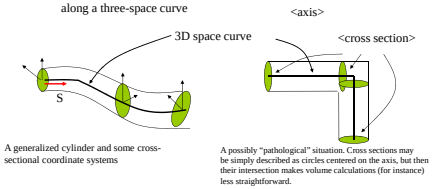
Function based representation

1. Classification of representation
2. Superquadric
3. Generalized cylinder
4. Symmetry seeking
5. Spherical attribute image

Generalized Cylinder



"the sweep volume" of a two-dimensional set moved along a three-space curve

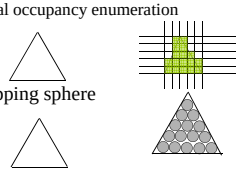


A generalized cylinder and some cross-sectional coordinate systems

A possibly "pathological" situation. Cross sections may be simply described as circles centered on the axis, but then their intersection makes volume calculations (for instance) less straightforward.

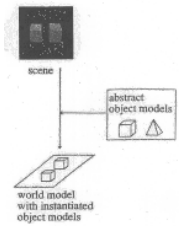
Volume based representation

- Represent a solid as a collection of primitive solids
  - – spatial occupancy enumeration



- overlapping sphere
- requires many spheres or voxels to represent to represent a relatively simple smooth solid

Object Recognition

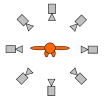


VISION FOR NAVIGATION

Autonomous Driving

VISION FOR MOTION MODELING

One way of Observation



One of eight sequences

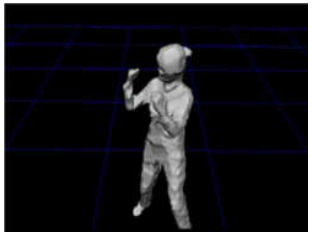
Background subtraction

Video image

Background

Human area

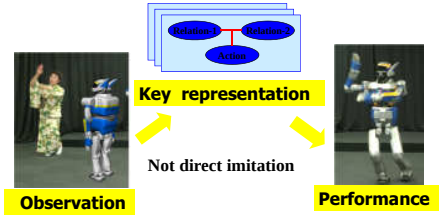
Obtained 3D Sequence

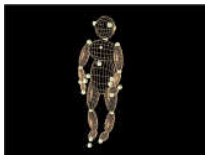


VISION FOR MOTION LEARNING

Learning from observation

Top-down approach

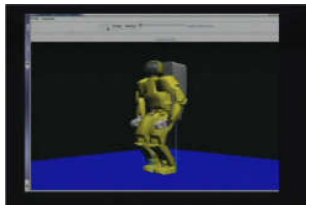




Joint angles obtained

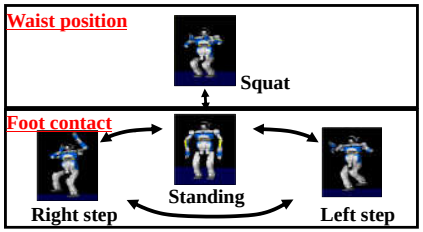
Theoretically, a robot can imitate the same dance???

Issues



AIST dynamic simulator

State transitions (lower body)



Upper body states

Costarring with the dance teacher

Nakaoka 2006, Shiratori 2007

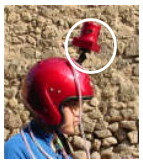
With cooperation of AIST, Kawata

VISION FOR GRAPHICS

Pompeii Walker

Pompeii Walker

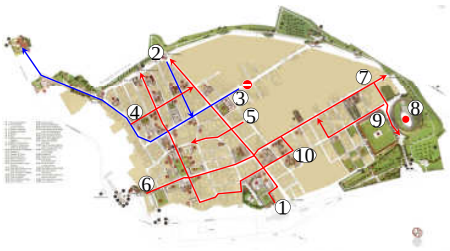
- Data collection by a probe person with a omnidirectional camera



Issues

- **Spatial Structure**
- **Vibration**

Video + GPS



Stabilization

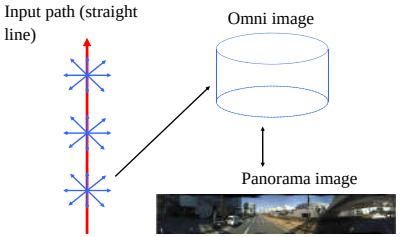
Issue in Pompeii Walker

- Can display only images along the acquisition path

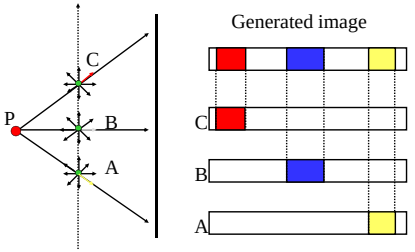
Can we?

- Generated paths different from the input one?

Image-based rendering



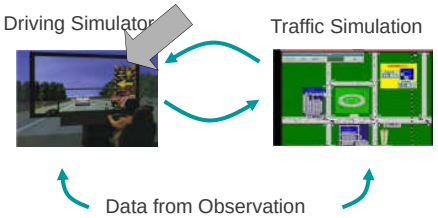
Ray space



Demonstration

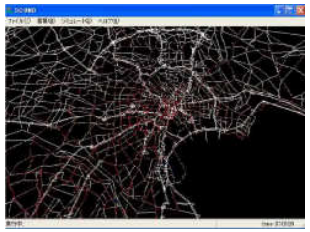
- Generated paths different from the input one

Mixed Reality Driving Environment



Traffic Simulation

(Kuwahara group)



Driving Simulator

(Suda Group)

VISION FOR VIRTUAL REALITY

3D DISPLAY: VIRTUAL ASUKA

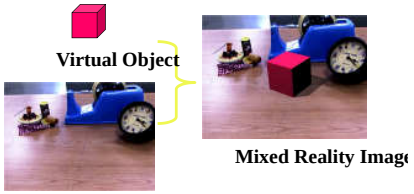
Mixed Reality Display

- Real cite
- From ancient time
- Fusion current with ancient

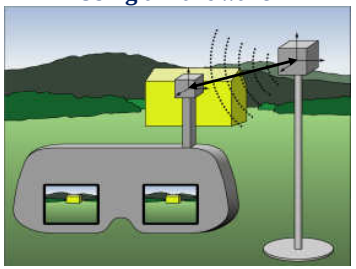
Issues in Mixed Reality

- Geometric consistency
- Photometric consistency

Geometric Consistency

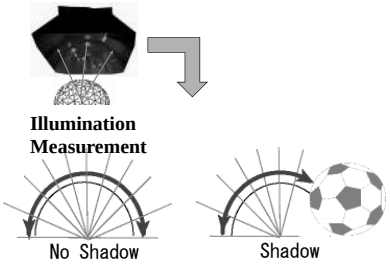


Using a Hardware



Photometric Consistency

Calculation of Shadow



Asukadera, Tyumon Gate

Issue: Occlusion

Occlusion of sight-seers
-Segmentation
-Distance estimation

Occlusion of shadows
-Segmentation
-Recasting

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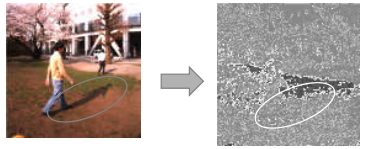
Segmentation

- Black-body assumption
- Illumination invariant



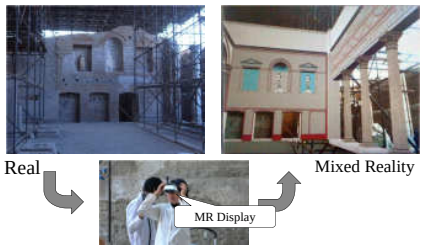
Segmentation based using invariant (no shadow)

90

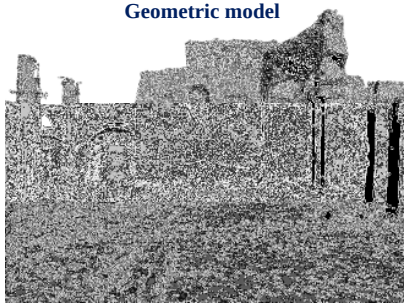
Sonnma Vesuviana

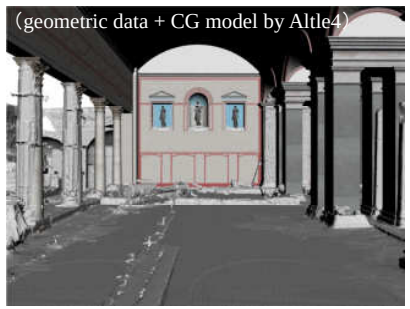
Oct 2008

MR in the Aoyagi site



Geometric model





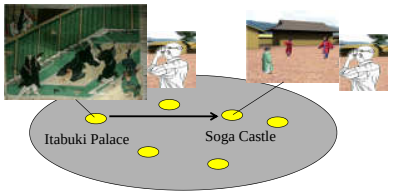
Foro Romano

Dec 2008

Proposed visit

Synchronic display

- Watching events on the site



Tram in Heijo Palace

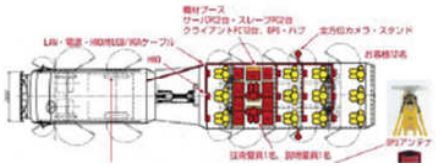
With ASUKA LAB

Issue: Location and Direction

- Location: GPS

- Direction: E. Compass＋Gyro

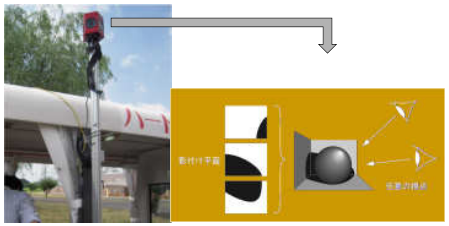
Issue: Multiple Viewers



- Image distribution
- 12 viewers

Multiple Viewers

Issues: Illumination Estimation



Illumination measurement **Real time shadow plane**

Extraction of characters from move archive

[One scene from NHK drama]

Display Video

Anyway, what is Computer Vision?

- Vision is … an information processing task that constructs efficient symbolic descriptions of the world from images. (Marr)
- Vision is … inverse graphics.
- Vision looks easy, but is difficult.
  Vision is … difficult, but is fun. (Kanade)
- Vision is an engineering science to create an alternative of human visual systems on computers（Ikeuchi）

References

- Journals
  - Inter. J. Computer Vision
  - IEEE Trans. Pattern Analysis and Machine Intelligence
  - IEICE D-2
  - IPSJ Trans CVIM
- International conferences
  - Inter. Conf. Computer Vision (ICCV)
  - Computer Vision and Pattern Recognition (CVPR)
  - Asian Conf. Computer Vision (ACCV)
- Special interest groups
  - IPSJ CVIM
  - IEICE PRMU

Schedules

- Shape-from-X
  - Time varying images — Dec 4 & Oct 11 — Ono
  - Color analysis — Oct 23 & Oct 30 — Kawakami
  - 3D Data Processing — Jan15 & Jan 22 — Oishi
- Interpretation
  - Object representation — Nov20 & Nov27 — Zheng
  - Object recognition — Nov 6 & Nov 13 — Kagesawa
  - 3D visualization — Dec 18 & Jan 8 — Okamoto

Issues

- Purpose: to Recognize 3D Objects for Grasping
- How to obtain 3D info: Light-projection
- How to represent objects:
  - Snake-based segmentation
  - Superquadric