디지털영상처리II (2021학년도 2학기)

5주: 영상특징과 서술자(2)

김 남 규 (ngkim@deu.ac.kr)

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1 모서리(corner) 검출

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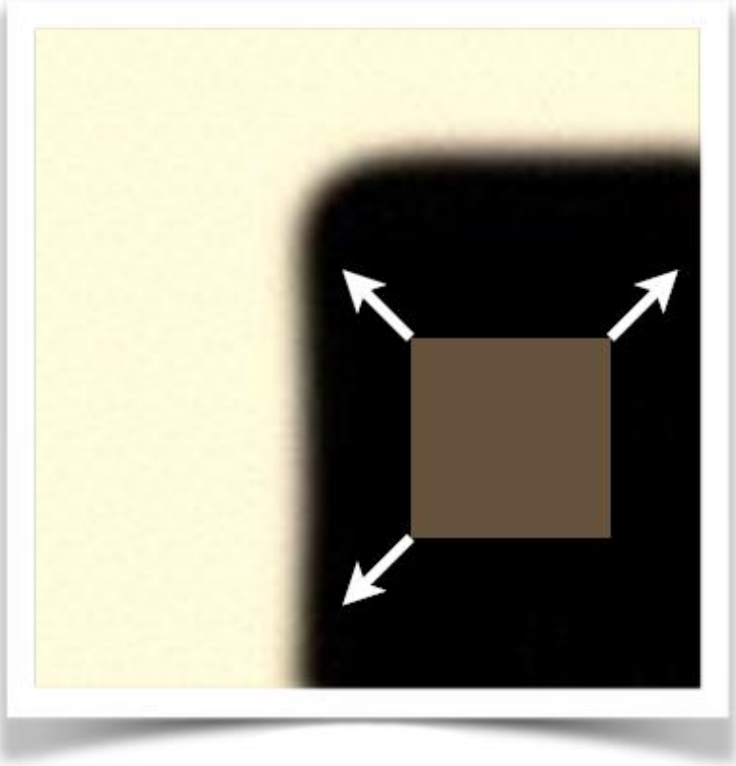
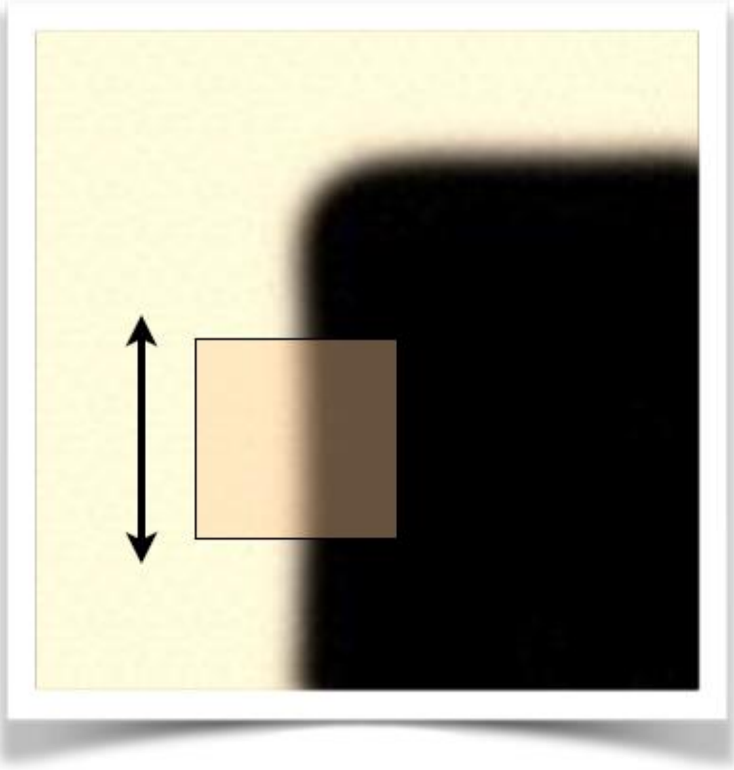
지역 특징(local feature) 관찰 (by Moravec 1980)



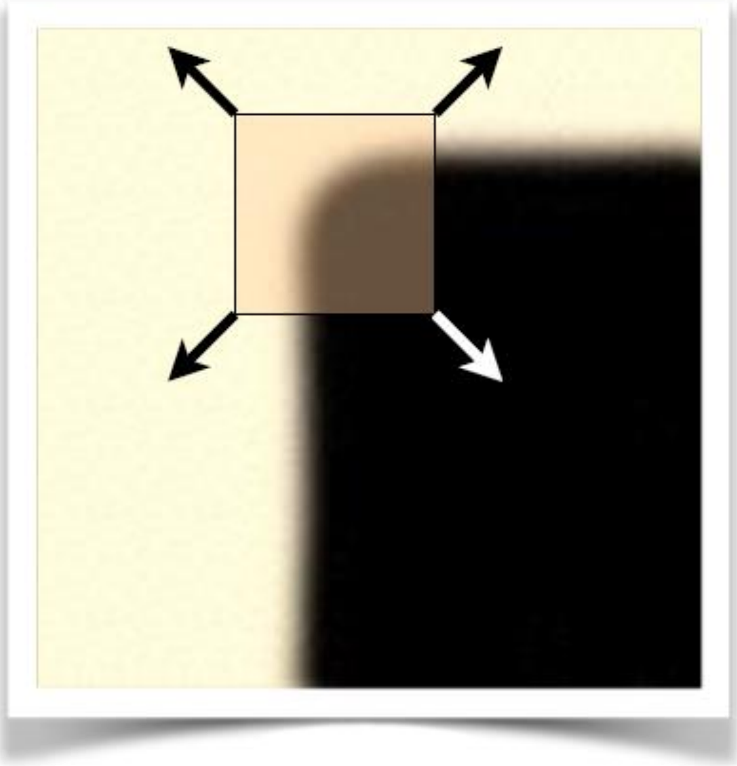
평면(flat) 영역

어떤 방향에도 변화가 없음



경계(edge) 영역

경계 방향으로는 변화가 없음



모서리(corner) 영역

모든 방향으로 변화가 있음

모라벡 알고리즘(1/2)

- 밝기 변화: 차의 제곱 합

$$E(u,v) = \sum_x \sum_y w(x,y)(I(x+u,y+v) - I(x,y))^2$$

		u -1	u 0	u 1
	-1	3	4	4
v	0	2	0	2
	1	4	3	2

a

		u -1	u 0	u 1
	-1	3	1	6
v	0	3	0	4
	1	3	0	3

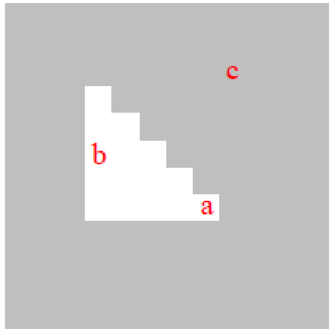
b

		u -1	u 0	u 1
	-1	0	0	0
v	0	0	0	0
	1	0	0	0

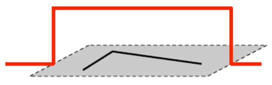
c

- a(코너): 모든 방향으로 변화가 심함
- b(에지): 에지 방향으로 변화 적지만, 수직 방향으로 변화 심함
- c(평면)와 같은 곳은 모든 방향으로 변화 적음
- a에 높은 값, c는 아주 낮은 값, b는 그 사이 값을 부여하는 함수를 만들면 됨

	0	1	2	3	4	5	6	7	8	9	10	11
0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	c 0	0	0	0
3	0	0	0	1	0	0	0	0	0	0	0	0
4	0	0	0	1	1	0	0	0	0	0	0	0
5	0	0	0	b 1	1	1	0	0	0	0	0	0
6	0	0	0	1	1	1	1	0	0	0	0	0
7	0	0	0	1	1	1	1	a 1	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0



- 윈도우 함수: $w(x,y)$, 예) 3x3 가정



1 in window, 0 outside

모라벡 알고리즘(2/2)

- 모라벡 함수: 0, 45, 90, 135도 중 최소값

$$C = \min(E(1,0), E(1,1), E(0,1), E(-1,1))$$

a

v \ u	-1	0	1
-1	3	4	4
0	2	0	2
1	4	3	2

b

v \ u	-1	0	1
-1	3	1	6
0	3	0	4
1	3	0	3

c

v \ u	-1	0	1
-1	0	0	0
0	0	0	0
1	0	0	0

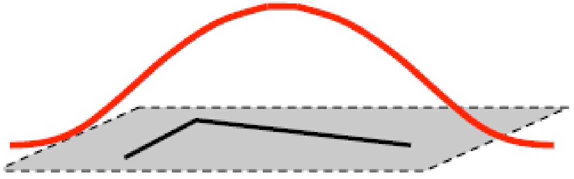
- Eg) a = 2, b = 0, c = 0

- 한계
  - 회전에 대해 의존적 ~ 회전 불변(rotation invariant)이 아님
  - 에지 점에 대해 반응이 커지거나 작아질 수 있음
  - 잡음에 대처하기 힘듦

해리스(Harris) 알고리즘(1/2)

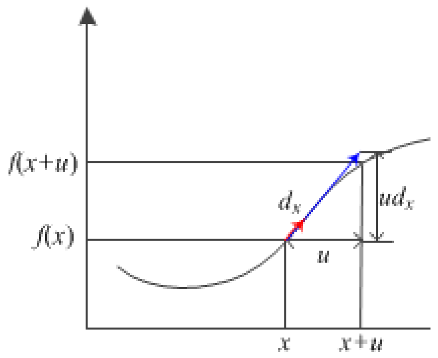
- 윈도우 함수를 가우시안 사용: 잡음 대처

$$w(x,y) = G(x,y)$$



$$E(u,v) = \sum_x \sum_y w(x,y)(I(x+u,y+v) - I(x,y))^2$$

- 테일러 확장 활용



$$I(x+u,y+v) \sim I(x,y) + u \cdot I_x(x,y) + v \cdot I_y(x,y)$$

$$E(u,v) = \sum_x \sum_y G(x,y)(uI_x + vI_y)^2 = \sum_x \sum_y G(x,y)(u^2 I_x^2 + 2uvI_xI_y + v^2 I_y^2)$$

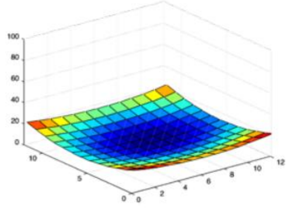
$$I_x = \frac{\partial I}{\partial x}, I_y = \frac{\partial I}{\partial y}$$

그레디언트 공분산 행렬 (gradient covariance matrix), M

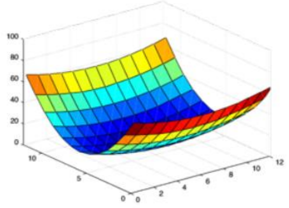
$$E(u,v)=\sum_x\sum_y G(x,y)(uI_x+vI_y)^2=\sum_x\sum_y G(x,y)(u^2I_x^2+2uvI_xI_y+v^2I_y^2)$$

$$E(u,v)=\sum_x\sum_y G(x,y)(u,v)\begin{pmatrix} I_x^2 & I_xI_y \\ I_xI_y & I_y^2 \end{pmatrix}\begin{pmatrix} u \\ v \end{pmatrix}$$

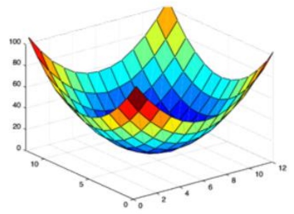
$$E(u,v)=(u,v)\begin{pmatrix} \sum\sum G(x,y)\,I_x^2 & \sum\sum G(x,y)\,I_xI_y \\ \sum\sum G(x,y)\,I_xI_y & \sum\sum G(x,y)\,I_y^2 \end{pmatrix}\begin{pmatrix} u \\ v \end{pmatrix}\approx(u,v)M\begin{pmatrix} u \\ v \end{pmatrix}$$



flat



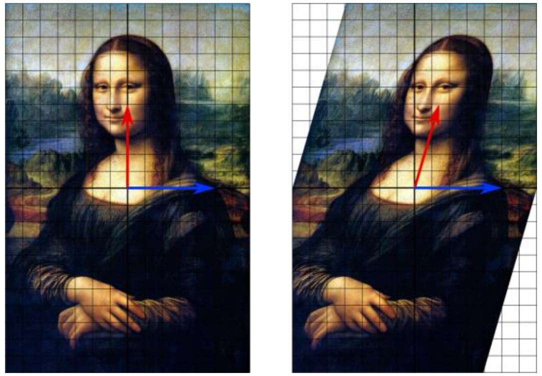
edge
'line'



corner
'dot'

고유값(eigen value), 고유벡터(eigen vector)

- 고유벡터: 선형 변환에 대해 불변인 영벡터가 아닌 벡터, 예) 기저벡터
- 고유값: 고유벡터의 배수 값

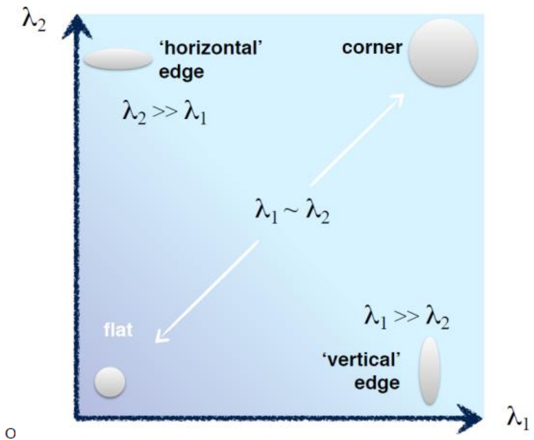


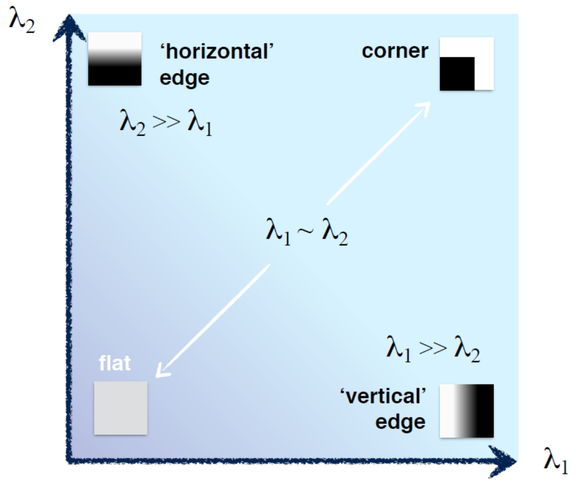
eigenvalue

$$Me = \lambda e$$

eigenvector

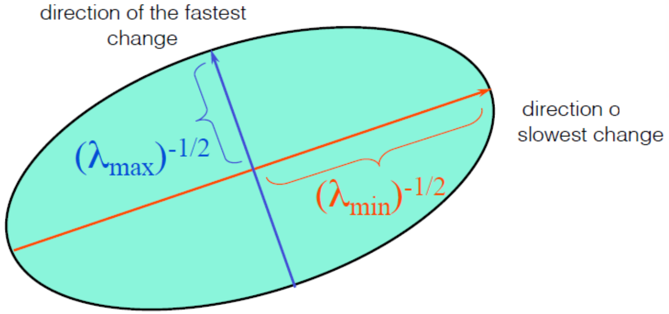
$$(M - \lambda I)e = 0$$





- M: 대칭

$$[u \;\; v] \; M \begin{bmatrix} u \\ v \end{bmatrix} = \text{const}$$

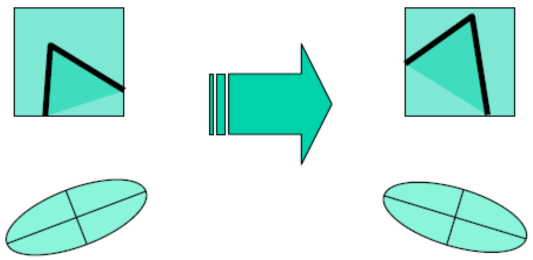


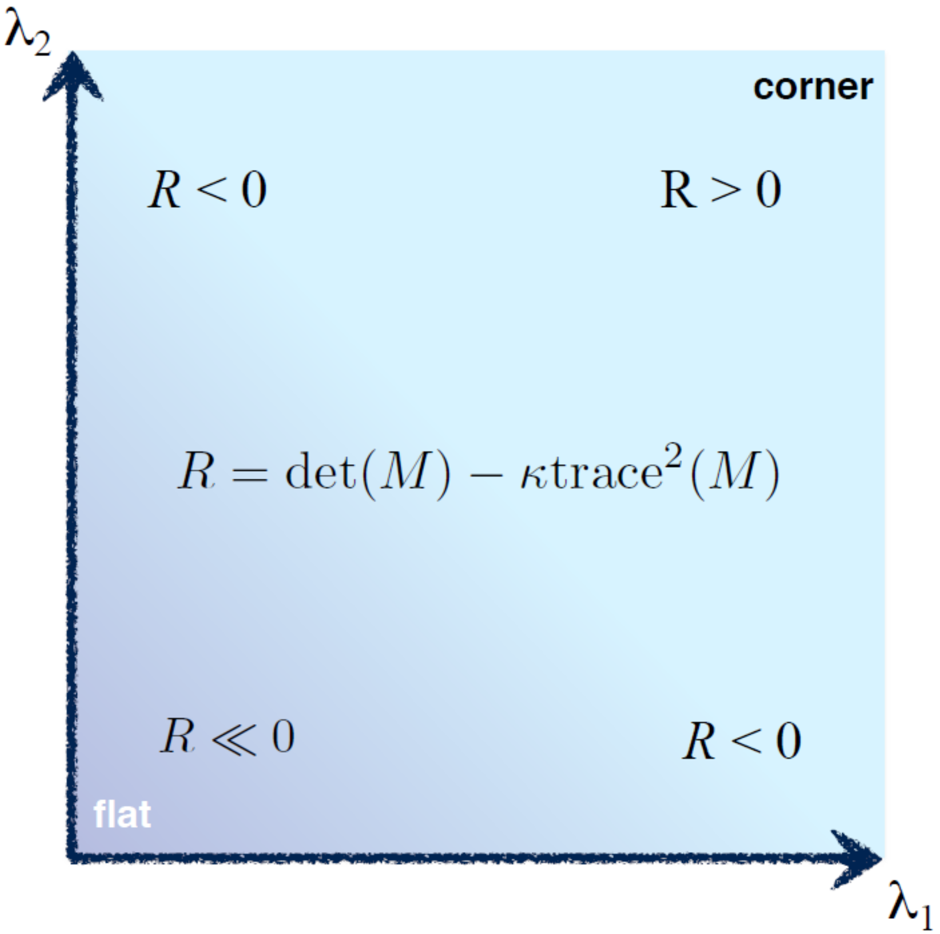
임계식 설정과 특징 (행렬식과 대각합의 조합)

- R :에 대해 임계값 설정 - κ로 정도 설정

- 비최대 억제
  Non-max suppression
  으로 위치 설정

- 특징: 회전 불변성=고유값은
  회전 불변



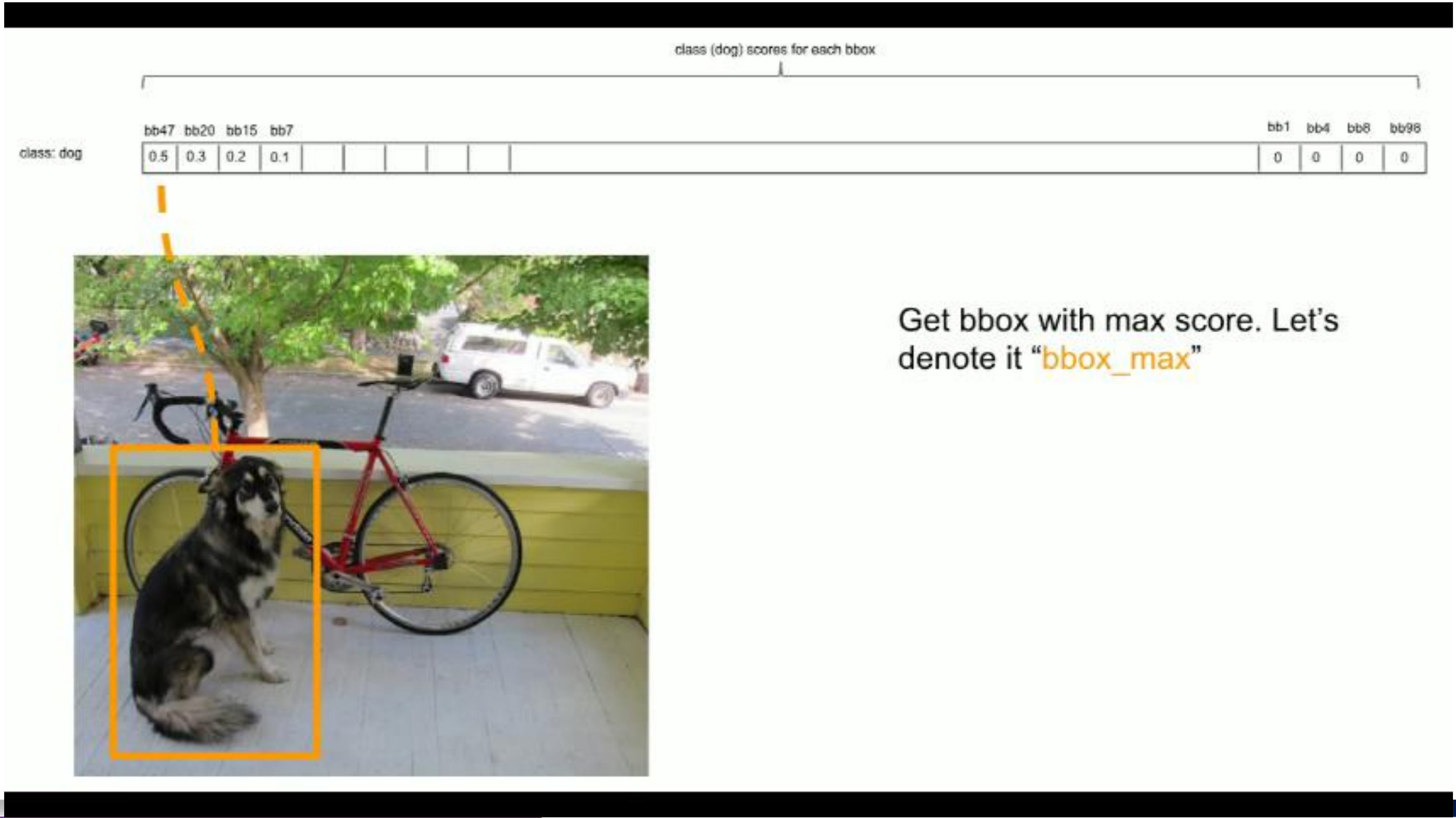


$$\det M = \lambda_1 \lambda_2$$
$$\operatorname{trace} M = \lambda_1 + \lambda_2$$

$$det\left(\begin{bmatrix} a & b \\ c & d \end{bmatrix}\right) = ad - bc$$

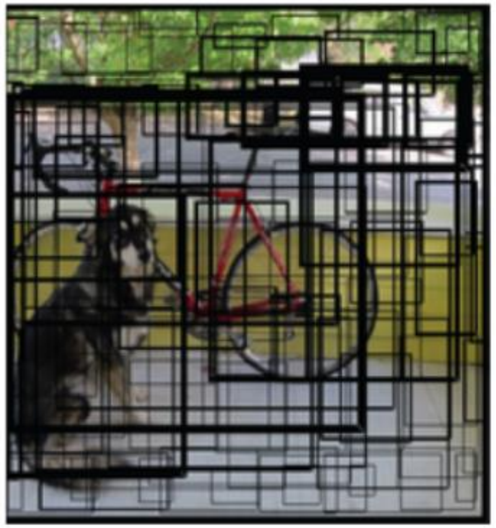
$$trace\left(\begin{bmatrix} a & b \\ c & d \end{bmatrix}\right) = a + d$$

비최대 억제 (2/2)

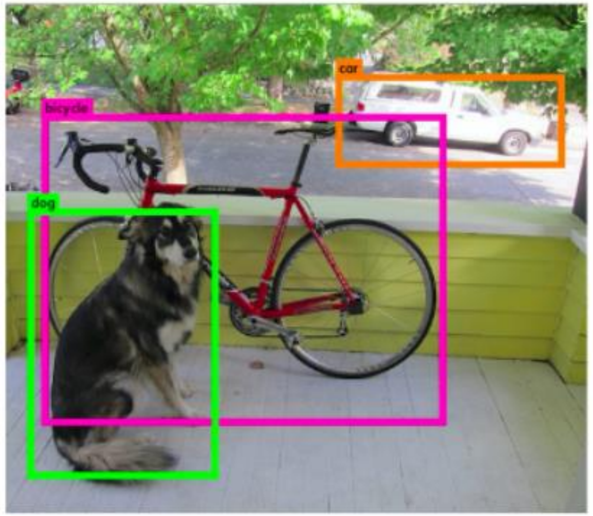

class (dog) scores for each bbox
class: dog
bb47 bb20 bb15 bb7
0.5 0.3 0.2 0.1
bb1 bb4 bb8 bb98
0 0 0 0
Get bbox with max score. Let's denote it "bbox_max"

비최대치 억제 (1/2)

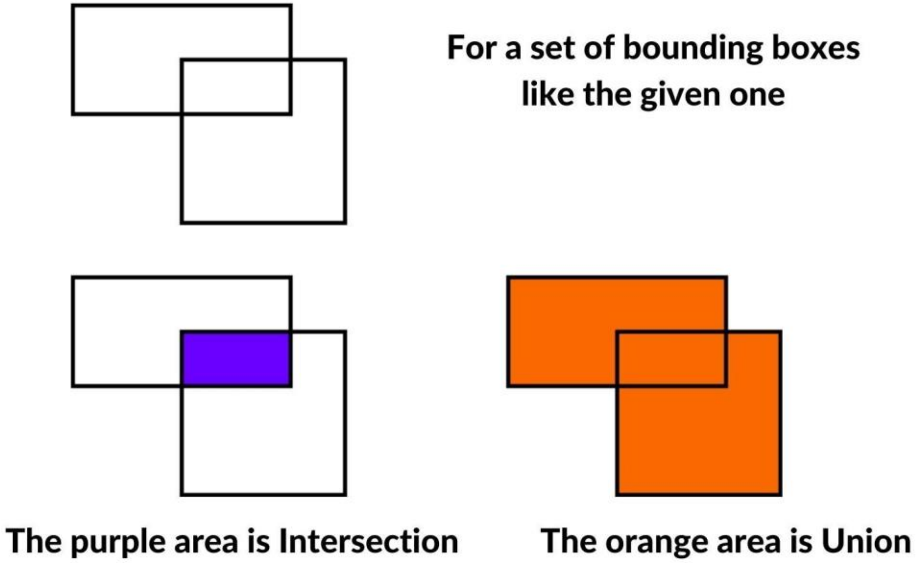
- Intersection Over Union (IoU) = (Target ∩ Prediction) / (Target U Prediction)
- IoU (Box1, Box2) = Intersection_Size (Box1, Box2) / Union_Size (Box1, Box2)



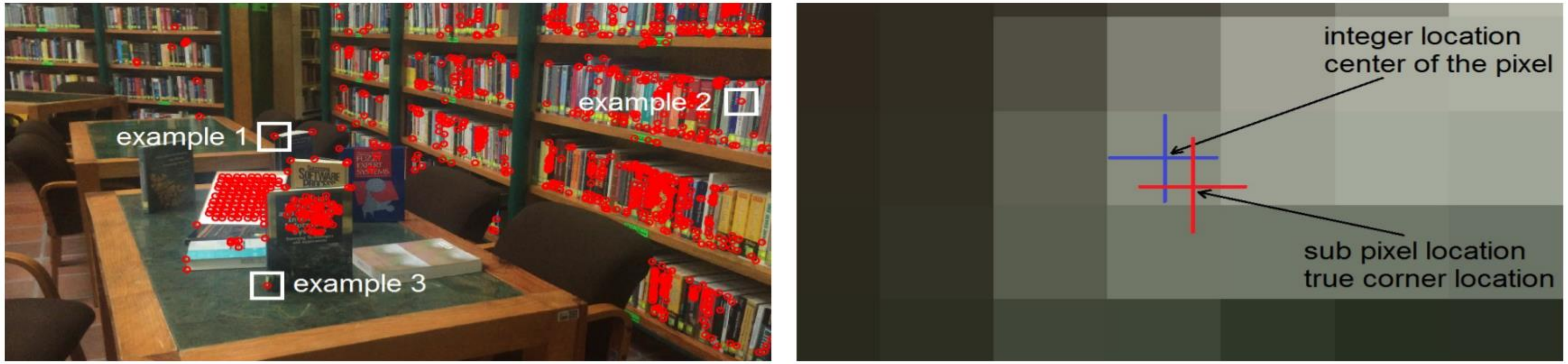
Multiple Bounding Boxes



Final Bounding Boxes

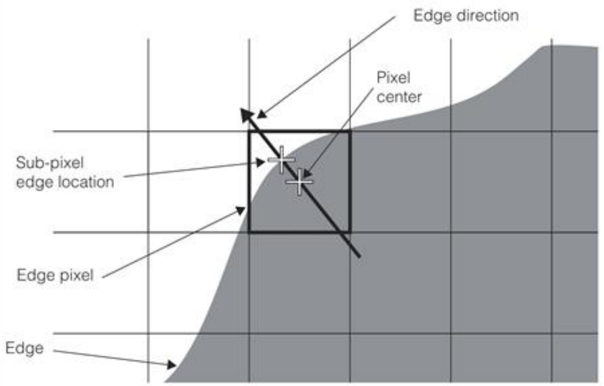


위치 정제 : peak & subpixel refinement



(a) Corners with subpixel location (b) Example 1

(c) Example 2 (d) Example 3



모서리 추출을 위한 다양한 특징 기술

- 모라벡: $C = \min(S(0,1), S(0,-1), S(1,0), S(-1,0))$

- 해리스: $C = det(\mathbf{A}) - k \times trace(\mathbf{A})^2 = (pq - r^2) - k(p+q)^2$

- 헤시안: $C = det(\mathbf{H}) = d_{yy}(\sigma)d_{xx}(\sigma) - d_{yx}(\sigma)^2$

- LoG: $C = \nabla^2 = trace(\mathbf{H}) = d_{yy}(\sigma) + d_{xx}(\sigma)$

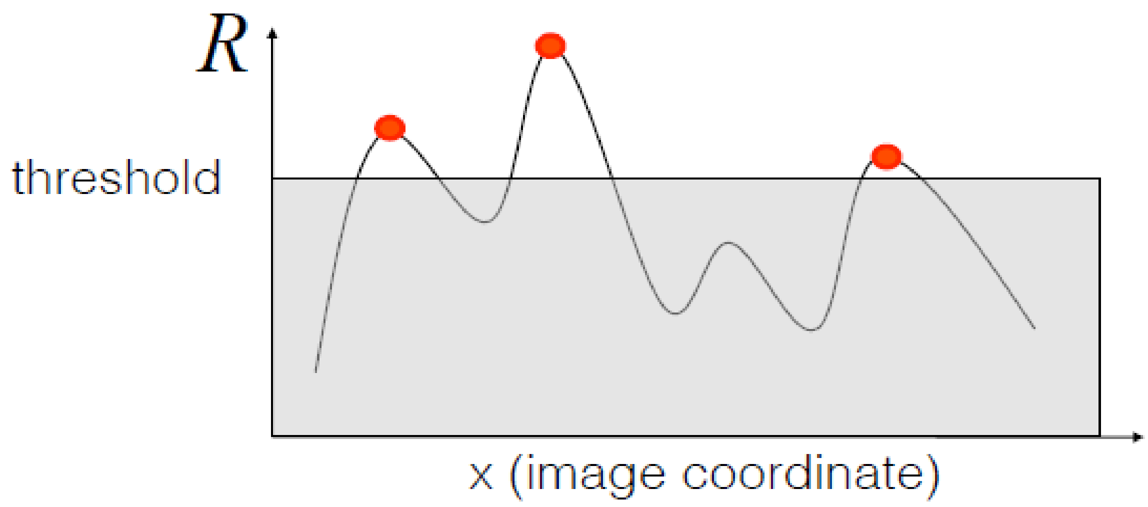
- 슈산: $C = \begin{cases} q - usan\_area(r_0), & usan\_area(r_0) \le t_2 \\ 0, & \text{그렇지 않으면} \end{cases}$

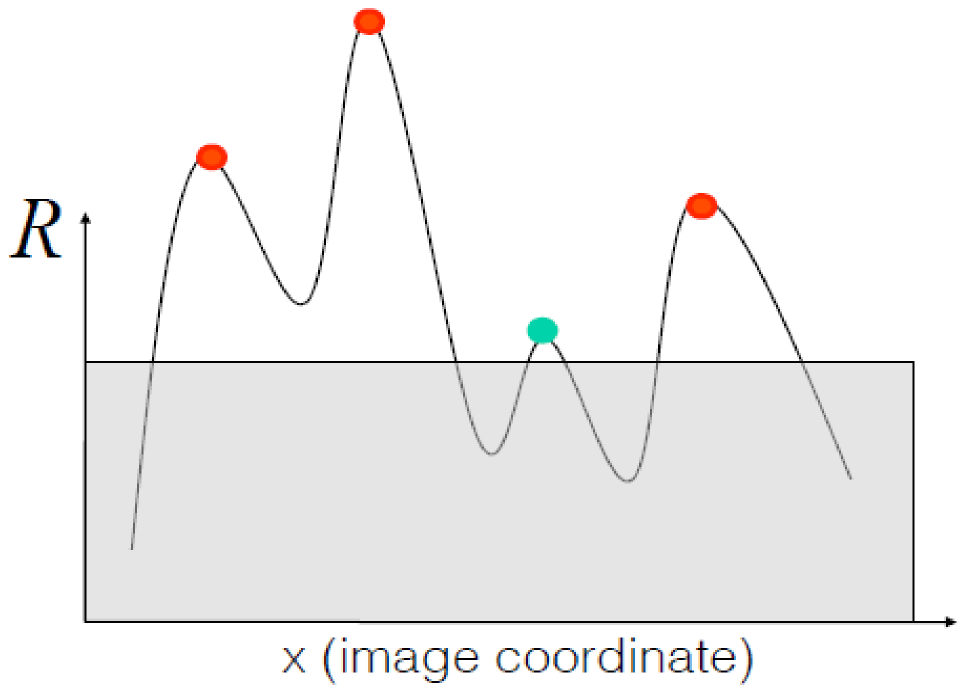
$$usan\_area(r_0) = \sum_r s(r, r_0)$$

이때 $s(r, r_0) = \begin{cases} 1, & |f(r) - f(r_0)| \le t_1 \\ 0, & \text{그렇지 않으면} \end{cases}$

픽셀 값의 단순 변환

- 픽셀의 변화값 기반의 특징 추출의 특성 : 위치/회전 변환은 해결, 크기 해결 불가능





5주: 영상특징과 서술자(2)

2 매칭

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2차원 변환(2D Transformations)

translation

rotation

aspect

affine

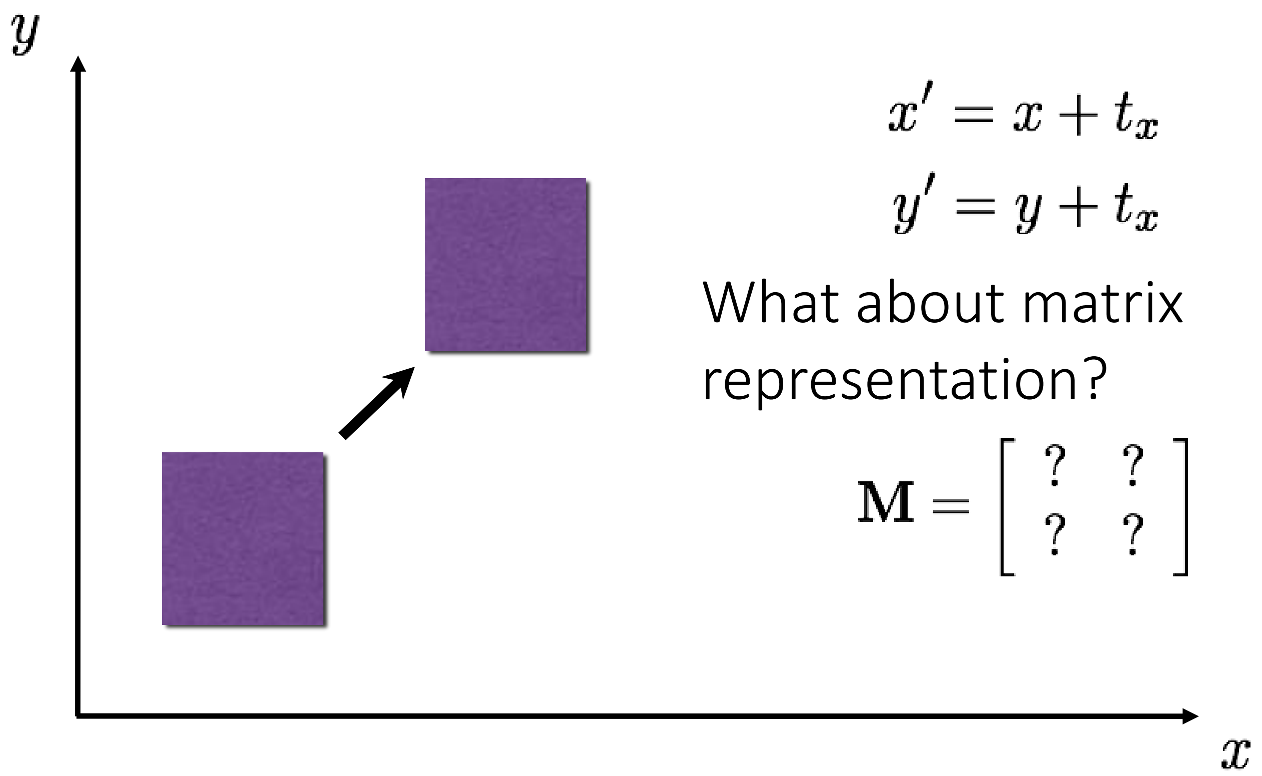
perspective

cylindrical

선형 변환

Scale	Flip across y
$$\mathbf{M} = \begin{bmatrix} s_x & 0 \\ 0 & s_y \end{bmatrix}$$	$$\mathbf{M} = \begin{bmatrix} -1 & 0 \\ 0 & 1 \end{bmatrix}$$
Rotate	Flip across origin
$$\mathbf{M} = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix}$$	$$\mathbf{M} = \begin{bmatrix} -1 & 0 \\ 0 & -1 \end{bmatrix}$$
Shear	Identity
$$\mathbf{M} = \begin{bmatrix} 1 & s_x \\ s_y & 1 \end{bmatrix}$$	$$\mathbf{M} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

위치 변환(Translation) & 동차 좌표(Homogeneous Coord.)



$$x' = x + t_x$$
$$y' = y + t_x$$

What about matrix representation?

$$\mathbf{M} = \begin{bmatrix} ? & ? \\ ? & ? \end{bmatrix}$$

$$\begin{bmatrix} x \\ y \end{bmatrix} \Rightarrow \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} \quad \mathbf{M} = \begin{bmatrix} 1 & 0 & t_x \\ 0 & 1 & t_y \\ 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & t_x \\ 0 & 1 & t_y \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = \begin{bmatrix} x + t_x \\ y + t_y \\ 1 \end{bmatrix}$$

$$\begin{bmatrix} x \\ y \\ w \end{bmatrix} \Rightarrow \begin{bmatrix} x/w \\ y/w \end{bmatrix}$$

아핀 변환(Affine Transformation)

- uniform scaling + shearing + rotation + translation

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & t_x \\ 0 & 1 & t_y \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

translation

$$\begin{bmatrix} \boldsymbol{x}' \\ \boldsymbol{y}' \\ 1 \end{bmatrix} = \begin{bmatrix} \boldsymbol{s}_{\boldsymbol{x}} & 0 & 0 \\ 0 & \boldsymbol{s}_{\boldsymbol{y}} & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \boldsymbol{x} \\ \boldsymbol{y} \\ 1 \end{bmatrix}$$

scaling

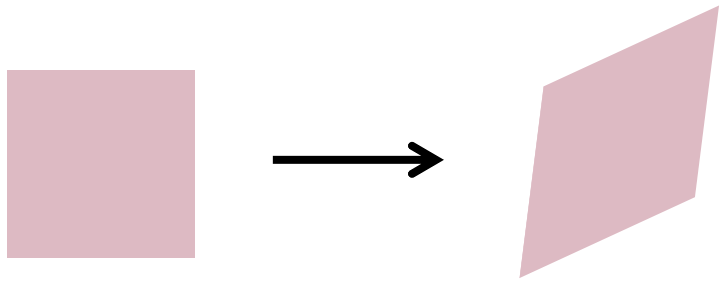
$$\begin{bmatrix} x' \\ y' \\ w' \end{bmatrix} = \begin{bmatrix} a & b & c \\ d & e & f \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ w \end{bmatrix}$$

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} \cos\Theta & -\sin\Theta & 0 \\ \sin\Theta & \cos\Theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

rotation

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & \beta_x & 0 \\ \beta_y & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

shearing



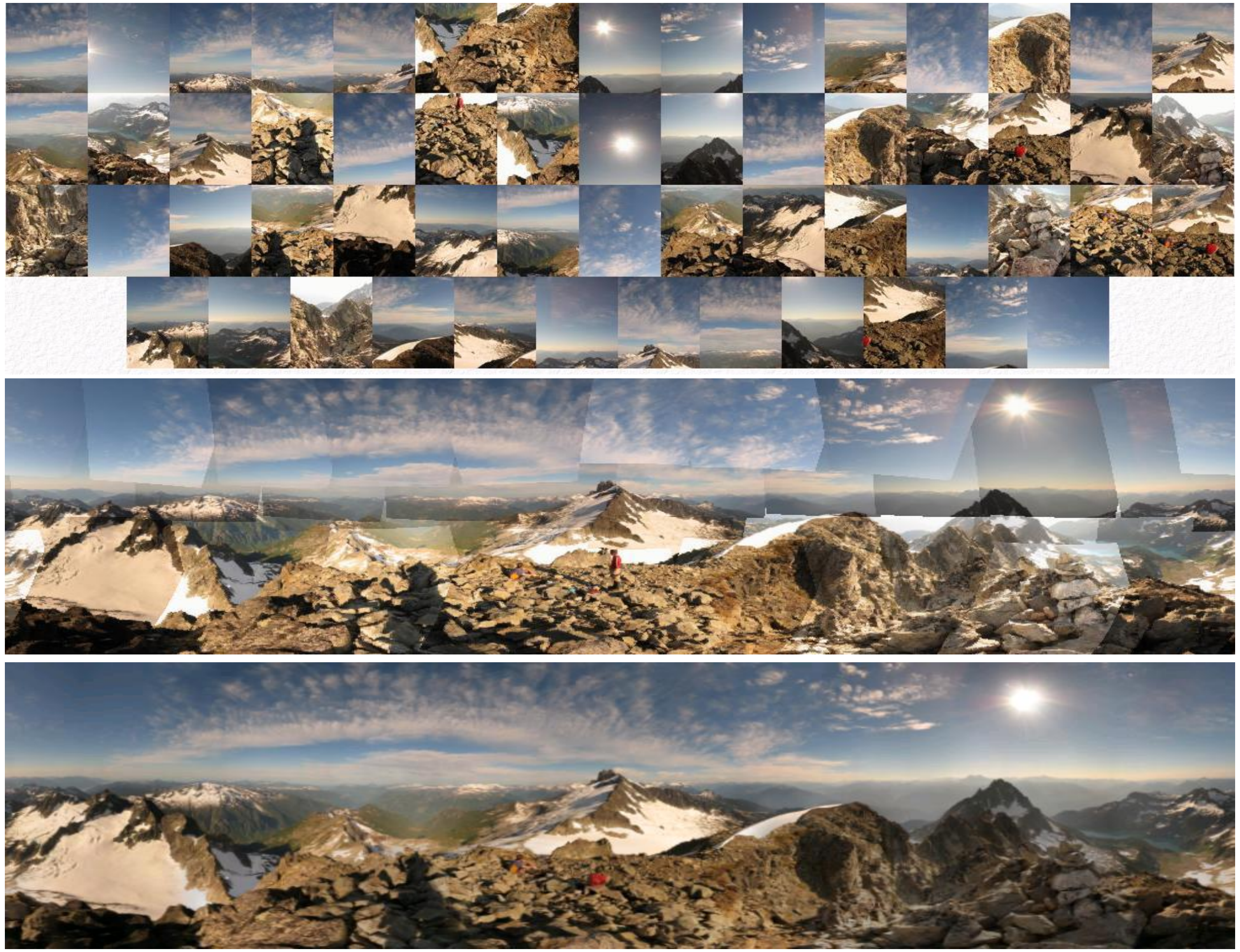
행렬 조합(Matrix composition)

$$\begin{bmatrix} x' \\ y' \\ w' \end{bmatrix} = \left(\begin{bmatrix} 1 & 0 & tx \\ 0 & 1 & ty \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos\Theta & -\sin\Theta & 0 \\ \sin\Theta & \cos\Theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} sx & 0 & 0 \\ 0 & sy & 0 \\ 0 & 0 & 1 \end{bmatrix} \right) \begin{bmatrix} x \\ y \\ w \end{bmatrix}$$

p' = translation(t_x,t_y) rotation(θ) scale(s,s) p

특징점 매칭 → 아핀 변환 추정

매칭에 따른 아핀 변환의 결과: Image Mosaicing



디지털영상처리II (2021학년도 2학기)

5주차 : 영상특징과 서술자

본 강의 자료의 내용 및 그림은 아래 책으로부터 발췌 되었음

- 파이썬으로 배우는 영상처리, Sandipan Dey 지음, 정성환 , 조보호 , 배종욱 옮김, 도서출판 홍릉, 2020년
- Digital Image Processing, 4th Ed., Rafael C . Gonzalez, Richard E. Woods 지음, Pearson, 2018년
- 컴퓨터 비전(Computer Vision) 기본 개념부터 최신 모바일 응용 예까지 IT CookBook, 오일석 지음, 한빛아카데미, 2014년

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