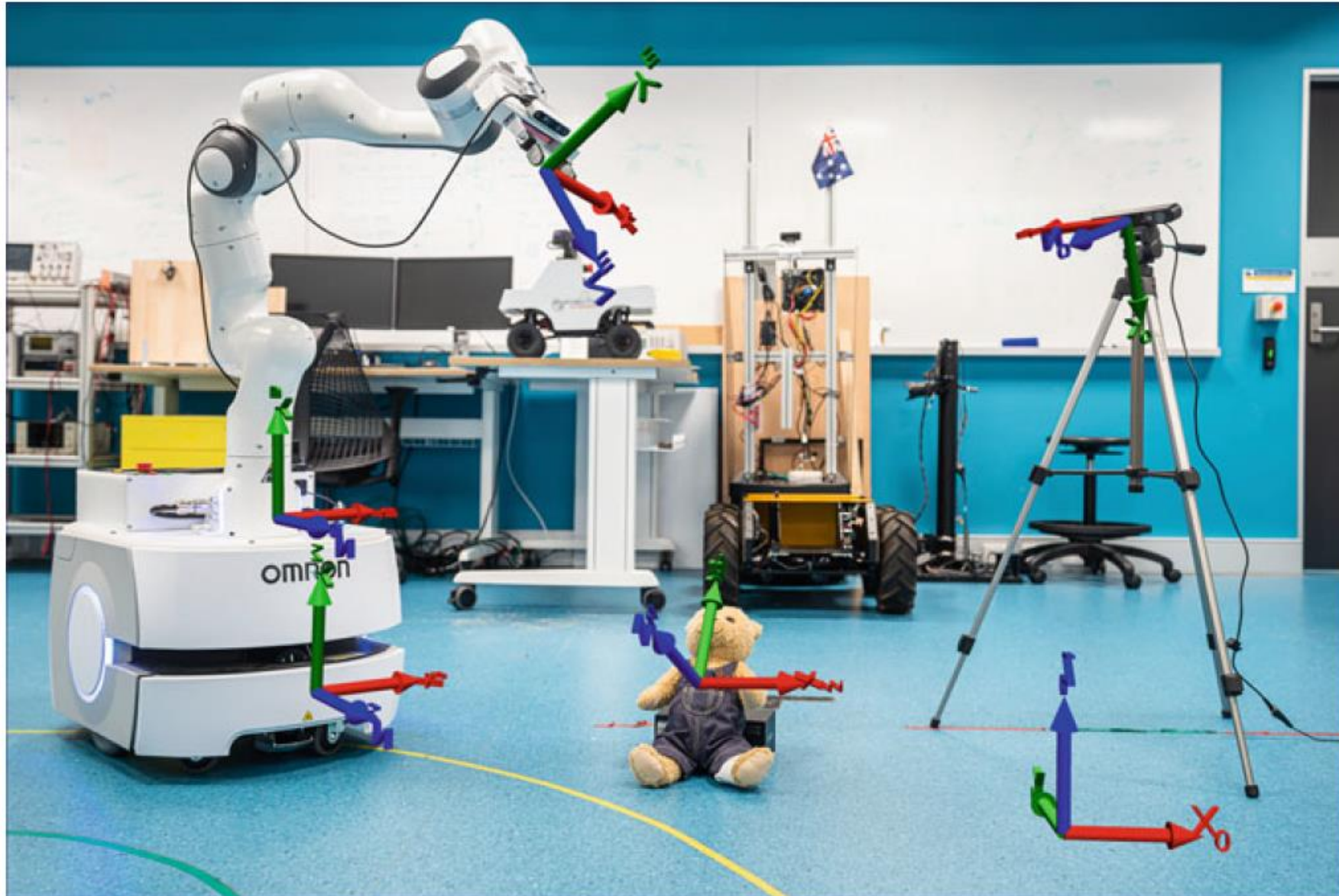




# 카메라 좌표계 Coordinate Frames

심주용  
숙명여자대학교  
기계시스템학부

# Coordinate Frames

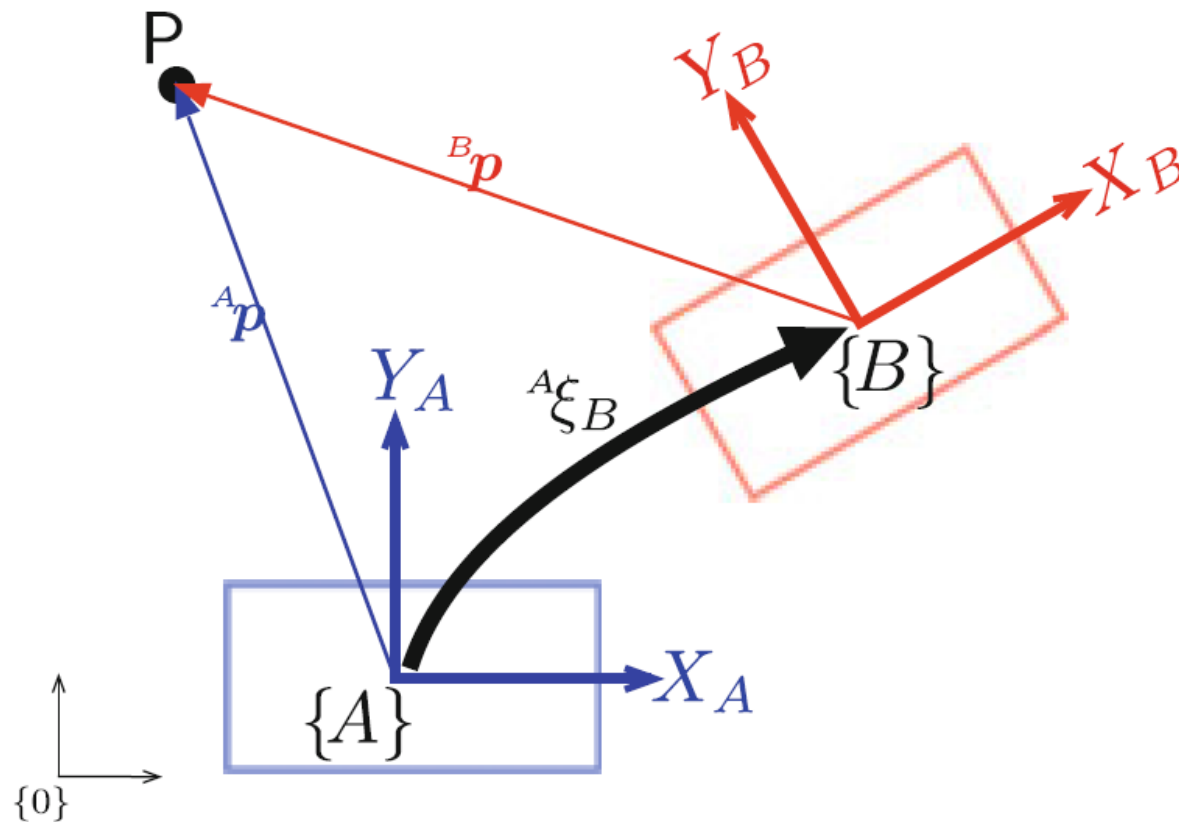


# Coordinate Frames



Point P can be described by coordinate vectors expressed in frame {A} or {B}

${}^A\xi_B$ : the pose of {B} relative to {A}



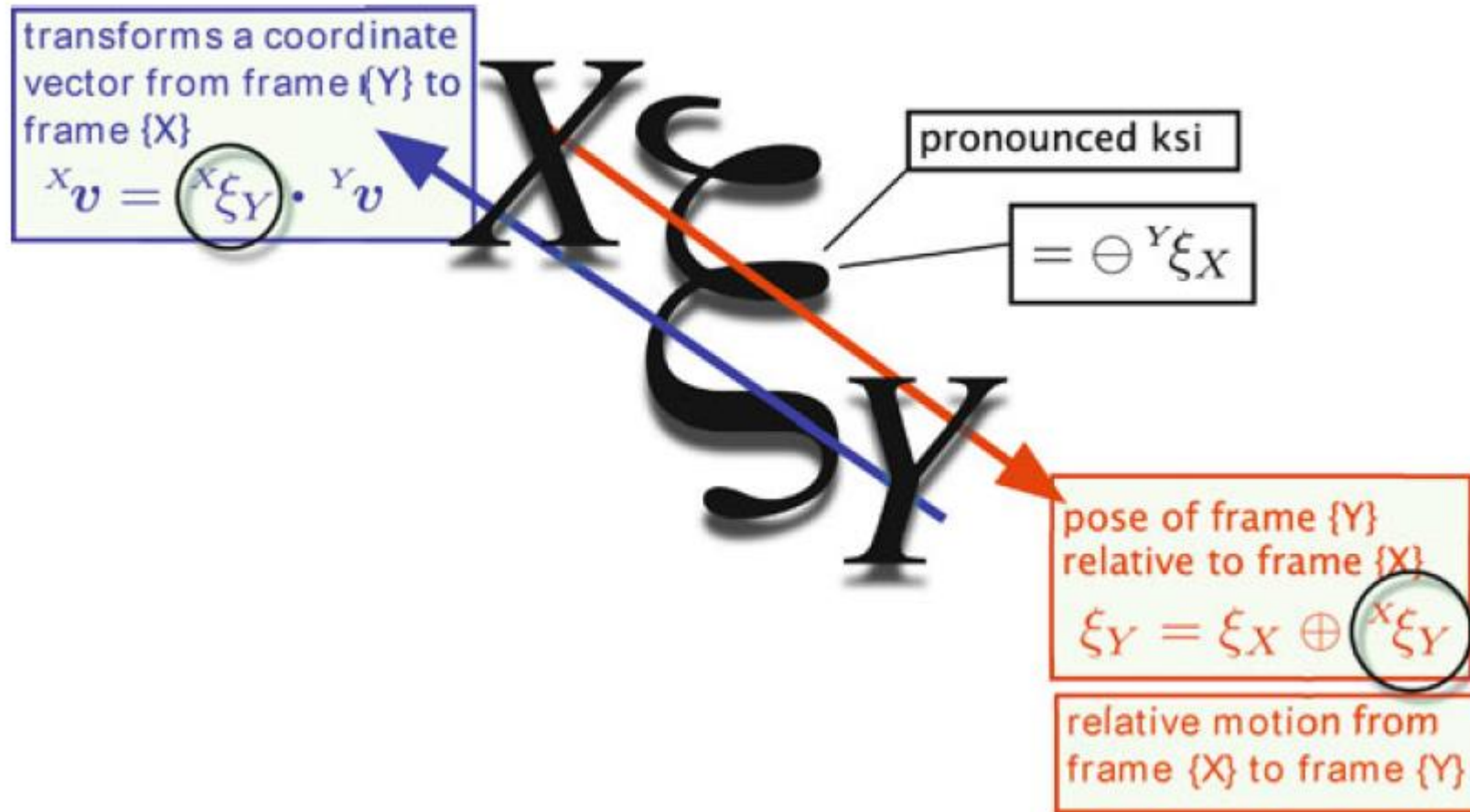
$${}^Ap = {}^A\xi_B \cdot {}^Bp$$

$${}^X\xi_Z = {}^X\xi_Y \oplus {}^Y\xi_Z$$

$$\textcircled{X}\xi\textcircled{Y} \oplus \textcircled{Y}\xi\textcircled{Z} = \textcircled{X}\xi\textcircled{Z}$$

same

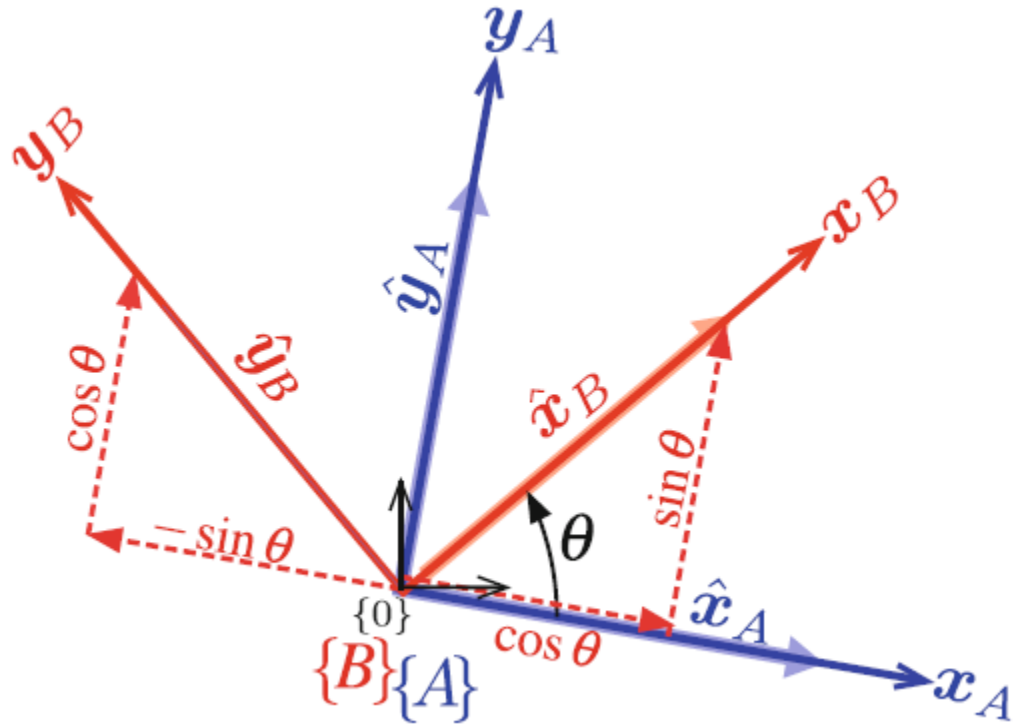
# Relative Poses



# 2D Rotation Matrix



${}^A\mathbf{R}_B(\theta)$  transforms a coordinate vector from frame  $\{B\}$  to  $\{A\}$ .



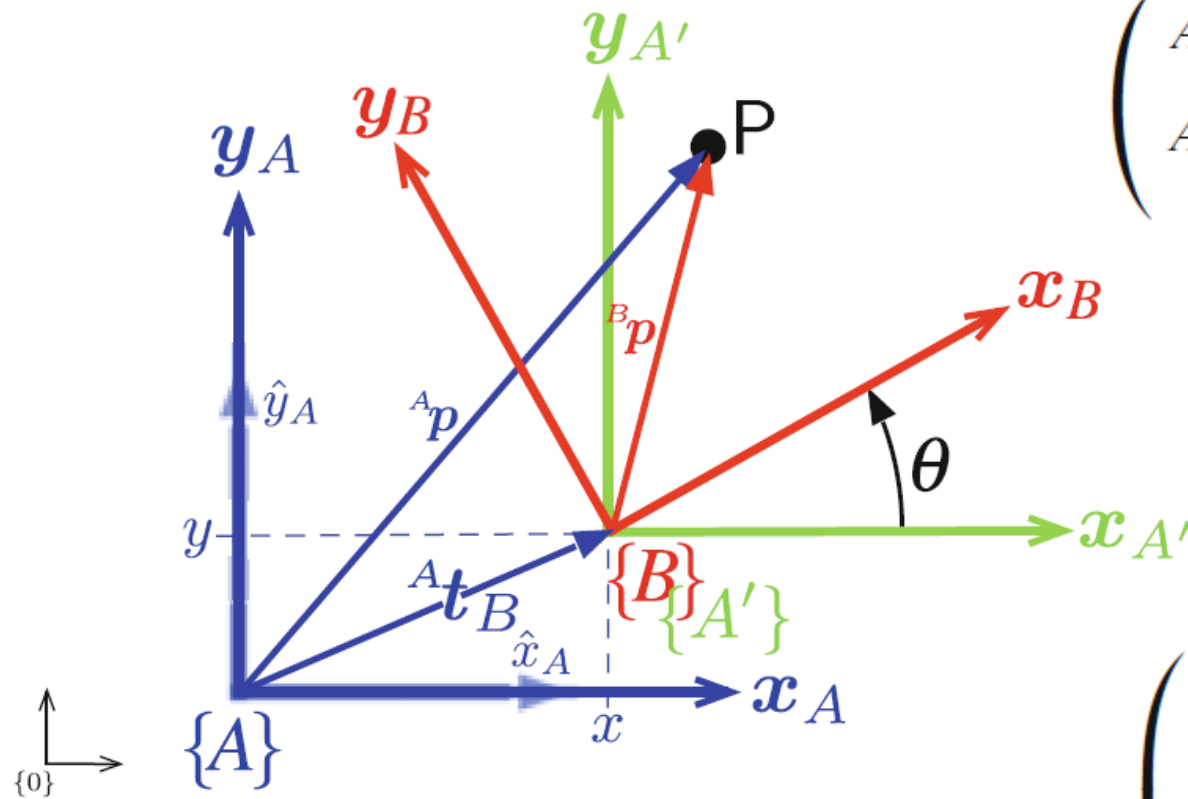
$${}^A\mathbf{R}_B(\theta) = \begin{pmatrix} \cos \theta & -\sin \theta \\ \sin \theta & \cos \theta \end{pmatrix}$$

$$\begin{pmatrix} {}^A p_x \\ {}^A p_y \end{pmatrix} = {}^A\mathbf{R}_B(\theta) \begin{pmatrix} {}^B p_x \\ {}^B p_y \end{pmatrix}$$

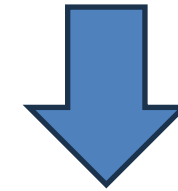
# 2D Homogeneous Transformation Matrix



Rotated and translated coordinate frames



$$\begin{pmatrix} {}^A x \\ {}^A y \end{pmatrix} = \begin{pmatrix} \cos \theta & -\sin \theta \\ \sin \theta & \cos \theta \end{pmatrix} \begin{pmatrix} {}^B x \\ {}^B y \end{pmatrix} + \begin{pmatrix} t_x \\ t_y \end{pmatrix}$$



Homogenous Coordinate

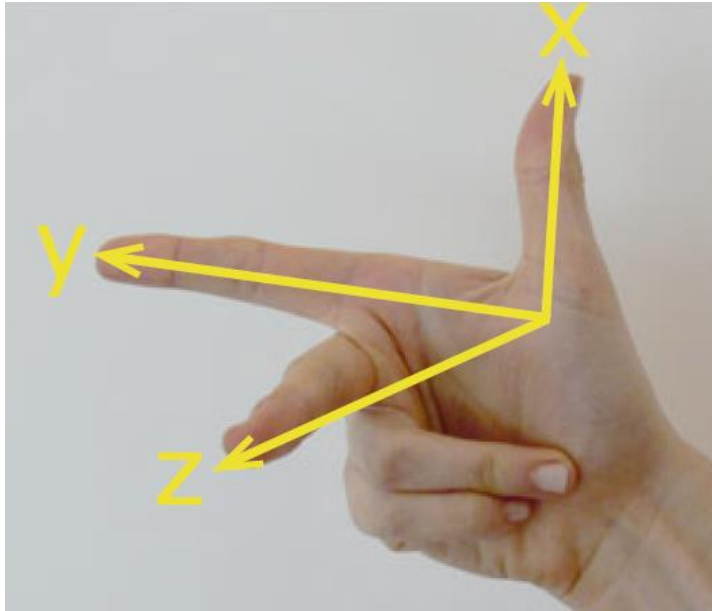
$$\begin{pmatrix} {}^A x \\ {}^A y \\ 1 \end{pmatrix} = \begin{pmatrix} {}^A \mathbf{R}_B(\theta) & {}^A \mathbf{t}_B \\ \mathbf{0}_{1 \times 2} & 1 \end{pmatrix} \begin{pmatrix} {}^B x \\ {}^B y \\ 1 \end{pmatrix}$$



# 3D Coordinate Frames

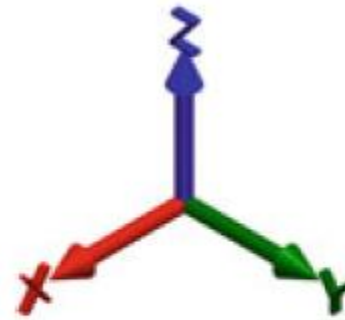


Right-hand rule



$$\mathbf{p} = x\hat{\mathbf{x}} + y\hat{\mathbf{y}} + z\hat{\mathbf{z}}$$

Rotation of Frames

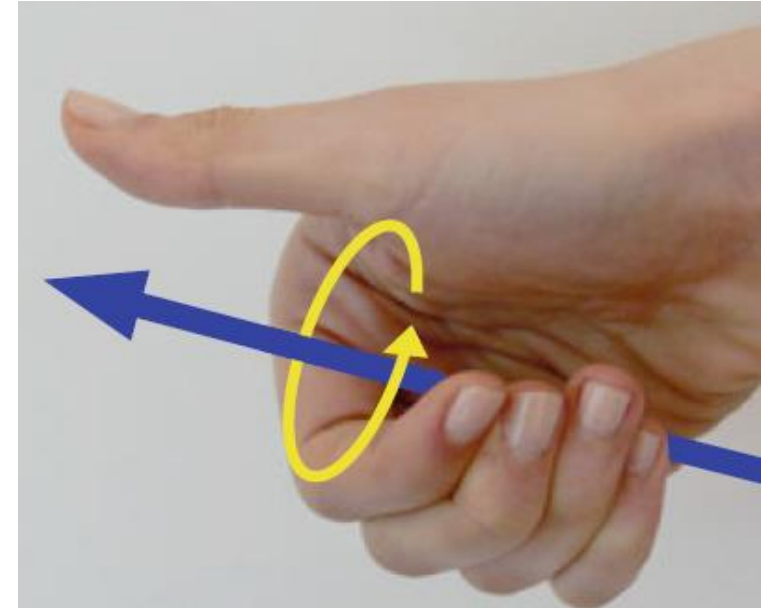


**a** Original



**b**  $\frac{\pi}{2}$  about  $x$ -axis

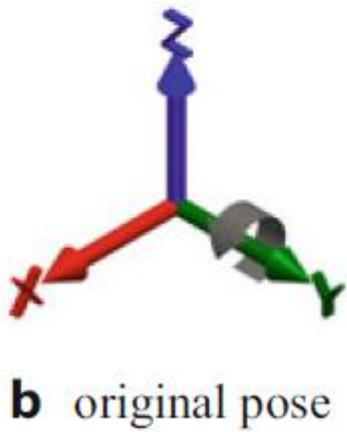
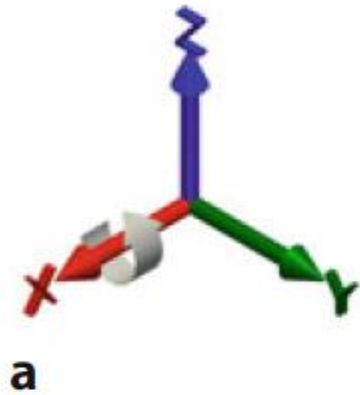
Rotation About a Vector



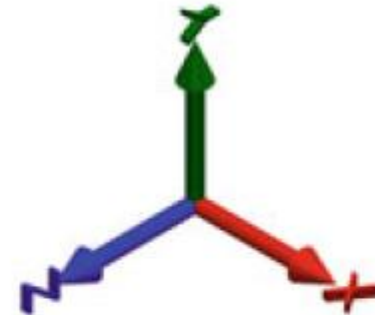
# 3D Coordinate Frames



Noncommutativity of rotation



after first rotation



after second rotation

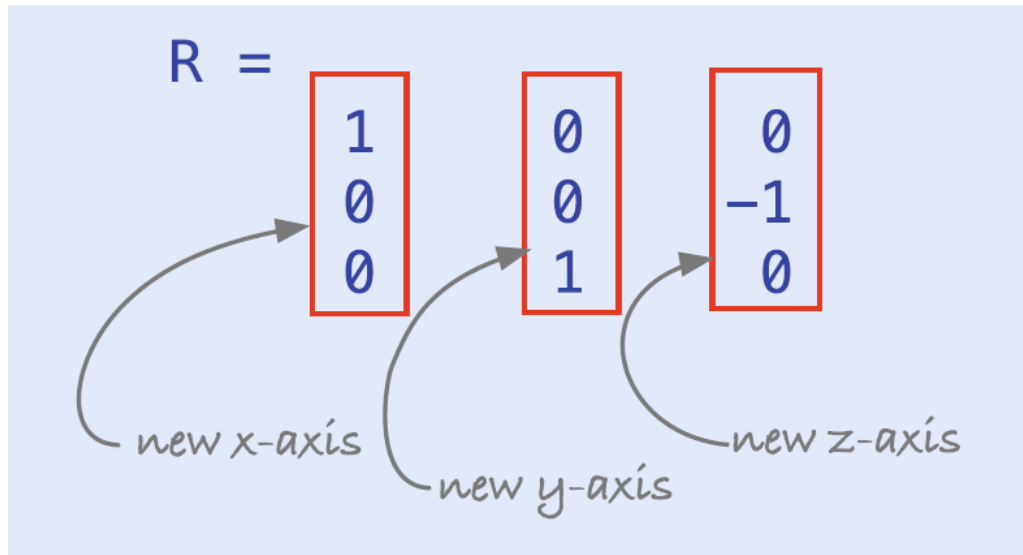


# 3D Rotation Matrix



Frame B to Frame A

$$\begin{pmatrix} {}^A p_x \\ {}^A p_y \\ {}^A p_z \end{pmatrix} = {}^A \mathbf{R}_B \begin{pmatrix} {}^B p_x \\ {}^B p_y \\ {}^B p_z \end{pmatrix}$$



$$\mathbf{R}_x(\theta) = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos \theta & -\sin \theta \\ 0 & \sin \theta & \cos \theta \end{pmatrix}$$

$$\mathbf{R}_y(\theta) = \begin{pmatrix} \cos \theta & 0 & \sin \theta \\ 0 & 1 & 0 \\ -\sin \theta & 0 & \cos \theta \end{pmatrix}$$

$$\mathbf{R}_z(\theta) = \begin{pmatrix} \cos \theta & -\sin \theta & 0 \\ \sin \theta & \cos \theta & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

# Three-Angle Representations



## Euler Angles

It is an ambiguous term: XYX, XZX, YXY, YZY, ZXZ, or ZYZ.

(e.g., mechanical dynamics: ZYZ)

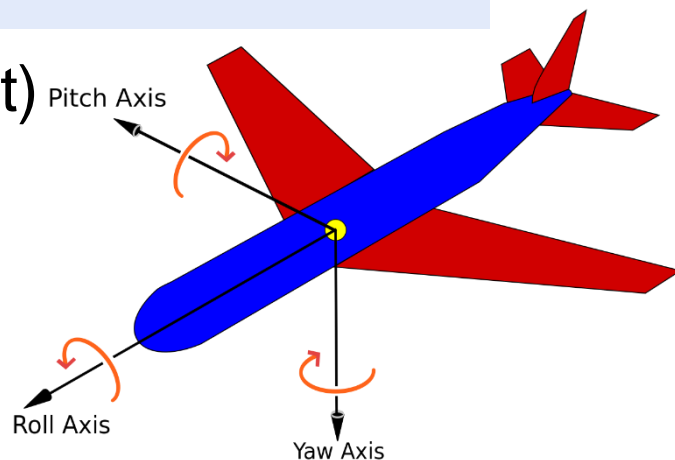
$$\mathbf{R}(\phi, \theta, \psi) = \mathbf{R}_z(\phi) \mathbf{R}_y(\theta) \mathbf{R}_z(\psi)$$

## Cardan Angles

Roll ( $\alpha$ )-pitch( $\beta$ )-yaw( $\gamma$ ) angle ambiguity: **XYZ**, XZY, YZX, YXZ, ZXY, or **ZYX**

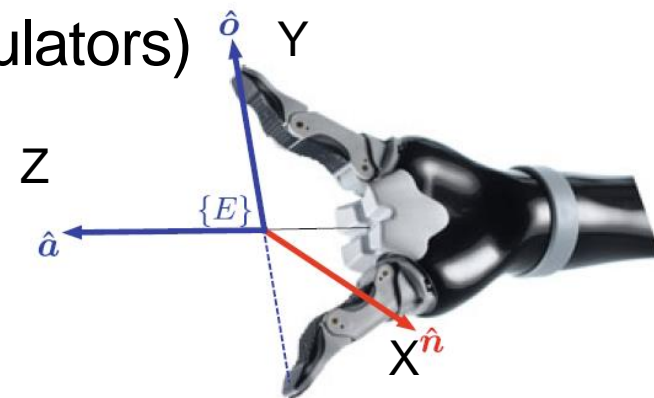
$$\mathbf{R}(\alpha, \beta, \gamma) = \mathbf{R}_z(\gamma) \mathbf{R}_y(\beta) \mathbf{R}_x(\alpha)$$

**ZYX** (Mobile Robot)



$$\mathbf{R}(\alpha, \beta, \gamma) = \mathbf{R}_x(\gamma) \mathbf{R}_y(\beta) \mathbf{R}_z(\alpha)$$

**XYZ** (Robot manipulators)





# Reality Capture: Camera Registration Export

심주용  
숙명여자대학교  
기계시스템학부

# Camera Pose Export



rene4\_cpu\_v2\* saved to C:\Users\Sim\Documents\카카오워크 받은 파일\20240501\_184023 frames - RealityCapture

WORKFLOW ALIGNMENT MESH MODEL VIEW TOOLS VIEW TOOLS VIEW TOOLS

Add Control Points Detect Markers Align Images Merge Components Draft Update Real-time Assistance Registration Metadata (XMP) Component Flight Log

Optional Registration Analyze Export Import

**Registration**  
Export camera registration - calibration, rotation, translation and undistorted images.

File Name	Tie Points
frame000572.png	541 tie points
frame000570.png	540 tie points
frame000578.png	424 tie points
frame000580.png	379 tie points
frame000582.png	396 tie points
frame000569.png	640 tie points
frame000568.png	740 tie points
frame000567.png	593 tie points
frame000583.png	360 tie points
frame000581.png	452 tie points
frame000584.png	243 tie points
frame000566.png	711 tie points
frame000565.png	686 tie points
frame000564.png	520 tie points
frame000585.png	363 tie points
frame000562.png	816 tie points
frame000563.png	703 tie points
frame000561.png	681 tie points
frame000557.png	578 tie points

Weight in texturing: 1.000000

Color correction reference: Disable

Color correction: Enable

Downscale for depth maps: 1

Registered: Yes

Enable in component: Enable

Lock pose for continue: No

**Prior pose**

Locked pose group: [ ]

Absolute pose: Position and orientation

Absolute coordinates: local:1 - Euclidean

x: 0.383550

y: 11.397185

z: 14.574832

Yaw / Heading: -74.209107

Pitch / Elevation: 4.672531

Roll / Bank: -43.765737

**Pose accuracy**

Accuracy settings so...: Global camera prior settings

**Prior calibration**

Calibration group: -1

Prior: Approximate

Focal length (35mm): 19.517181

Principal point x [mm]: -0.300586

Principal point y [mm]: -0.009895

Skew: 0.000000

Aspect ratio: 1.000000

3Ds

2D

2D

point 7

point 8

point 13

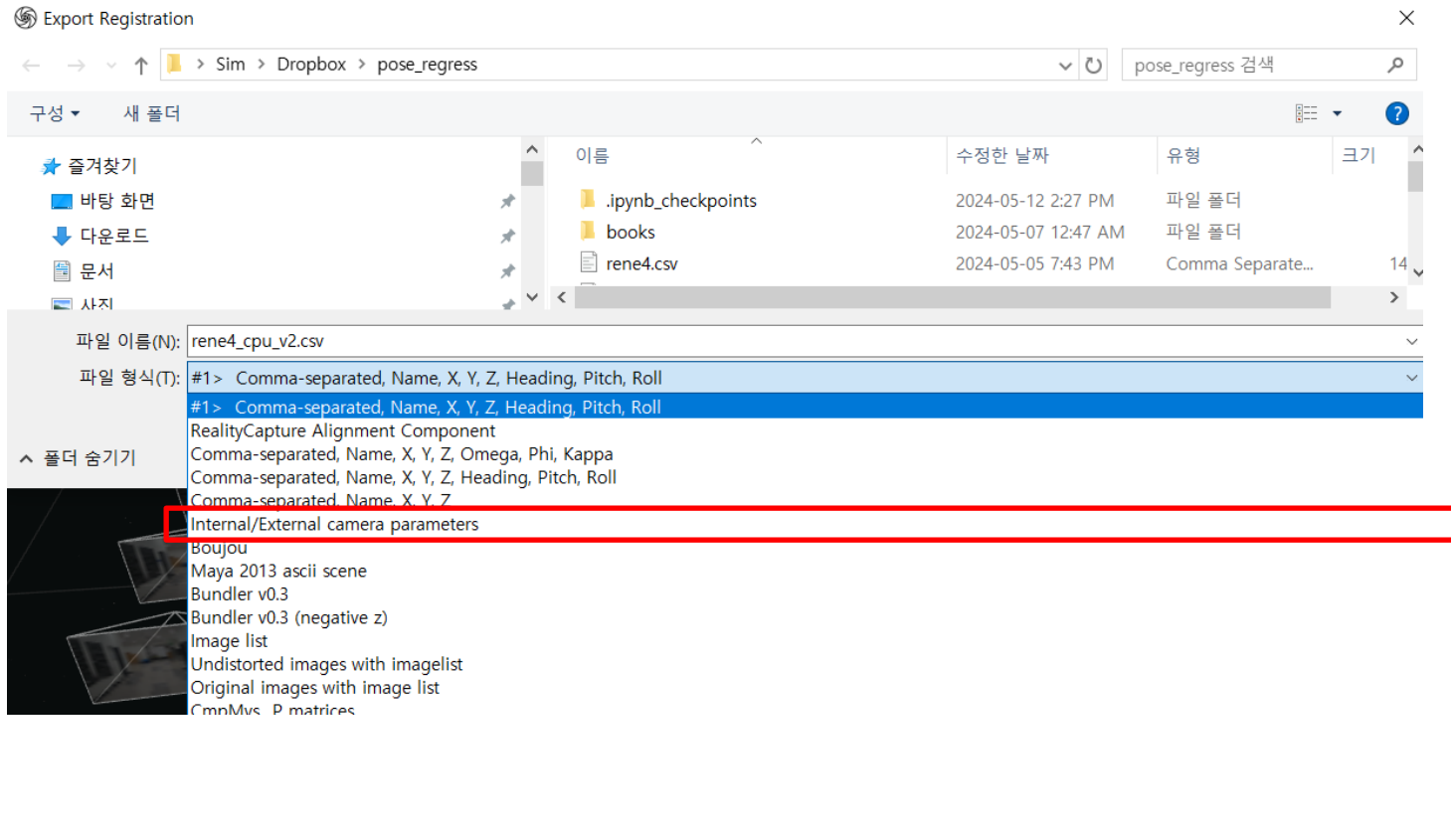
C:\Users\Sim\Documents\카카오워크 받은 파일\20240501\_184023 frames\frame000583.png [registered]

C:\Users\Sim\Documents\카카오워크 받은 파일\20240501\_184023 frames\frame000002.png [registered]

C:\Users\Sim\Documents\카카오워크 받은 파일\20240501\_184023 frames\frame000583.png [registered]

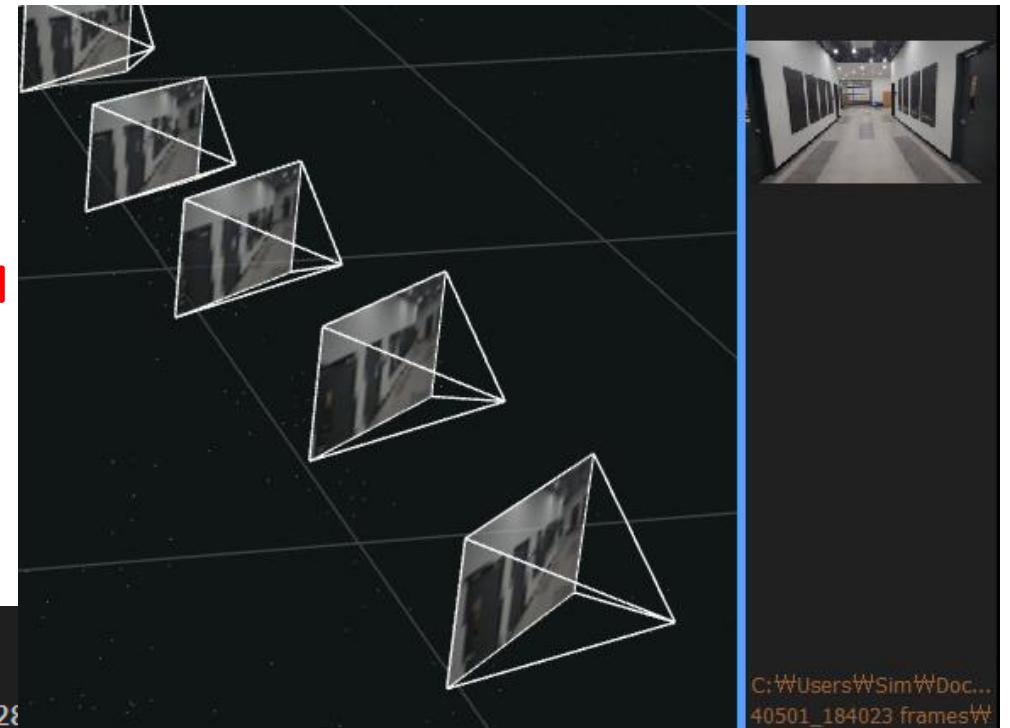
help

# Camera Pose Export



## Heading, Pitch, Roll

- Need to convert degree to radian



C: > Users > Sim > Dropbox > pose\_regress > rene4\_cpu\_int\_ext.csv

```
1 #name,x,y,alt,heading,pitch,roll,f,px,py,k1,k2,k3,k4,t1,t2
2 frame000073.png,8.242849089577009,28.82153654769631,1.284793488706929,-82.66228
3 frame000074.png,8.315626630247712,28.85726568726199,1.288443275987522,-86.19818085054767,84.09898026873439,-0.6112592333128565,17.50929
4 frame000075.png,8.312852163184834,28.91612268480087,1.283564208941917,-90.04488021130334,84.07744165974337,0.1633952638090864,17.537489
5 frame000076.png,8.305590132259928,28.99511588273064,1.294929081835999,-93.95549829531235,83.93654827736646,-0.3707139301559295,17.56345
6 frame000077.png,8.274867646137592,29.04837894455181,1.272630691041517,-99.49061741927936,83.97289255022996,-1.417861592209114,17.566207
7 frame000078.png,8.280084540254842,29.10011674068884,1.269980754305722,-104.659575574821,83.64214773414518,-2.720630270808134,17.5906871
8 frame000079.png,8.278448578202875,29.15957692675736,1.263355990255013,-105.4539430841437,83.31040610656544,-0.3568720927559521,17.50542
```

# Camera Pose Export



## Coordinate System

- Set Ground Plane 기준
- 독립적인 XMP 파일 기준

Export Registration

Please specify the export parameter details.

Exporter Settings	
File format	Comma-separated, Name, X, Y, Z, Heading, Pitch, Roll
File name	rene4_cpu_roll_again_v4_grid_plane.csv
Export location	C:\Users\Sim\Dropbox\pose_regress\
<b>Export transformation settings</b>	
Coordinate system	Grid plane
<b>Scene transformation</b>	Grid plane
Move X	Same as XMP
Move Y	0.000000
Move Z	0.000000
Rotate X	0.000000
Rotate Y	0.000000
Rotate Z	0.000000
Scale X	1.000000
Scale Y	1.000000
Scale Z	1.000000
<b>Normal transformation</b>	
Space	Tangent (Mikktspace)
Range	0 to 1
Flip X coordinate	No
Flip Y coordinate	No
Flip Z coordinate	No

OK Cancel



# 참고



SCENE 1D IMAGE 2D SCENE 3D rene4\_cpu\_v2\* saved to C:\Users\Sim\Documents\카카오워크 받은 파일\20240501\_184023 frames - RealityC

WORKFLOW ALIGNMENT MESH MODEL VIEW TOOLS VIEW TOOLS VIEW TOOLS

Set Reconstruction Region Point Rect Camera Lasso Select All Inspect Find Images Define Distance Lasso Expand Select All Filter Selection Ortho Projection Close Holes Cross Sections Tool Mesh and PointCloud Registration  
Set Ground Plane Point Lasso Deselect Expand Find CPs Rect Advanced Deselect Simplify Tool Texture Reprojection AI Classify Cut by Box Levels of Detail Control Points  
Camera Rect Invert Find Points Control Points Box Invert Smoothing Tool Duplicate Model Info Panel Reconstruction Region Ground Contr

Scene Alignment Registration & Sparse Point Cloud Mesh Model Export

frame000079.png 595 tie points 1Ds  
frame000078.png 596 tie points  
frame000075.png 361 tie points  
frame000643.png 441 tie points  
frame000646.png 531 tie points  
frame000647.png 486 tie points  
frame000645.png 382 tie points  
frame000648.png 486 tie points  
frame000642.png 292 tie points  
frame000076.png 550 tie points  
frame000074.png 485 tie points  
frame000644.png 459 tie points  
frame000073.png 400 tie points

Selected input  
File name C:\Users\Sim\Documents\...  
Width 1 920  
Height 1 088  
Pixel format 24-bit BGR  
Features 0  
Features source Use all image features  
Visible Yes  
Enable alignment Enable  
Enable meshing Enable  
Enable texturing and coloring Enable  
Weight in texturing 1.000000  
Color correction reference Disable  
Color correction Enable  
Downscale for depth maps 1  
Registered Yes  
Enable in component Enable  
Lock pose for combine no

Prior pose  
Locked pose group  
Absolute pose Position and orientation  
Absolute coordinates local1 - Euclidean  
x 0.898671  
y 16.464101  
z 12.452931  
Yaw / Heading -92.532877  
Pitch / Elevation 0.834041  
Roll / Bank 93.992294

Pose accuracy  
Accuracy settings so... Global camera prior settings

Prior calibration  
Calibration group -1  
Prior Approximate  
Focal length (35mm) 17.889311  
Principal point x [mm] 0.207206  
Principal point y [mm] -0.003440  
Skew 0.000000  
Aspect ratio 1.000000

Prior lens distortion  
Lens group -1  
Prior Approximate  
Camera model Brown3  
Radial 1 -0.006907  
Radial 2 0.047186  
Radial 3 -0.018298

Relative position uncertainty  
Uncertainty X 0.000082  
Uncertainty Y 0.000109  
Uncertainty Z 0.000080  
Units Meter

Registration calibration  
Calibration group -1  
Focal length (35mm) 17.889311  
Principal point x [mm] 0.207206  
Principal point y [mm] -0.003440  
Skew 0.000000  
Aspect ratio 1.000000

Registration lens distortion  
Lens group -1  
Camera model Brown3  
Radial 1 -0.006907  
Radial 2 0.047186  
Radial 3 -0.018298

frame000194.png [registered]

frame000572.png

frame000570.png

541 tie points

540 tie points

1Ds

Absolute coordinates

local:1 - Euclidean

x

0.465066

y

11.939553

z

13.226693

Yaw / Heading

-93.694961

Pitch / Elevation

0.376243

Roll / Bank

96.501750

Pose accuracy

Accuracy settings so...

Global camera prior settings

Prior calibration

Calibration group

-1

Prior

Approximate

Focal length (35mm)

17.889311

Principal point x [mm]

0.207206

Principal point y [mm]

-0.003440

Skew

0.000000

Aspect ratio

1.000000

Prior lens distortion

Lens group

-1

Prior

Approximate

Camera model

Brown3

Radial 1

-0.006907

Radial 2

0.047186

Radial 3

-0.018298

Relative position uncertainty

Uncertainty X

0.000082

Uncertainty Y

0.000109

Uncertainty Z

0.000080

Units

Meter

Registration calibration

Calibration group

-1

Focal length (35mm)

17.889311

Principal point x [mm]

0.207206

Principal point y [mm]

-0.003440

Skew

0.000000

Aspect ratio

1.000000

Registration lens distortion

Lens group

-1

Camera model

Brown3

Radial 1

-0.006907

Radial 2

0.047186

Radial 3

-0.018298

# Project Milestone



## 1. 기말 프로젝트 마일스톤 발표: ~5/27 (월) 16:00~17:00

- 발표: 4분 이내 + 2분 질의응답
- 데이터 획득 내용 및 학습 파이프 라인 구축 내용 설명
- 초기 모델 학습시킨 결과 포함

## 2. 기말 프로젝트 최종 발표: 6/19 (수) 16:00~17:50 예정

- 발표: 12분 이내 + 3분 질의응답
- 프로젝트 내용 및 결과 웹페이지 게시 (google sites, github pages, notion 등 이용)