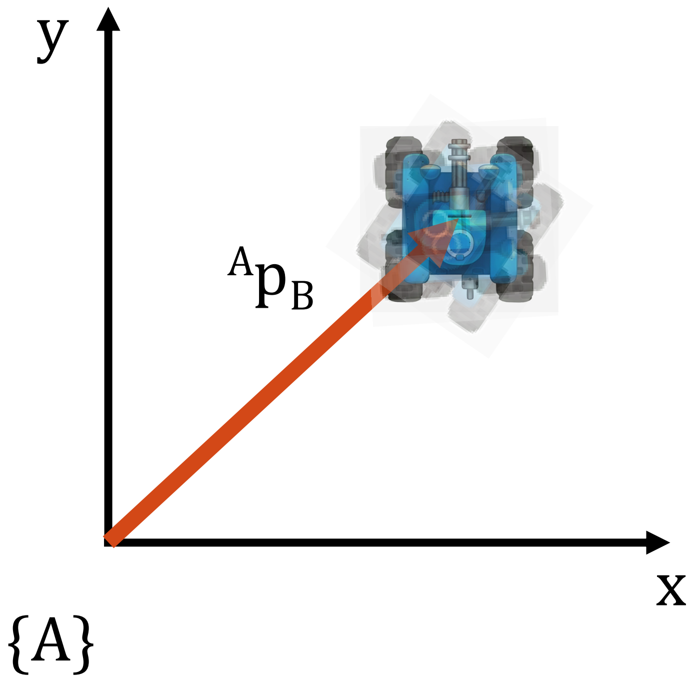
# INTRODUCTION TO ROBOTICS

Lecture 04

# POSITION




$$^{A}p_{B}$$

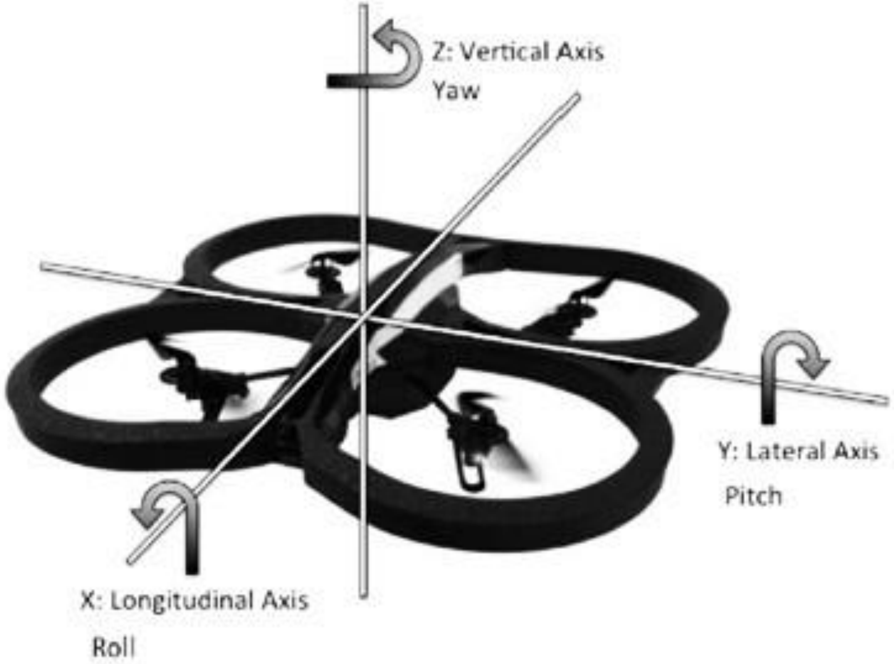
# POSE IN 2D

describes the position and orientation

$$(\mathbf{x}, \mathbf{y}, \boldsymbol{\theta})$$

# POSE IN 3D

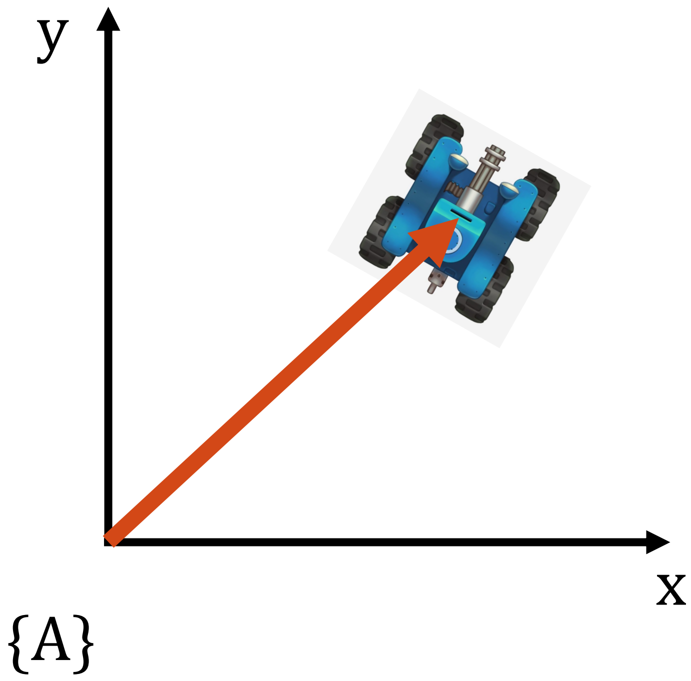

y
x
z


Z: Vertical Axis
Yaw
Y: Lateral Axis
Pitch
X: Longitudinal Axis
Roll

# POSE IN 3D

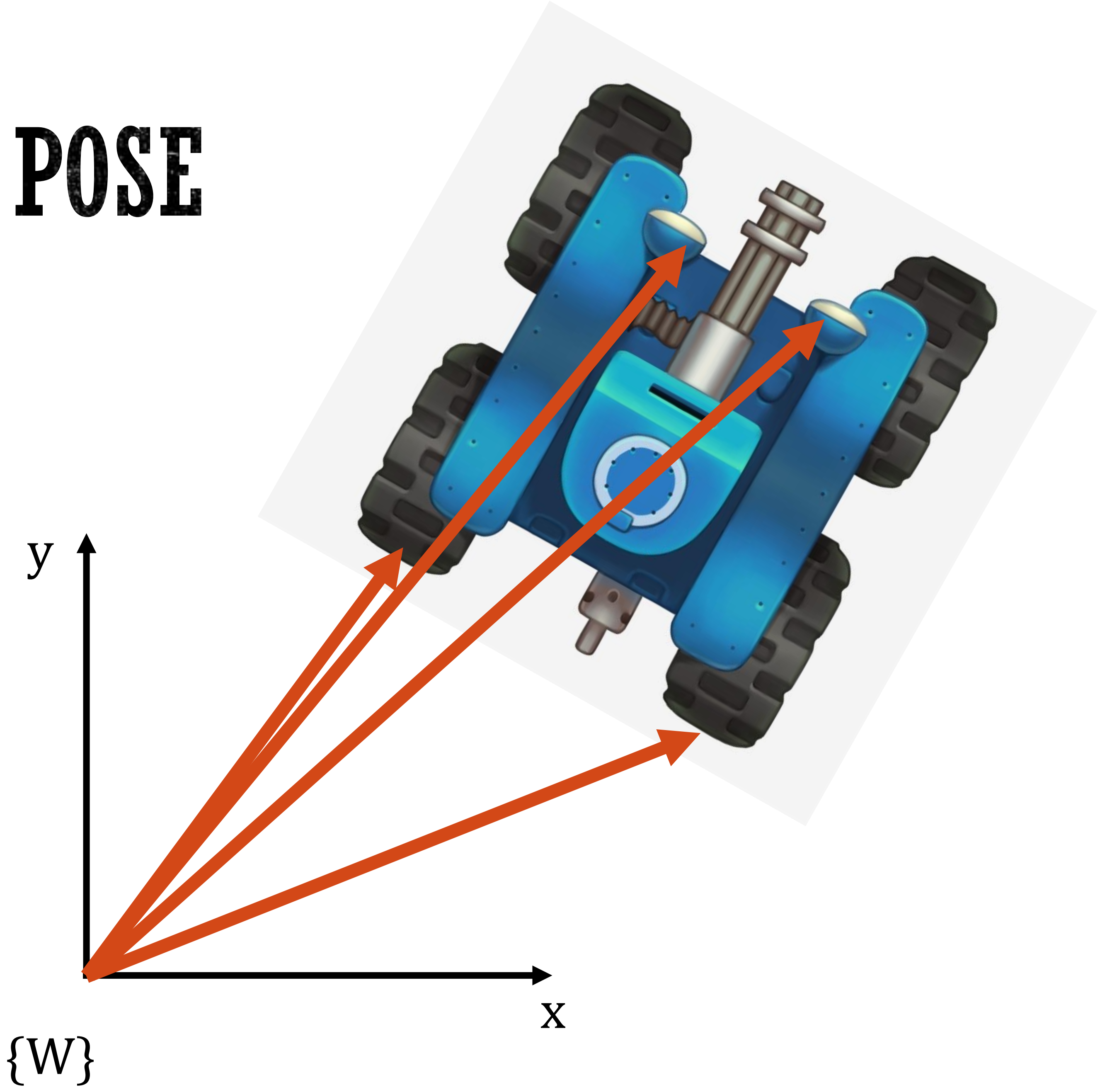
To completely describe the pose of a rigid object in a 3-dimensional world we need 6 not 3 dimensions: 3 to describe its position and 3 to describe its orientation.

# POSE



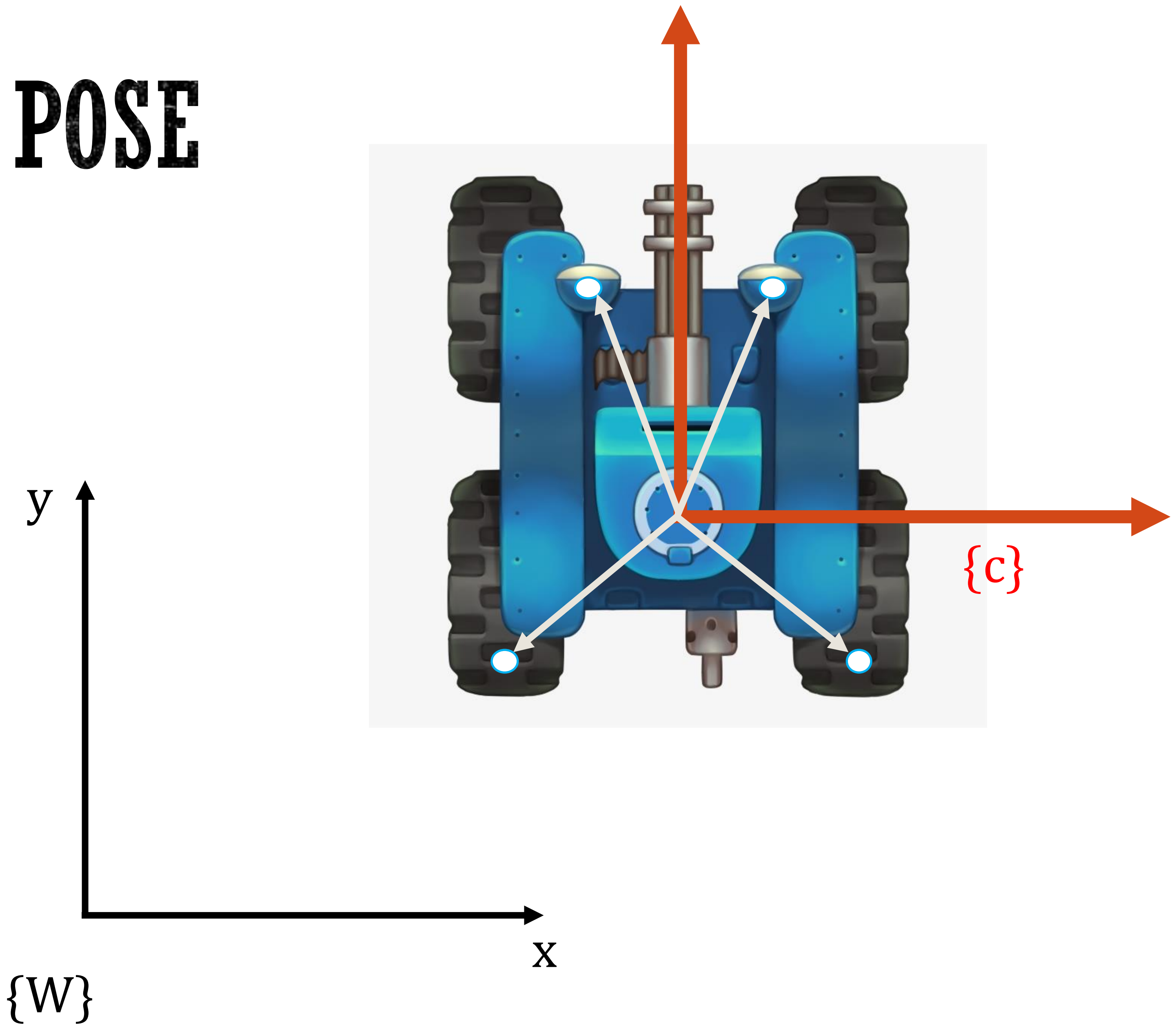

$${}^{A}\xi_{B}$$

# POSE

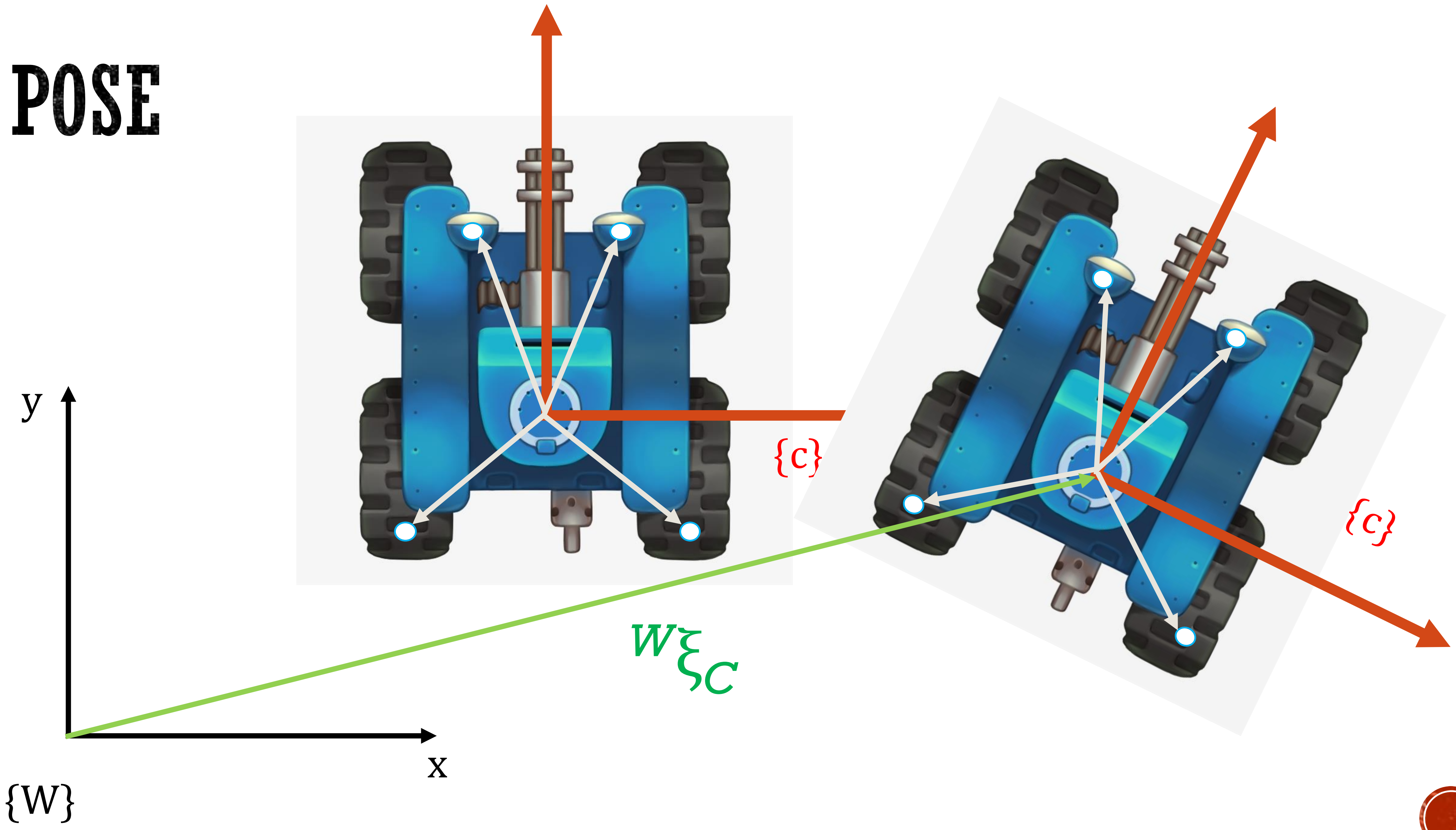



$$^{W}\xi_{B}$$

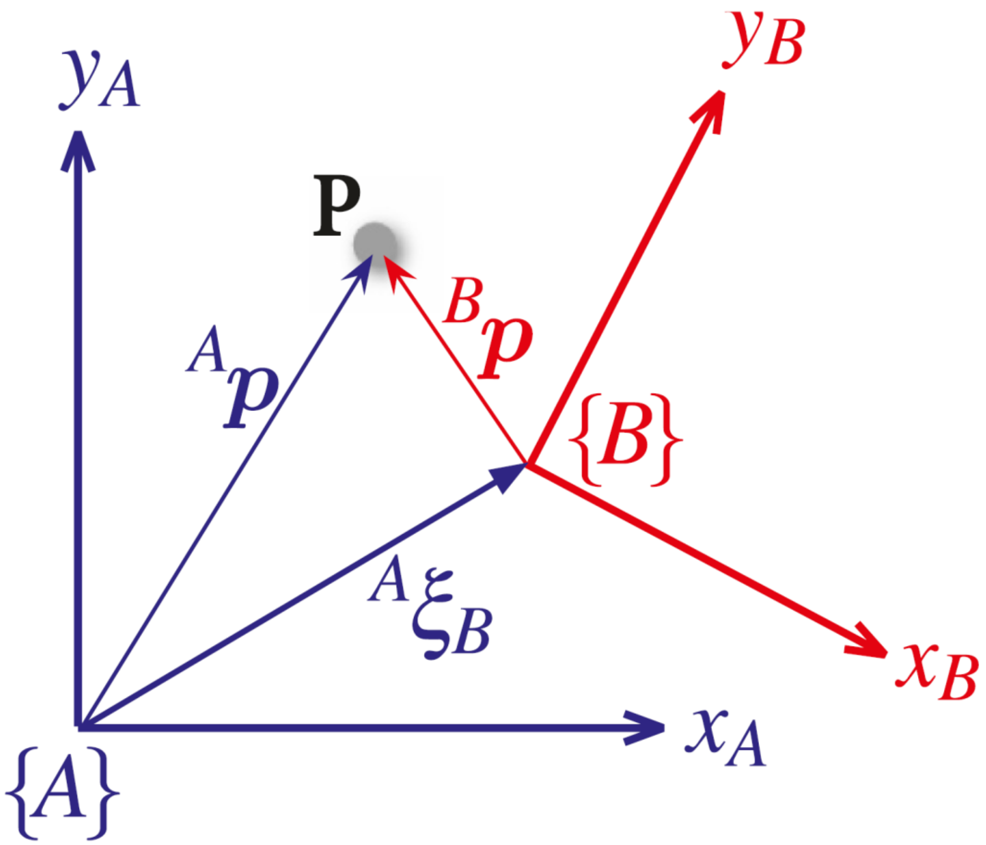
# POSE



# POSE

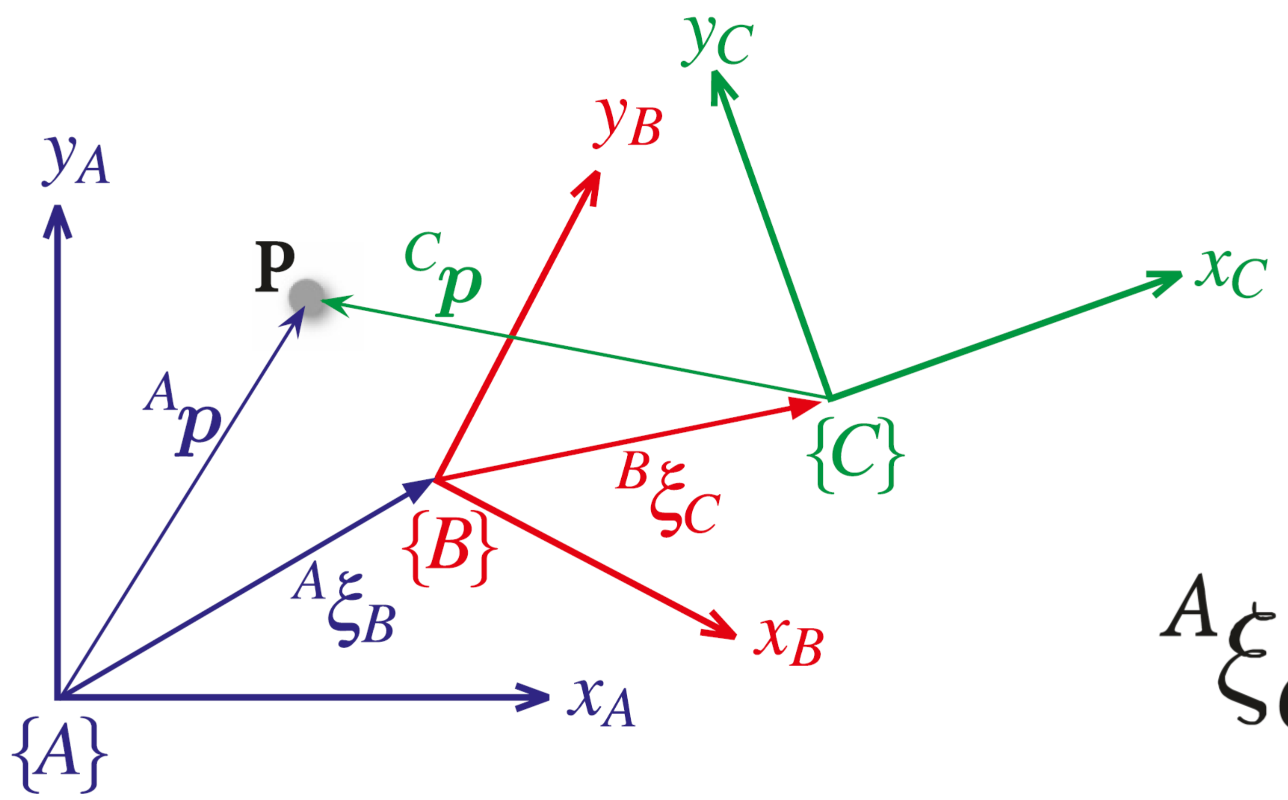


# RELATIVE POSITION



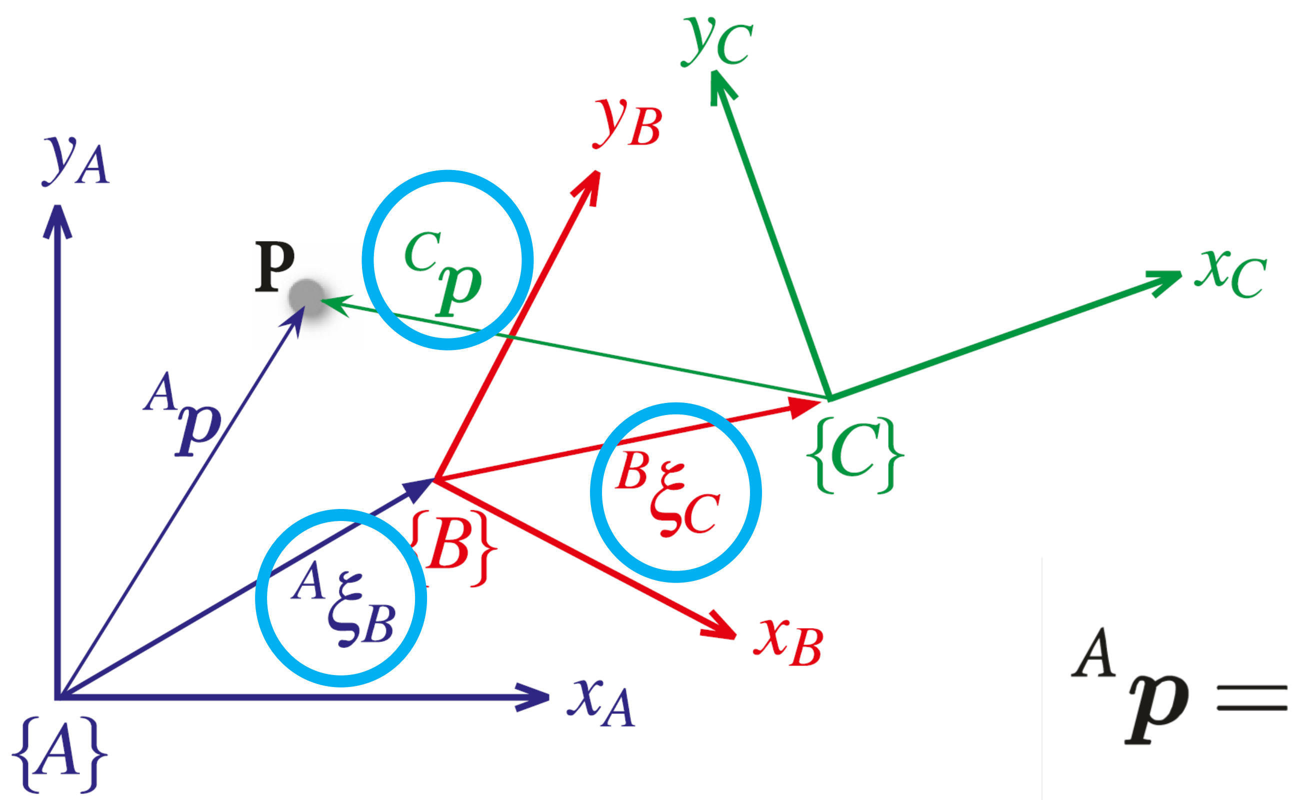

$$^A\boldsymbol{p} = {}^A\xi_B \bullet {}^B\boldsymbol{p}$$

# RELATIVE POSE




$$ {}^A\xi_C = {}^A\xi_B \oplus {}^B\xi_C $$

# RELATIVE POSE



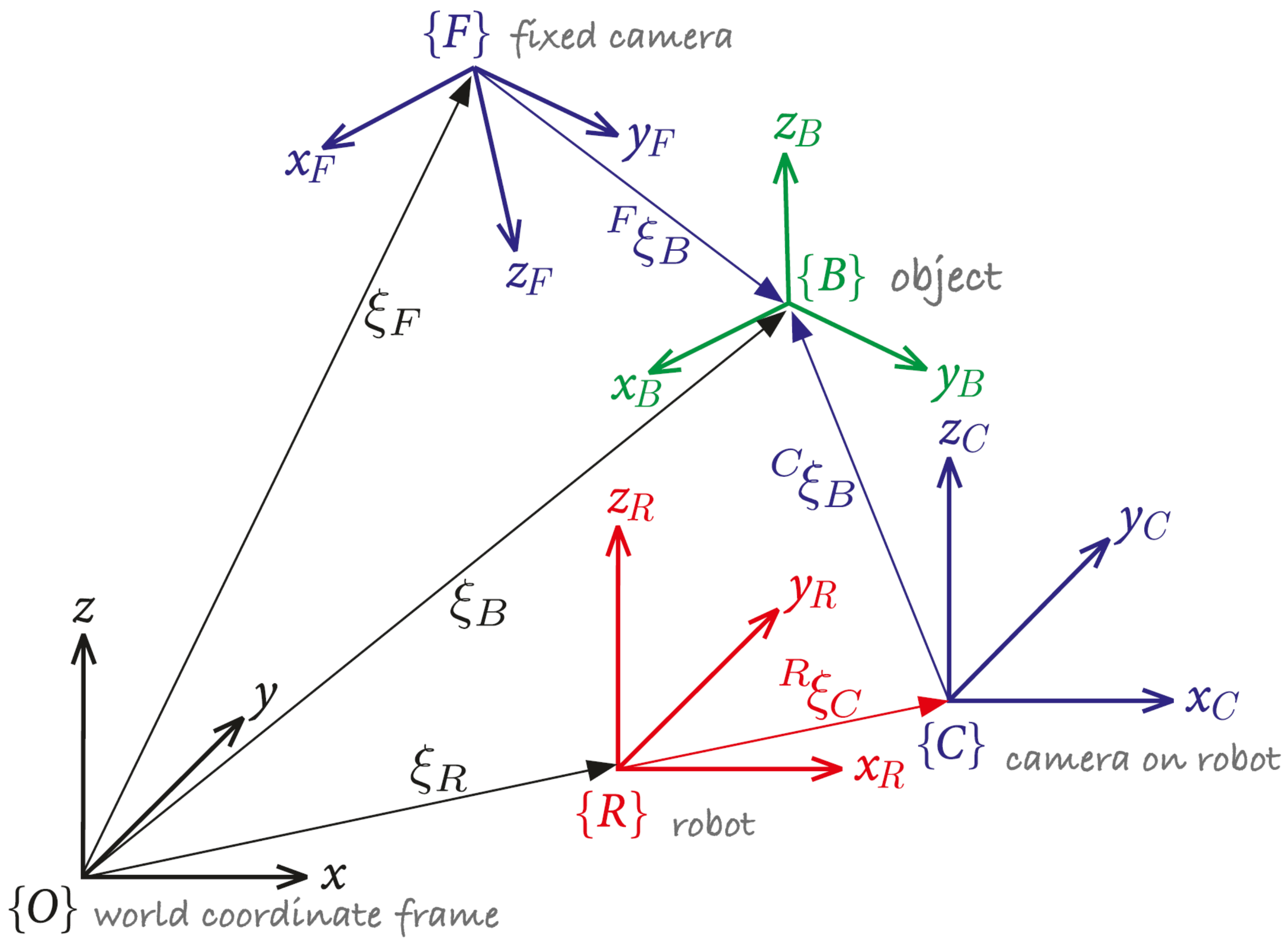

$$^{A}\boldsymbol{p} = \left( {}^{A}\xi_B \oplus {}^{B}\xi_C \right) \cdot {}^{C}\boldsymbol{p}$$

# RELATIVE POSE

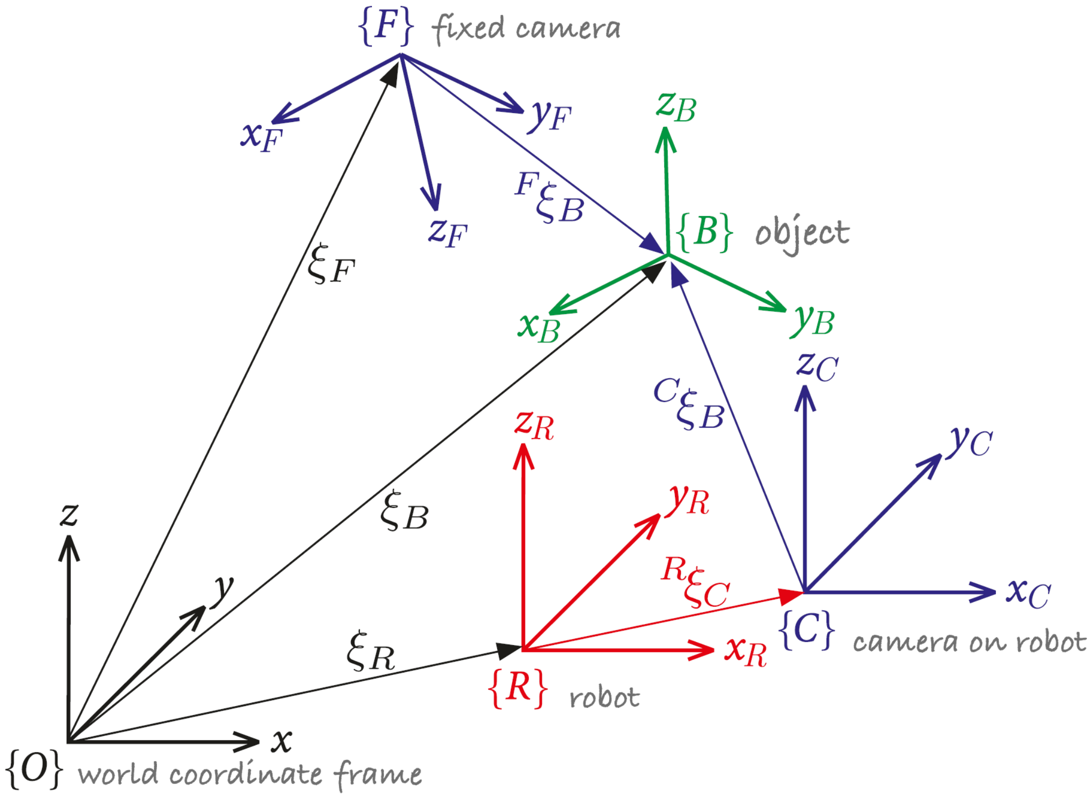
Relative poses can be composed

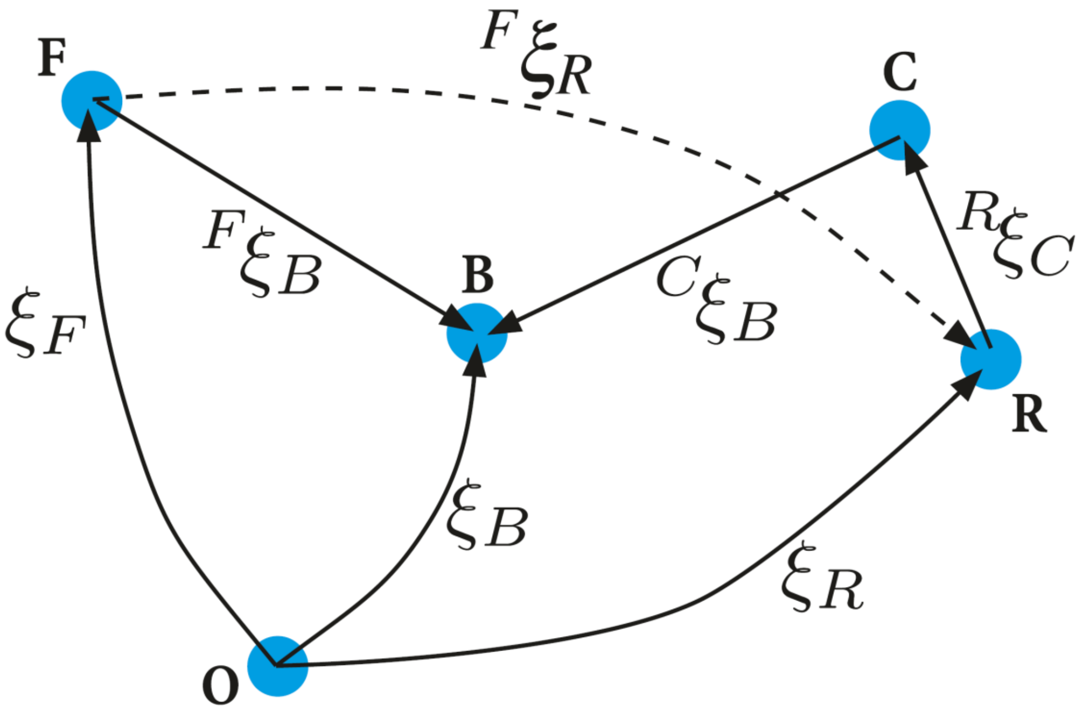
$$ {}^{A}\xi_{B} \oplus {}^{B}\xi_{C} $$

# RELATIVE POSE



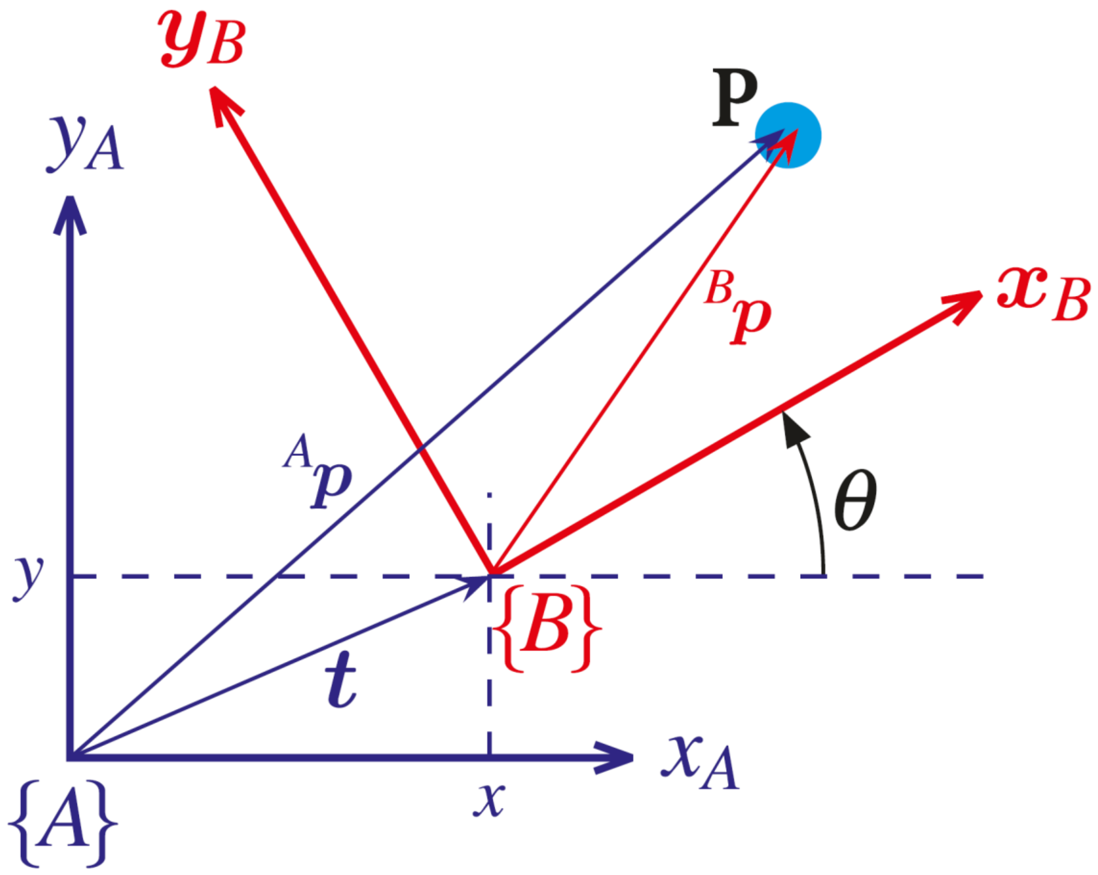
# RELATIVE POSES



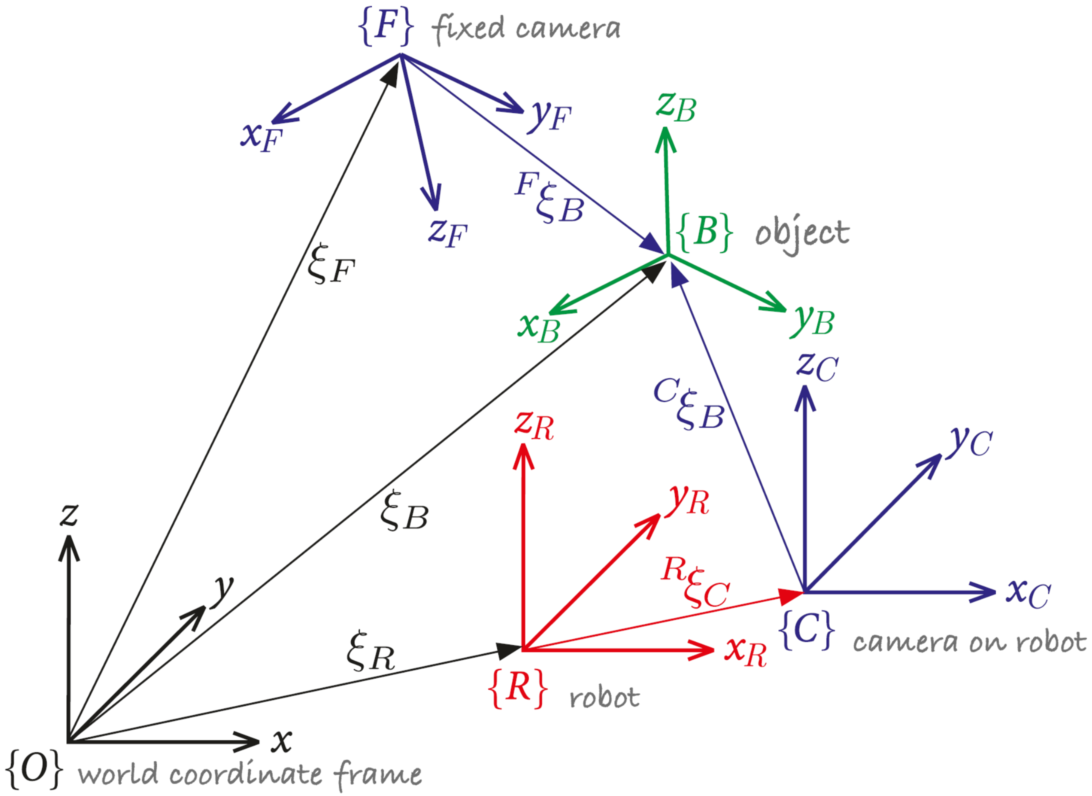



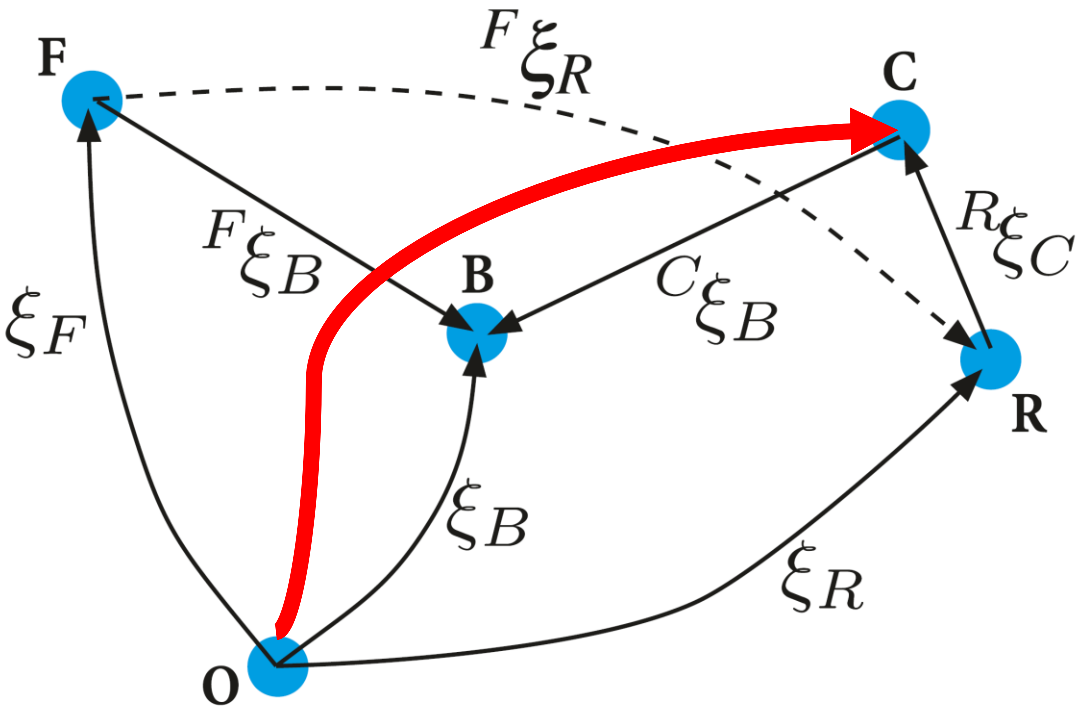
# POSE

$$\begin{bmatrix} R & \mathrm{t} \\ 0^T & 1 \end{bmatrix}$$



# RELATIVE POSES



# ROTATION IN 3D (REVIEW)

$$R_x^{3D}(\omega) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(\omega) & -\sin(\omega) \\ 0 & \sin(\omega) & \cos(\omega) \end{bmatrix} \quad R_y^{3D}(\phi) = \begin{bmatrix} \cos(\phi) & 0 & \sin(\phi) \\ 0 & 1 & 0 \\ -\sin(\phi) & 0 & \cos(\phi) \end{bmatrix}$$

$$R_z^{3D}(\kappa) = \begin{bmatrix} \cos(\kappa) & -\sin(\kappa) & 0 \\ \sin(\kappa) & \cos(\kappa) & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

# ORDER OF ROTATION

# EULER'S ROTATION THEOREM

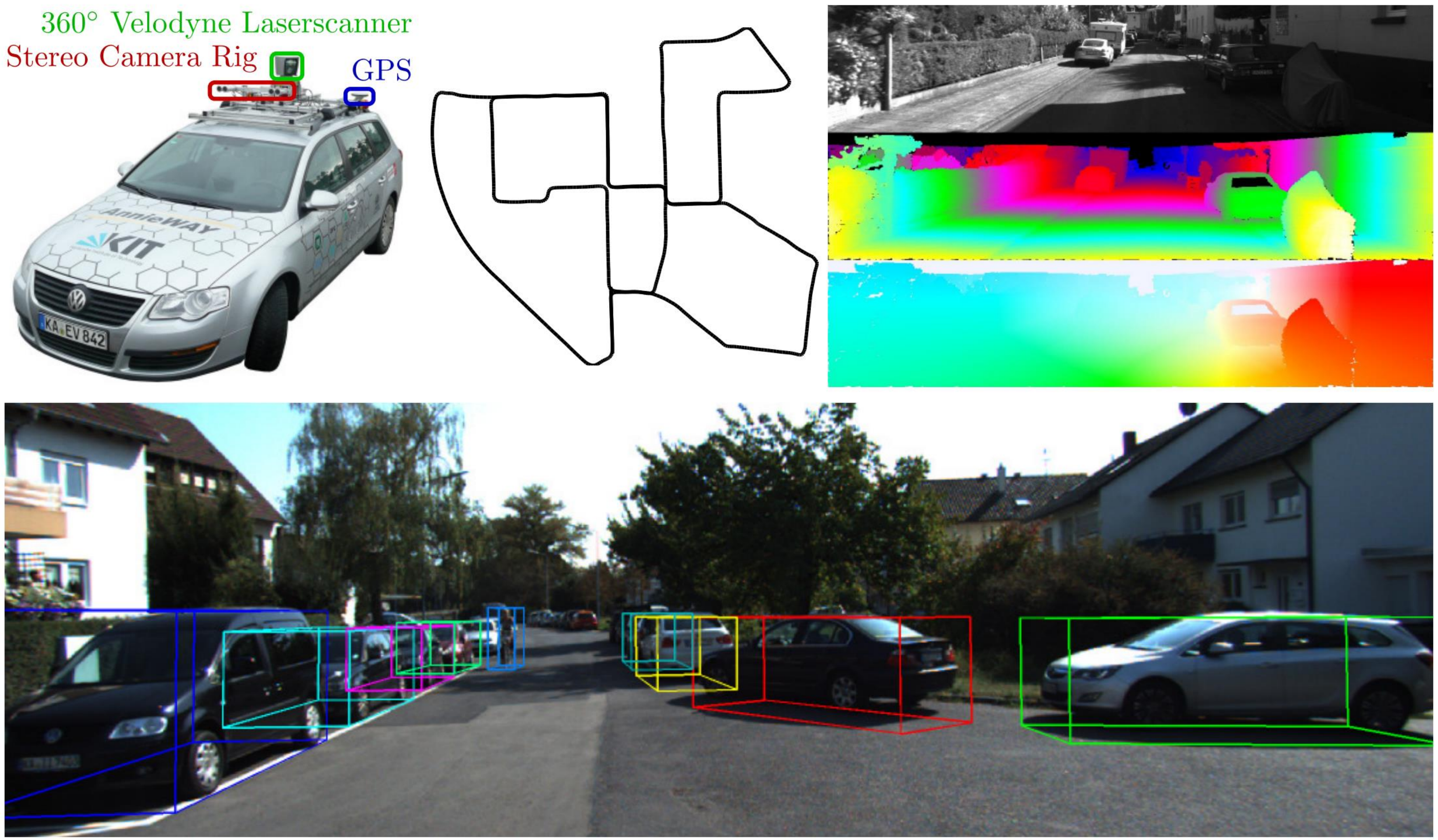
Any two independent orthonormal coordinate frames can be related by a sequence of rotations (not more than 3) about coordinate axes, where no two successive rotations may be about the same axis.

XYX XYZ XZY XZX

YXY YXZ YZX YZY

ZXY ZXZ ZYX ZYZ

# KITTI

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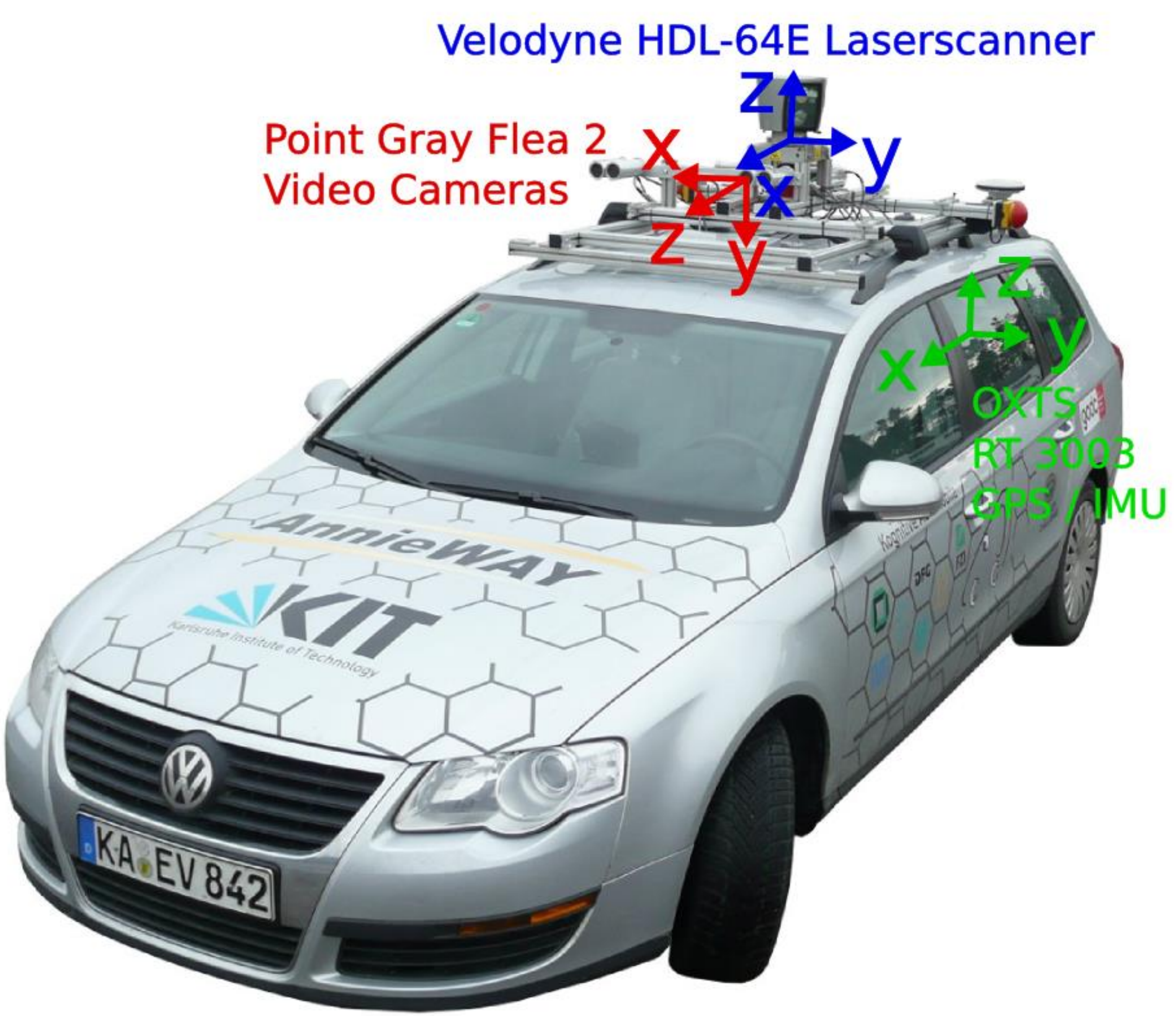
# KITTI


Velodyne HDL-64E Laserscanner
z
y
x
Point Gray Flea 2
Video Cameras
x
z
y
z
y
x
OXTS
RT 3003
GPS / IMU
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Karlsruhe Institute of Technology
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