Robotics & Internet-of-Things

ROS

Udemy Course
Robot Operating System
(Part II)
Navigation and SLAM

Prof. Anis Koubaa

Section 1. Frames

https://www.udemy.com/user/anis-koubaa/

Learning Outcome

- Recognize the concepts of pose and coordinate frames
- Represent the position and orientation of the robot in space

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Pose of a Robot in a Frame

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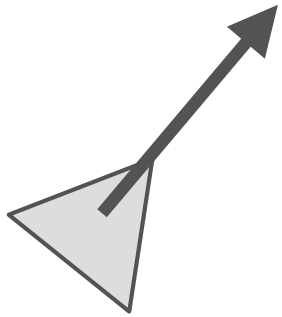
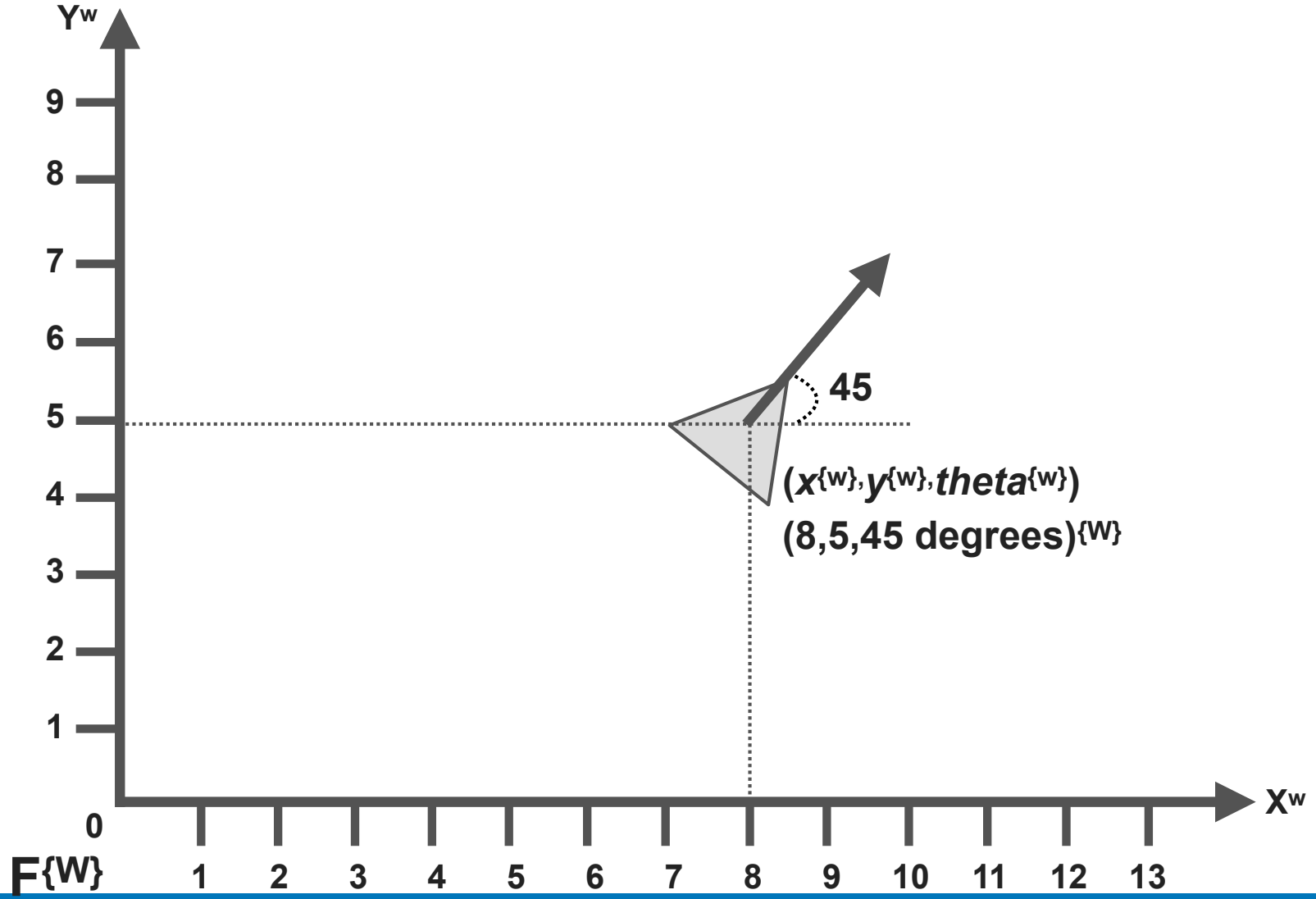
COORDINATE FRAME



What is the location of this robot?

COORDINATE FRAME AND POSE




Yw
9
8
7
6
5
4
3
2
1
0
F{W}
1
2
3
4
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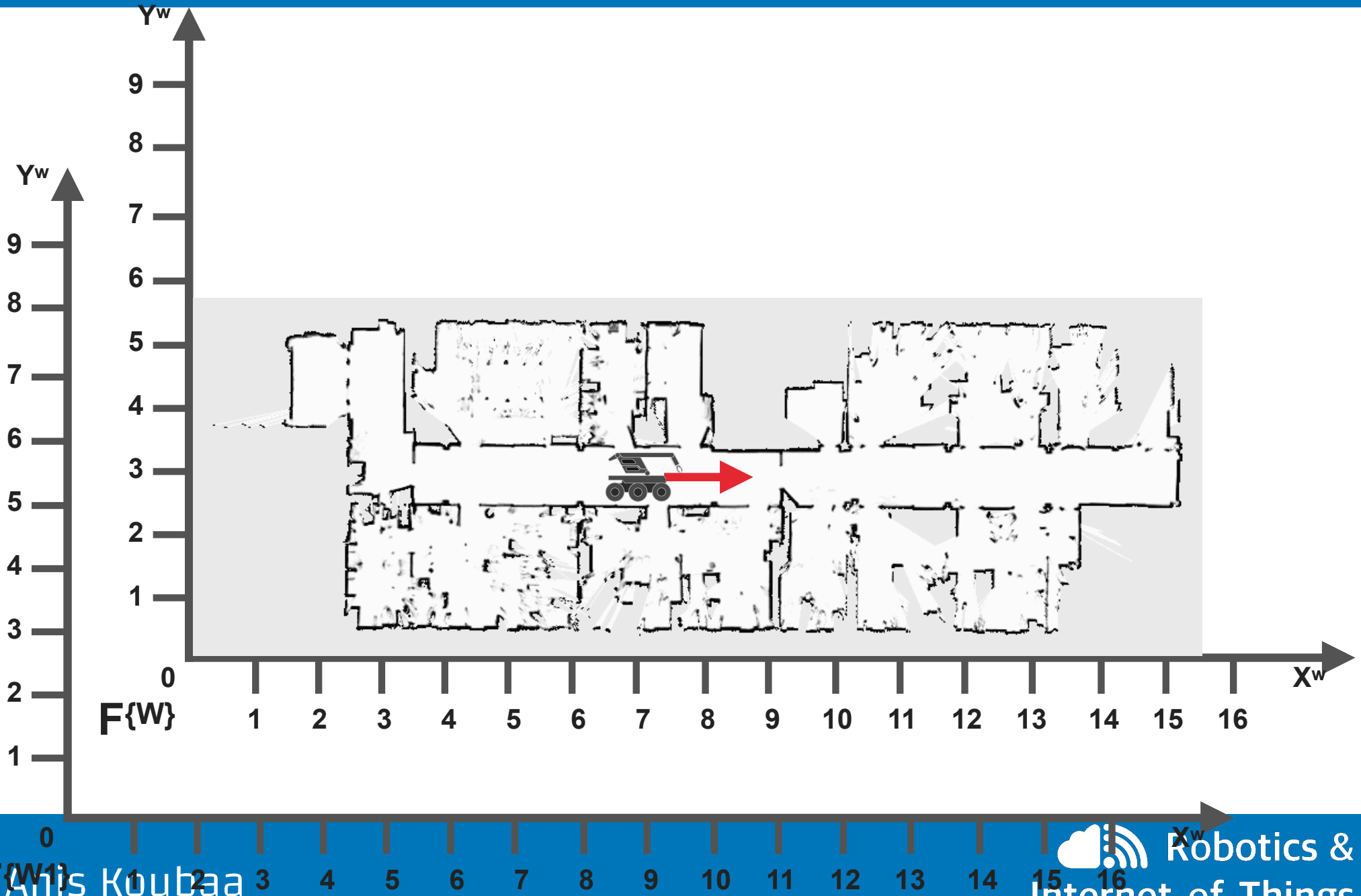
6
7
8
9
10
11
12
13
14
15
16
Xw


Yw
Xw
F{W}
F{W1}
0
1
2
3
4
5
6
7
8
9
10
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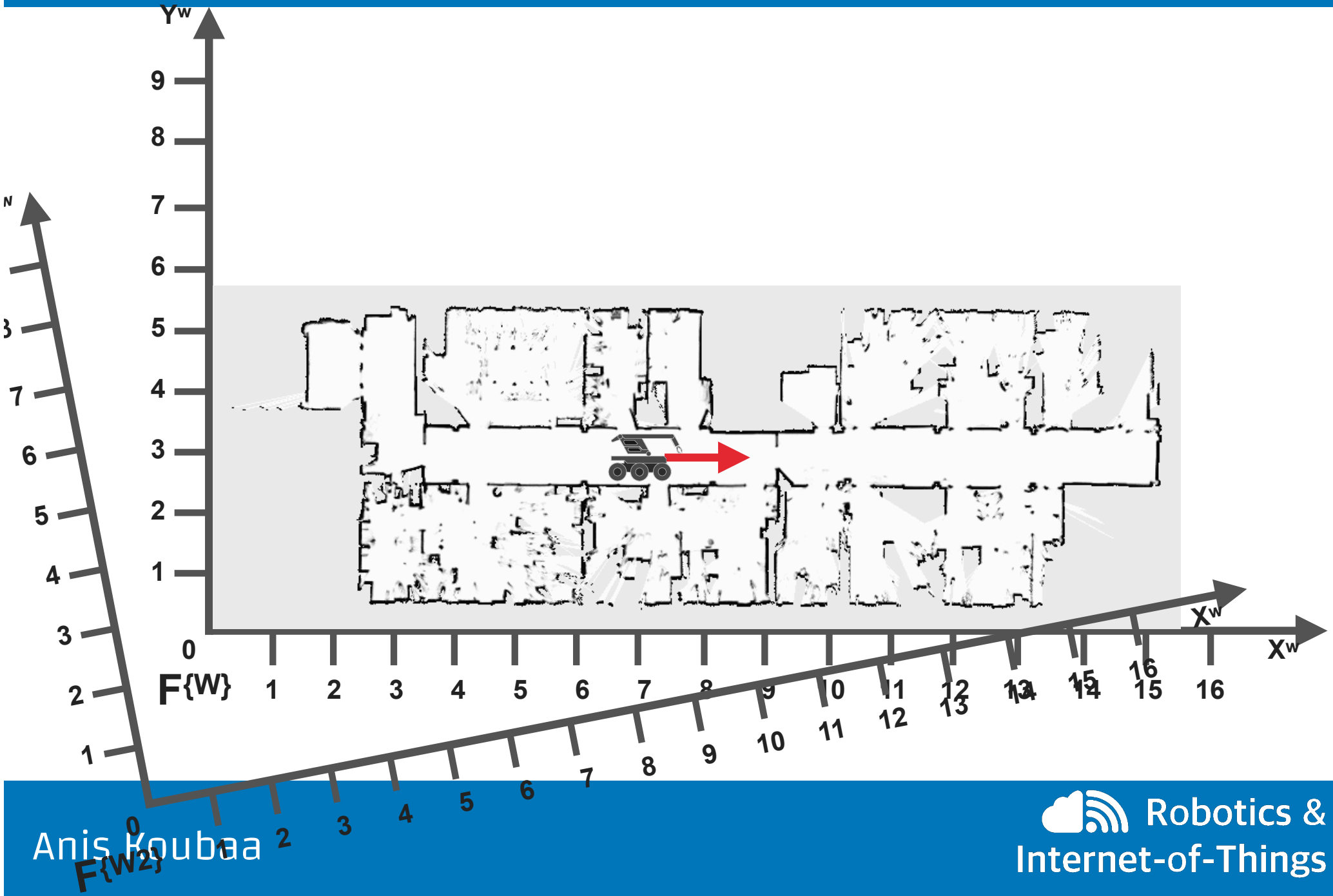
12
13
14
15
16



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Dealing with Multiple Frames

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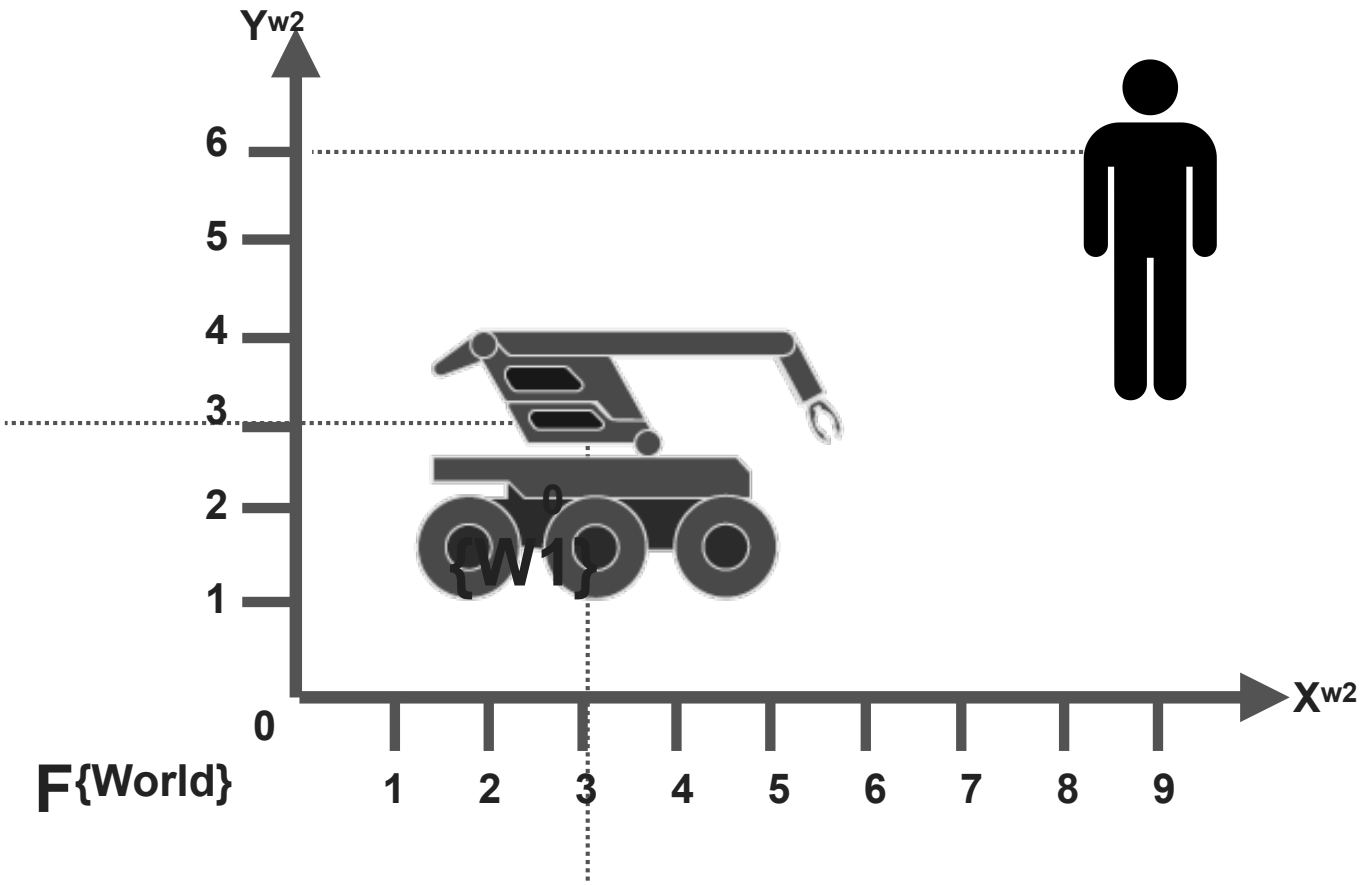
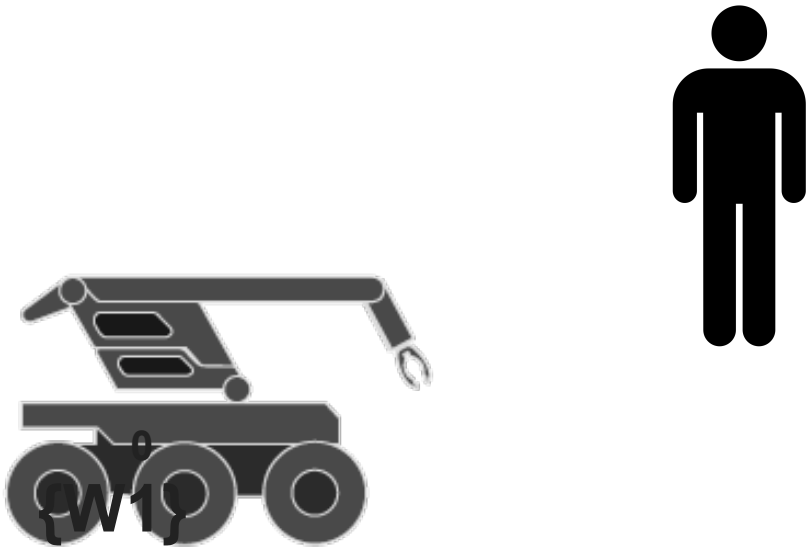
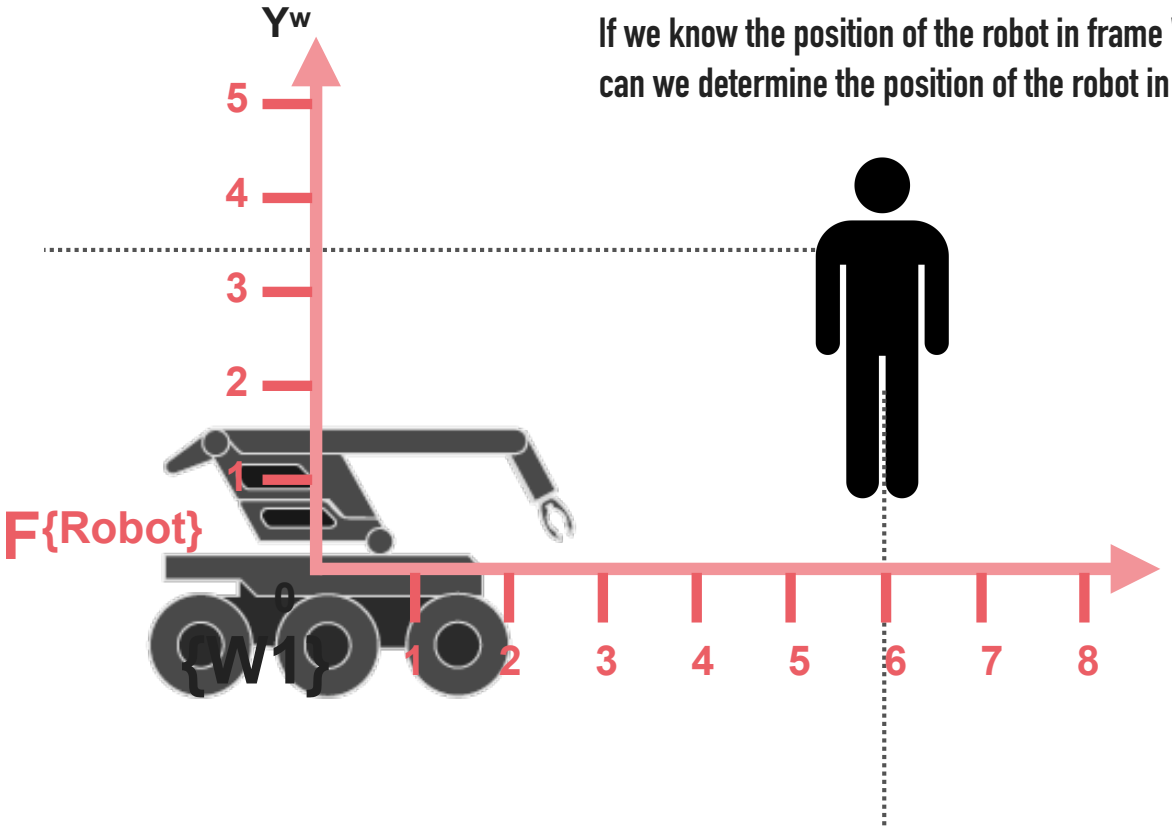
LOCATION IN WORLD COORDINATE FRAME



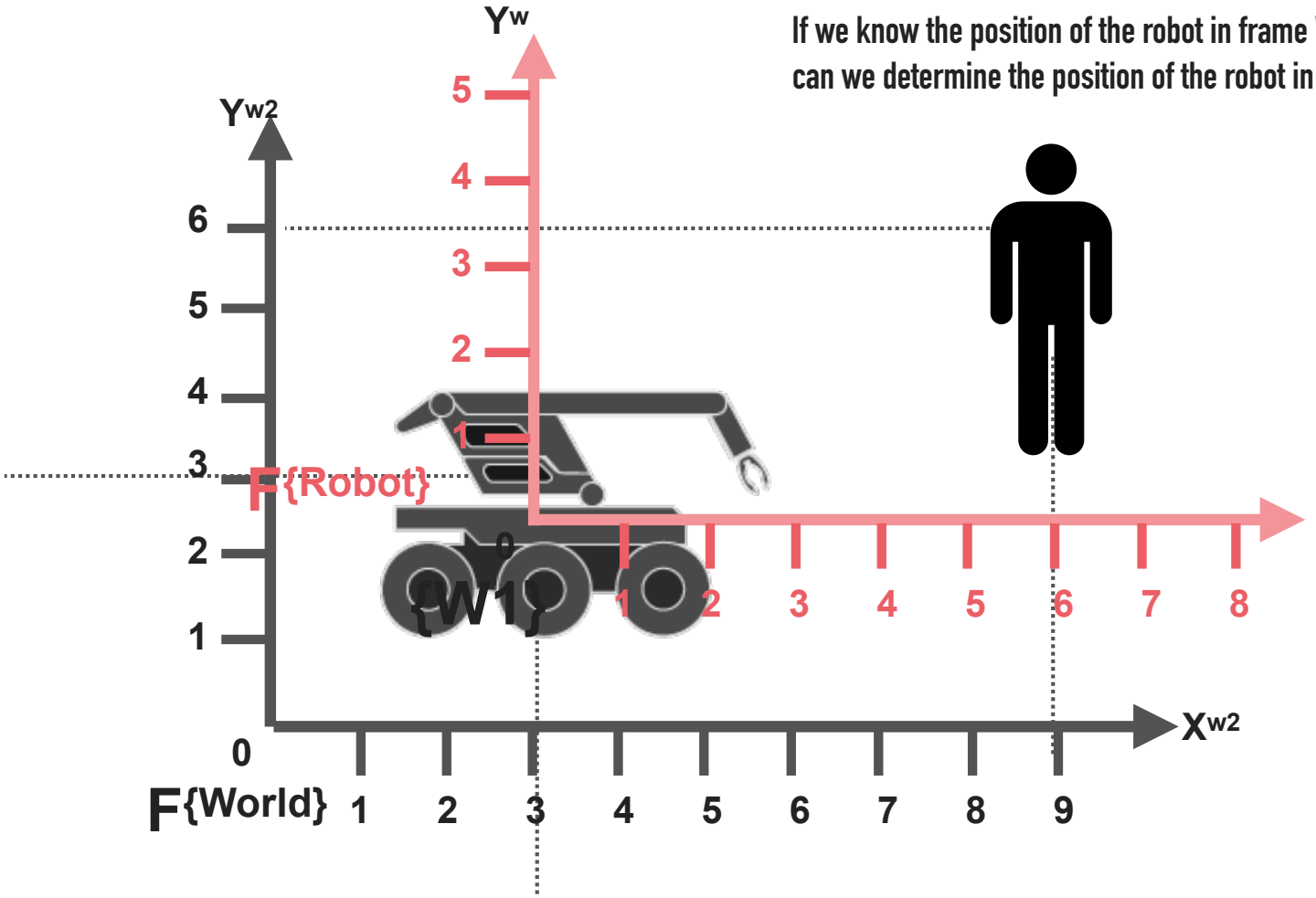
LOCATION IN THE ROBOT COORDINATE FRAME



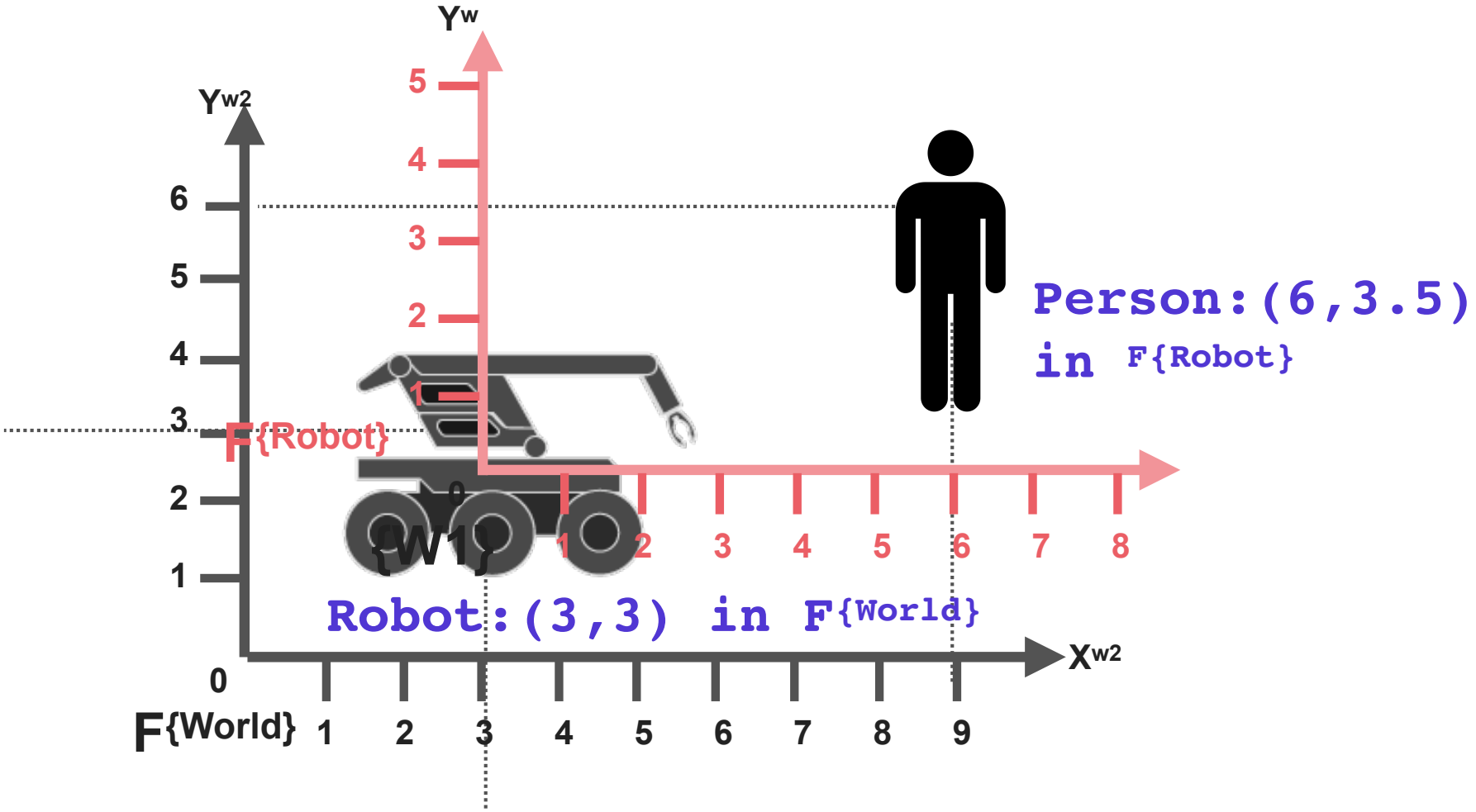
LOCATION IN THE ROBOT COORDINATE FRAME



LOCATION IN THE ROBOT AND WORLD COORDINATE FRAMES



LOCATION IN THE ROBOT AND WORLD COORDINATE FRAMES



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Coordinate Frame Transformation

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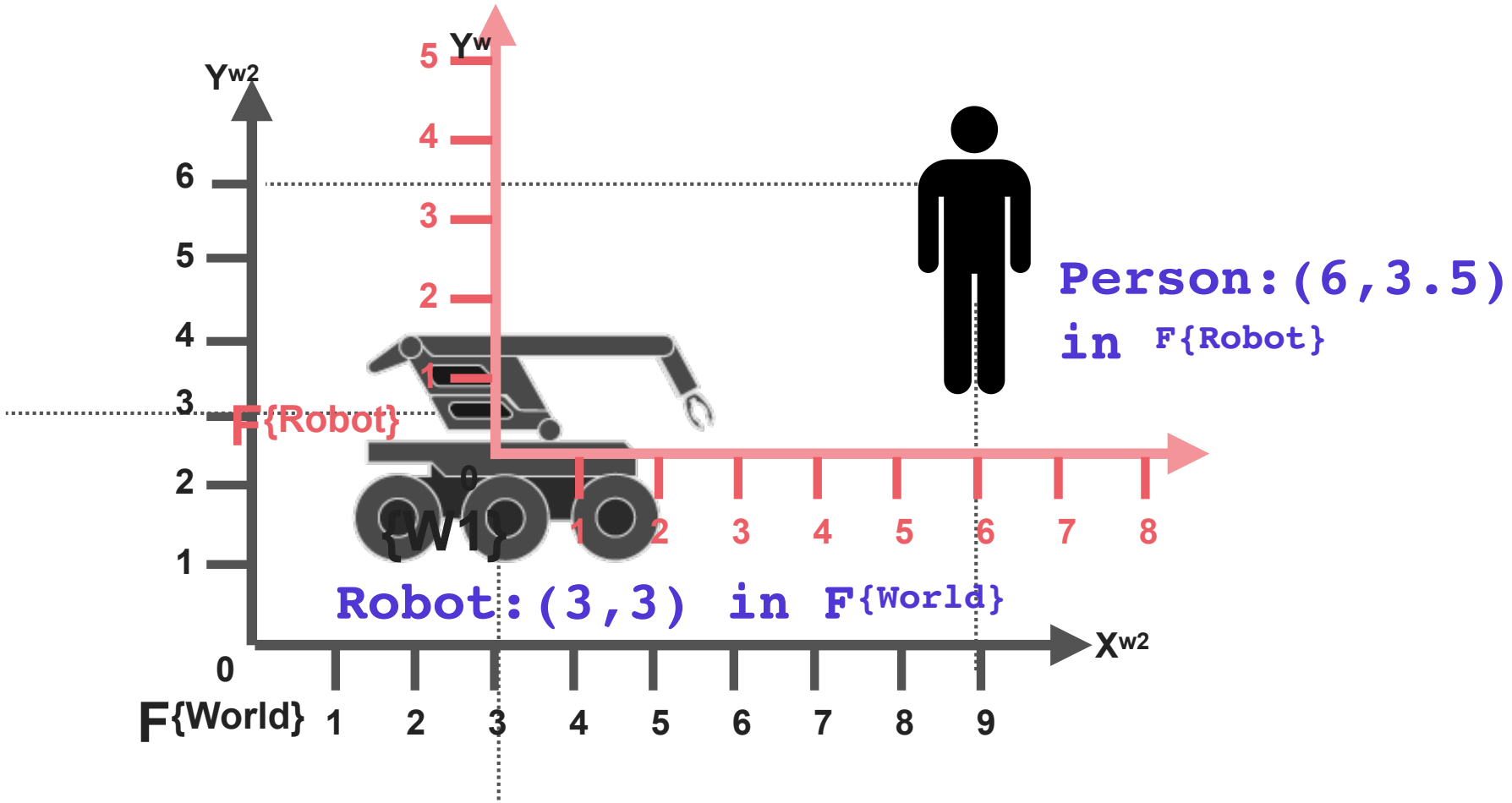
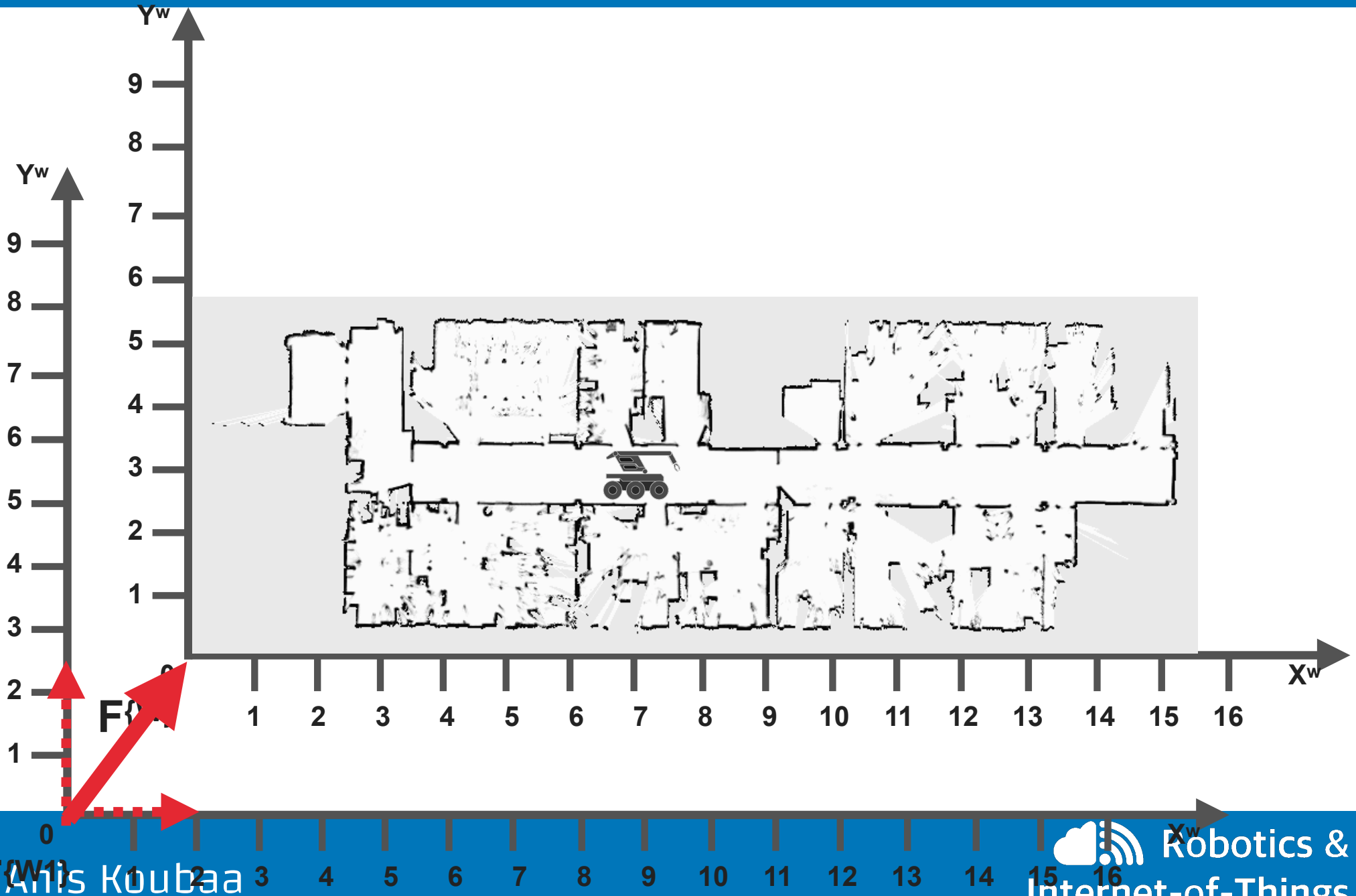
LOCATION IN THE ROBOT AND WORLD COORDINATE FRAMES



Person in F{world}?

TRANSFORMATION TYPES

- Translation
- Rotation


Yw
Xw
{W1}
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
0 1 2 3 4 5 6 7 8 9


Yw
Xw
F{W}
F{W2}
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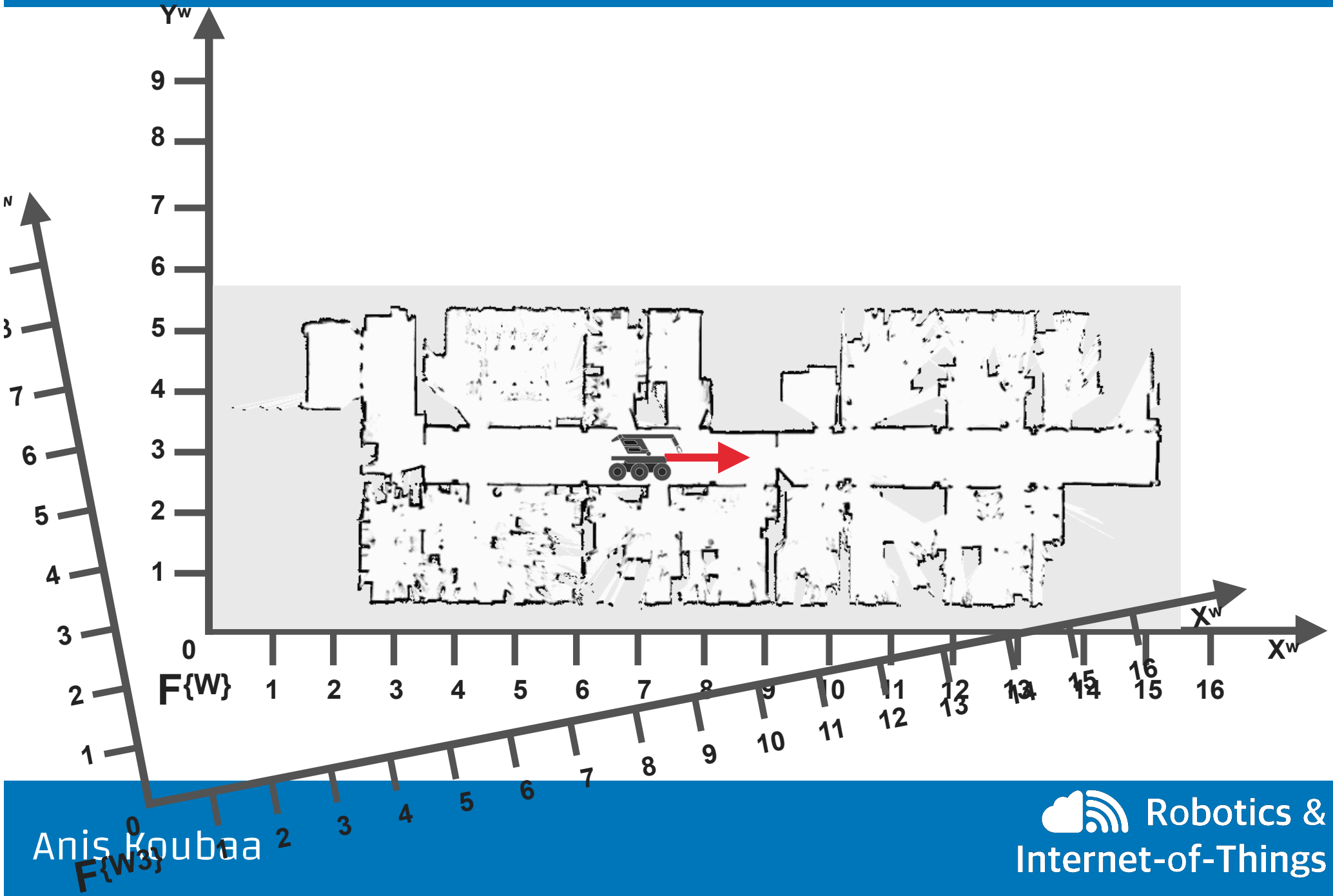

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2D Translation

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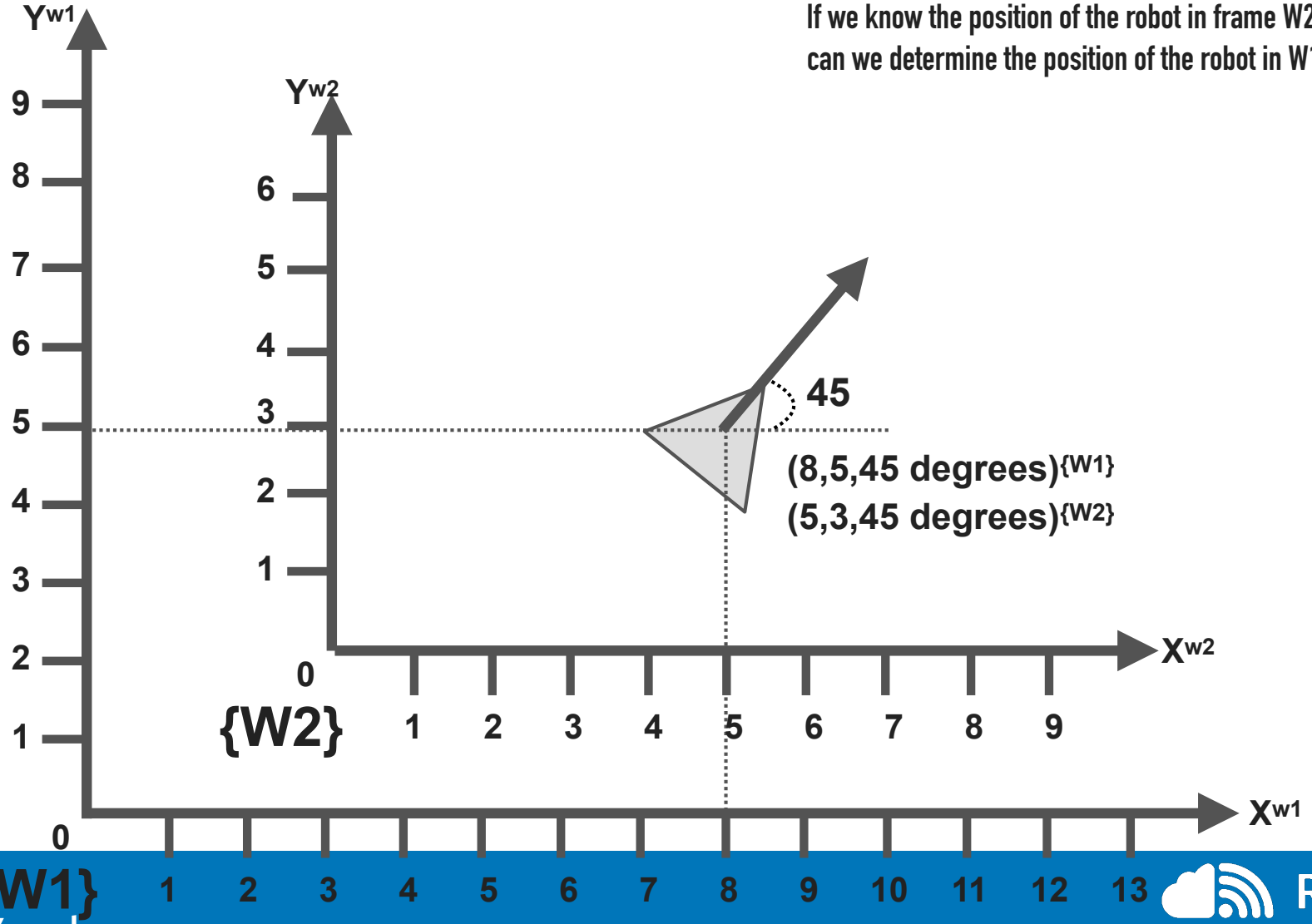
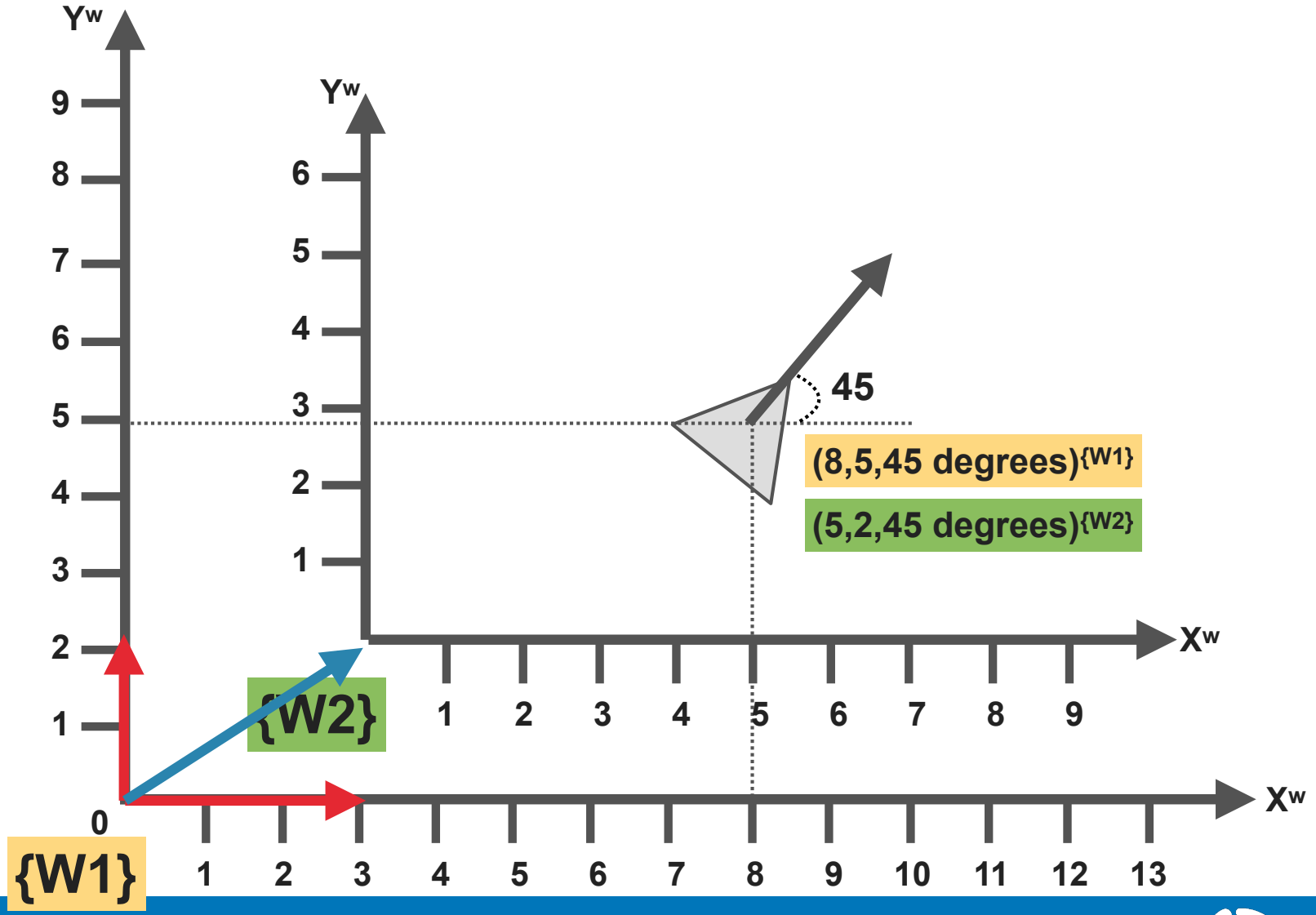
COORDINATE FRAME: TRANSLATION

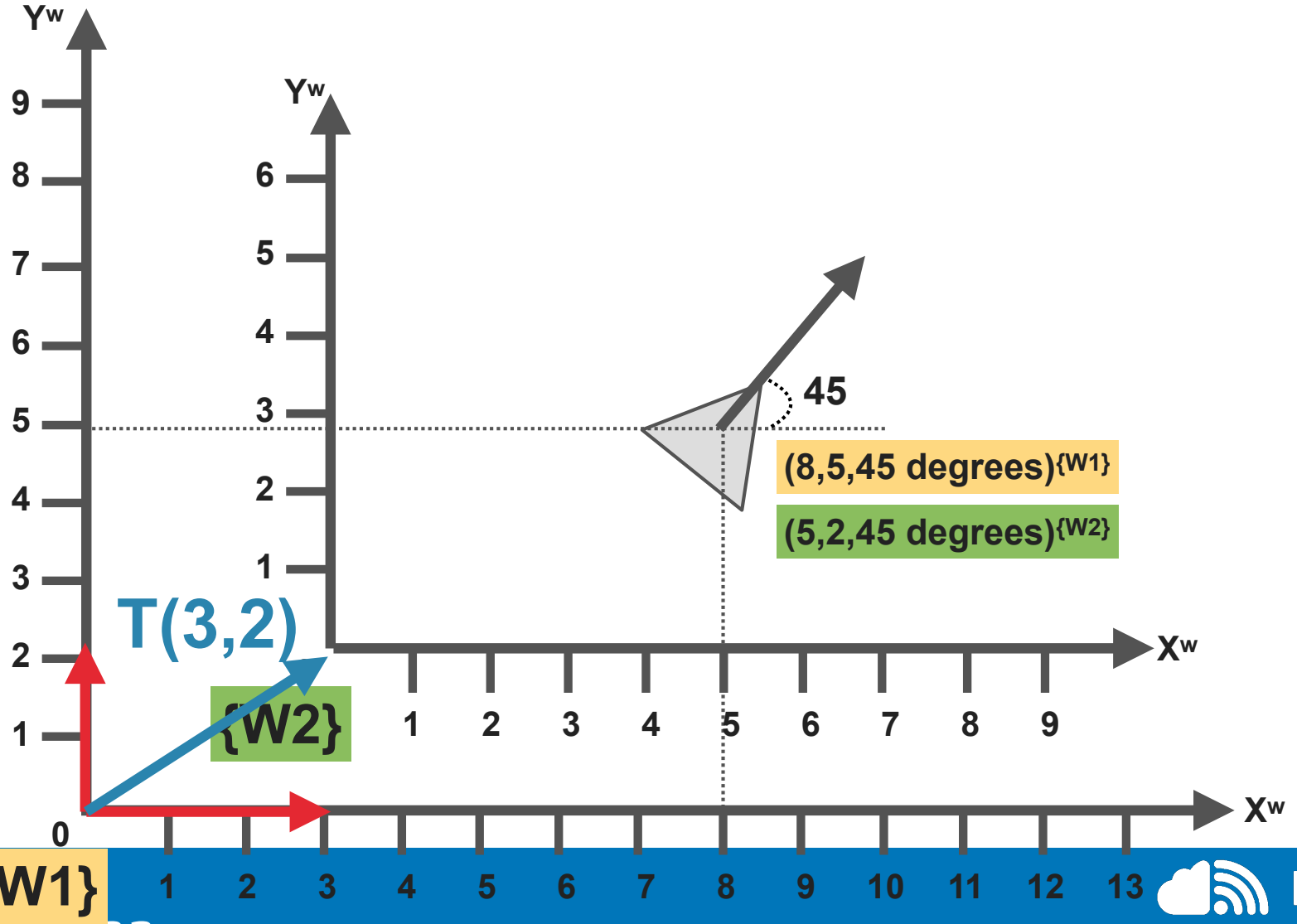
If we know the position of the robot in frame W2,
can we determine the position of the robot in W1?



COORDINATE FRAME: TRANSLATION

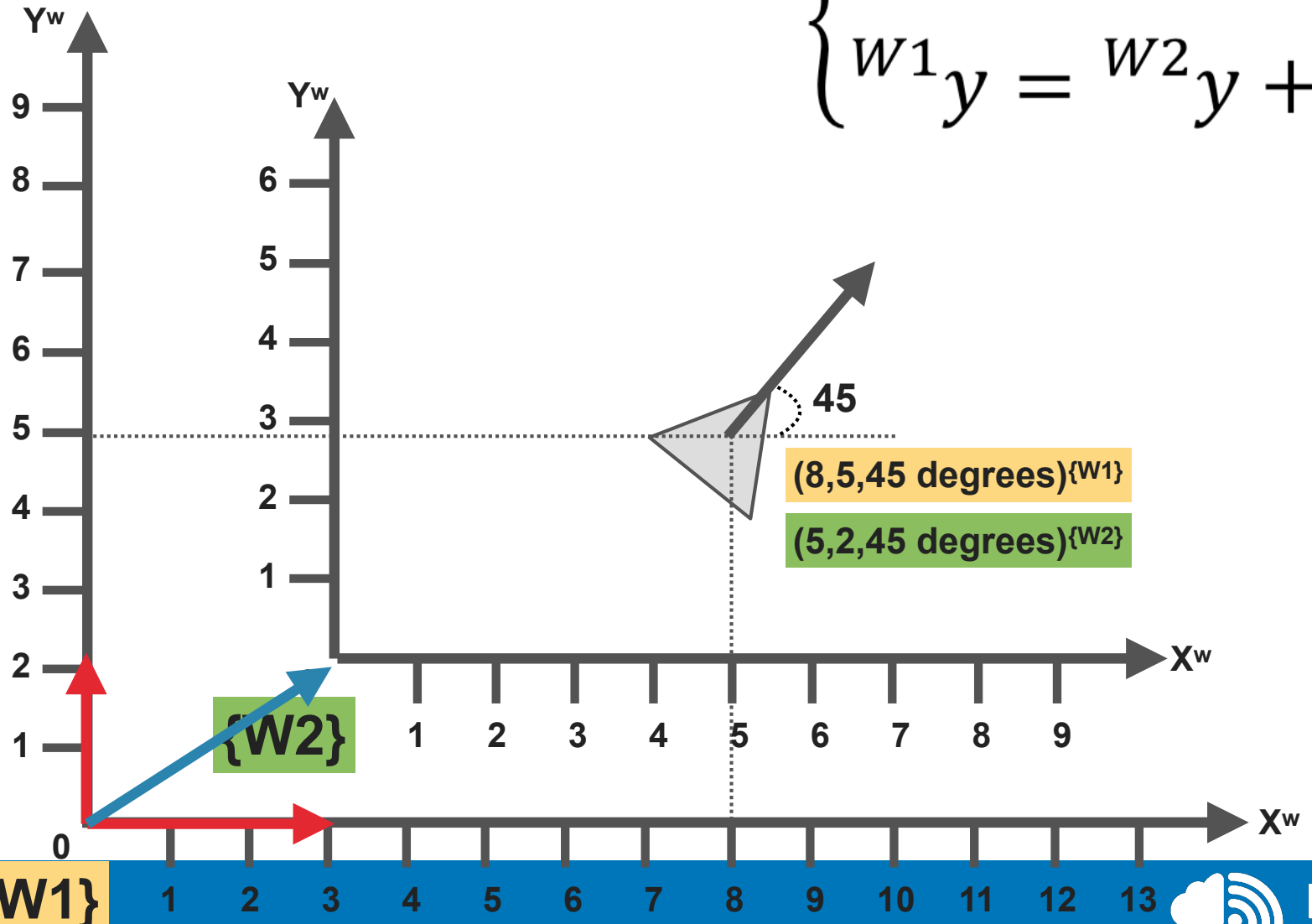


COORDINATE FRAME: TRANSLATION



COORDINATE FRAME: TRANSL

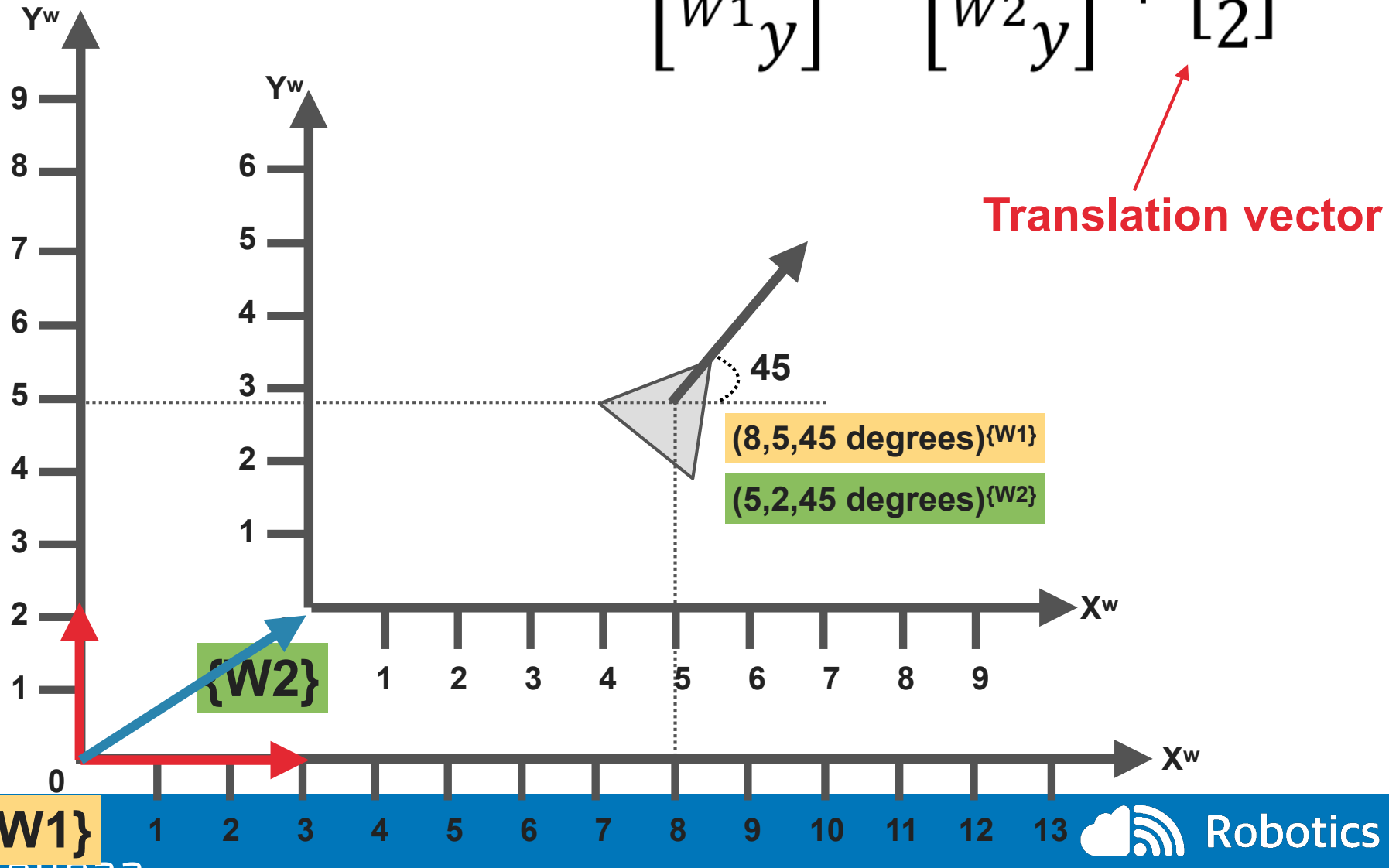
$$\begin{cases} {}^{W1}x = {}^{W2}x + 3 \\ {}^{W1}y = {}^{W2}y + 2 \end{cases}$$



COORDINATE FRAME: TRAN

$$\begin{bmatrix} {}^{W1}x \\ {}^{W1}y \end{bmatrix} = \begin{bmatrix} {}^{W2}x \\ {}^{W2}y \end{bmatrix} + \begin{bmatrix} 3 \\ 2 \end{bmatrix}$$

Translation vector



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2D Rotation

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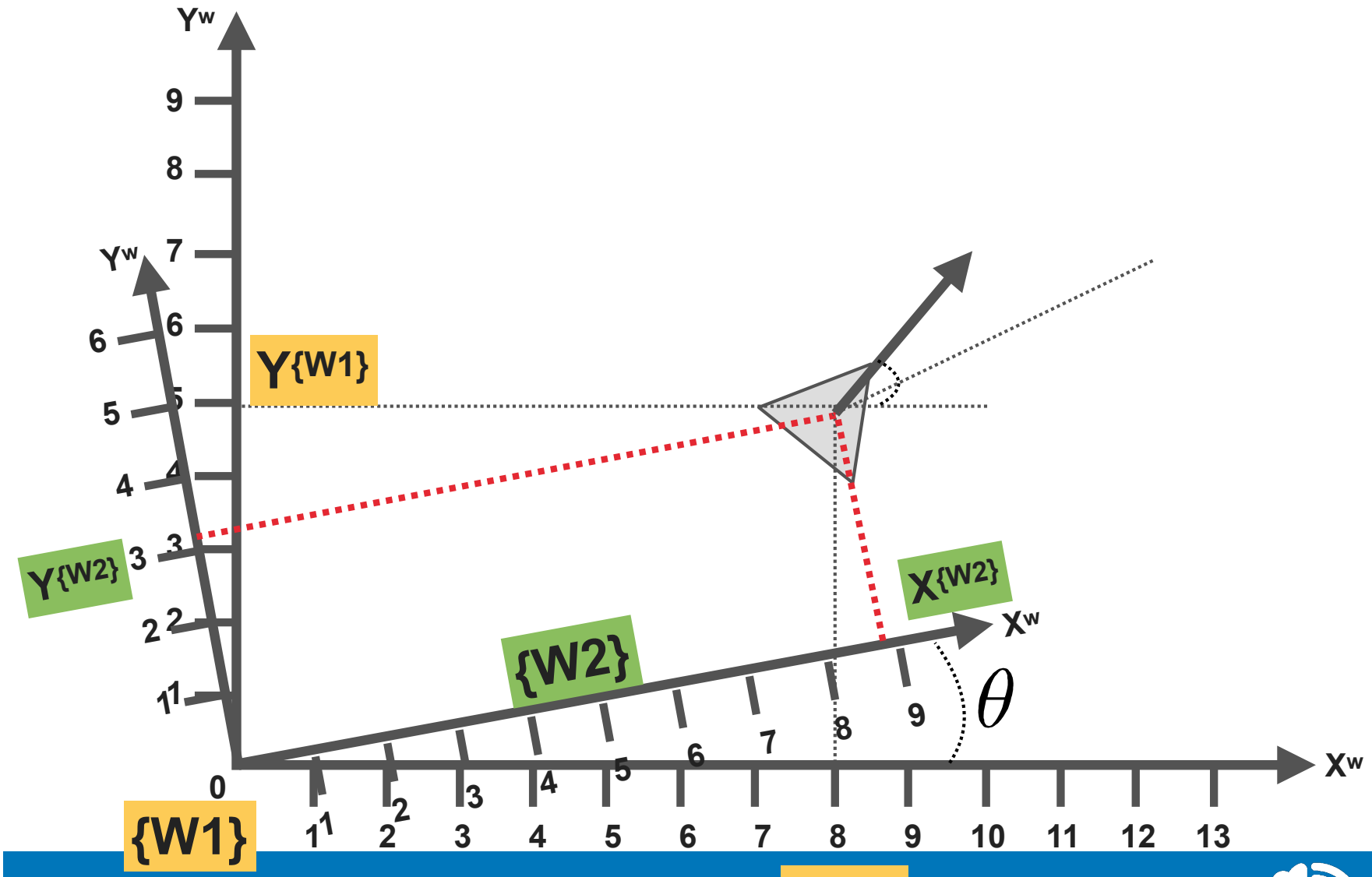
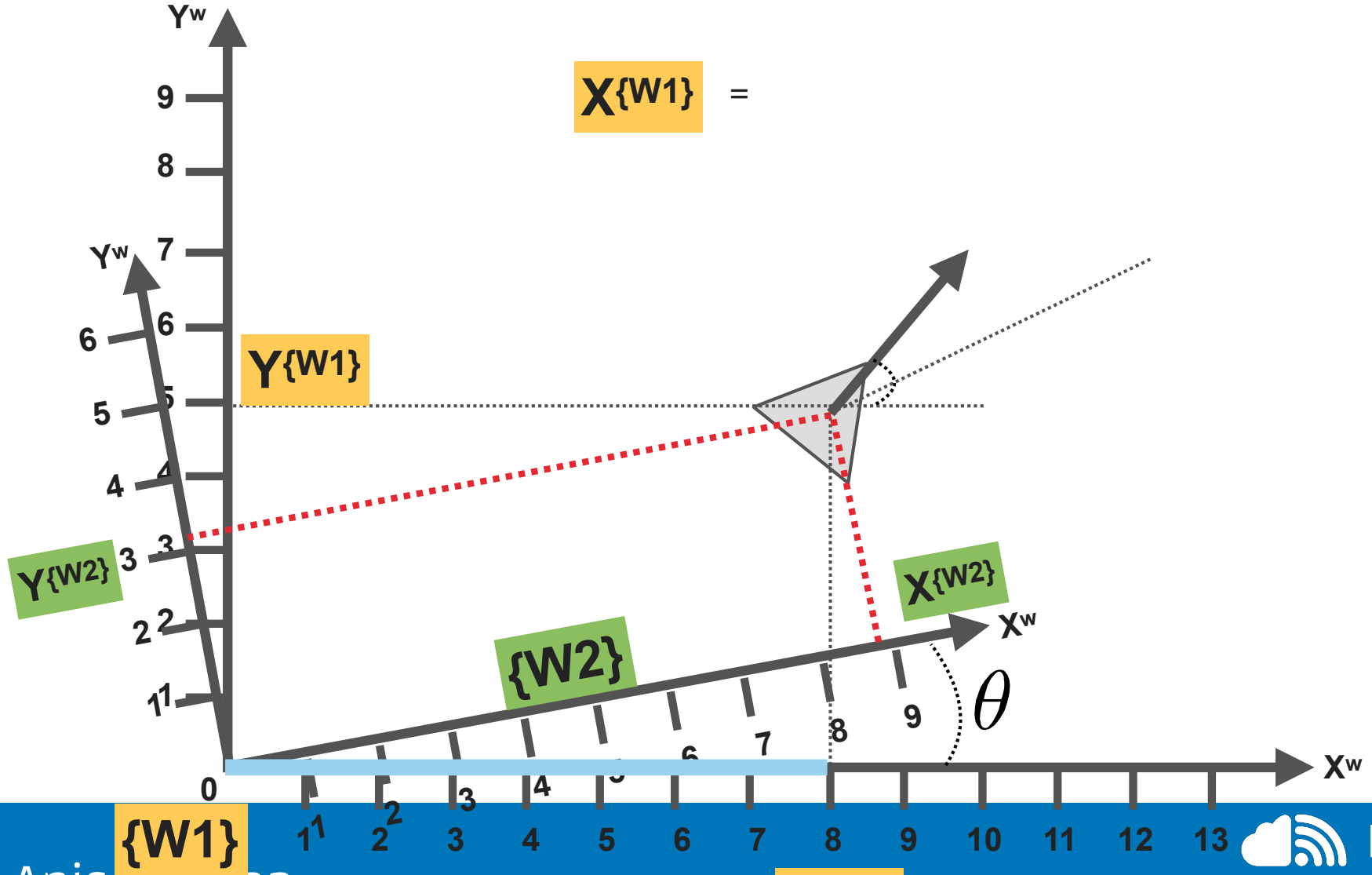
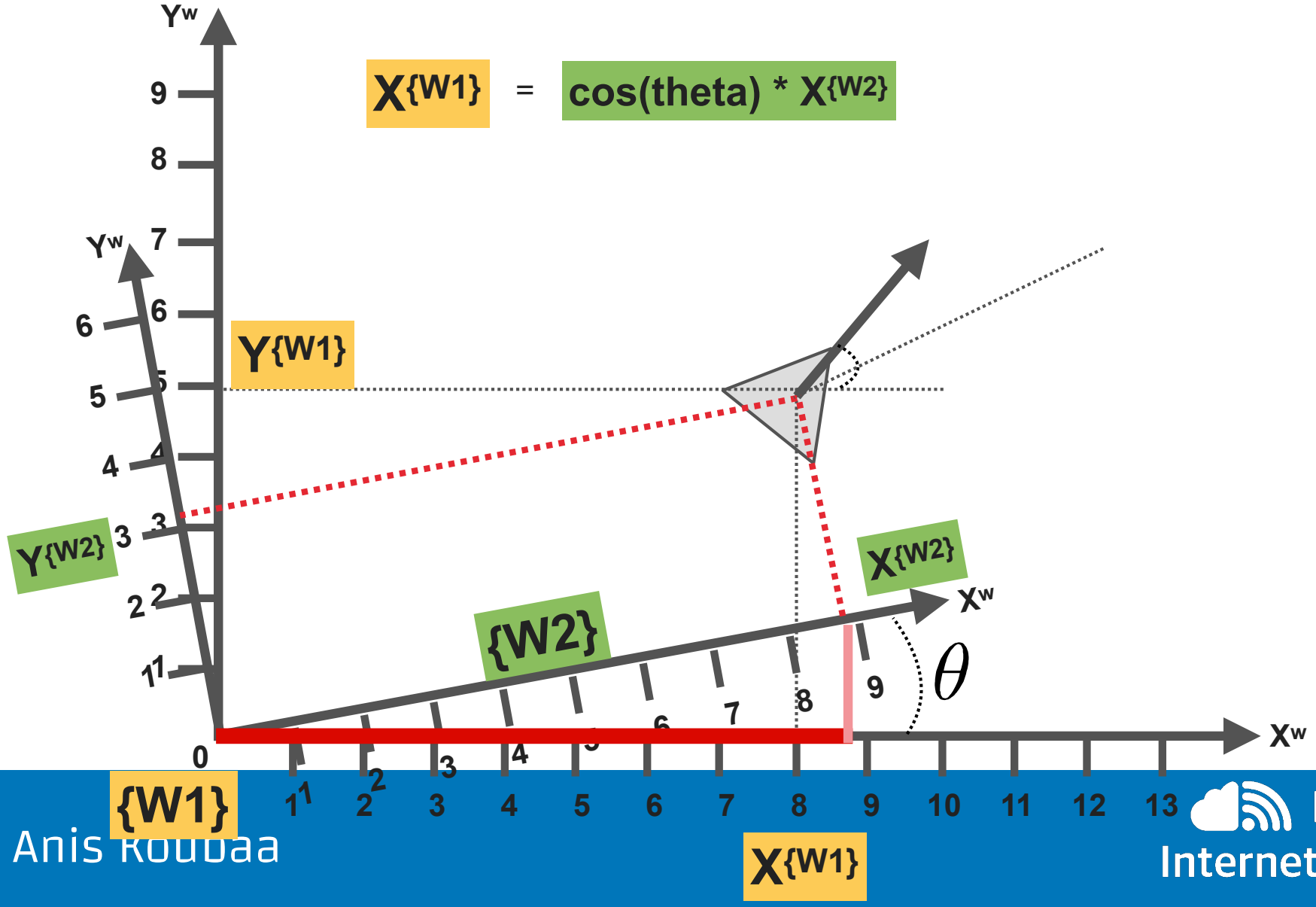
COORDINATE FRAME: ROTATION



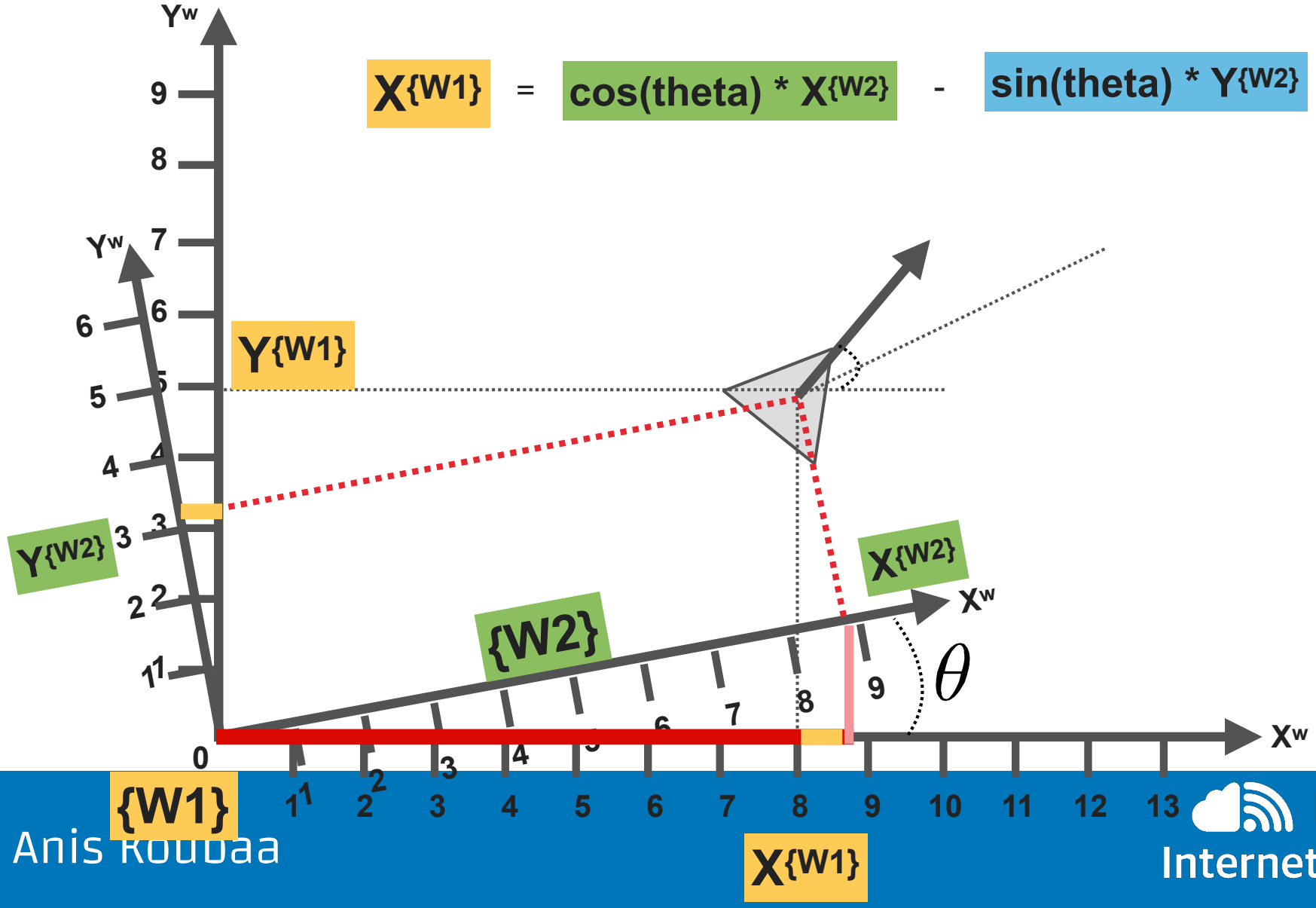
COORDINATE FRAME: ROTATION



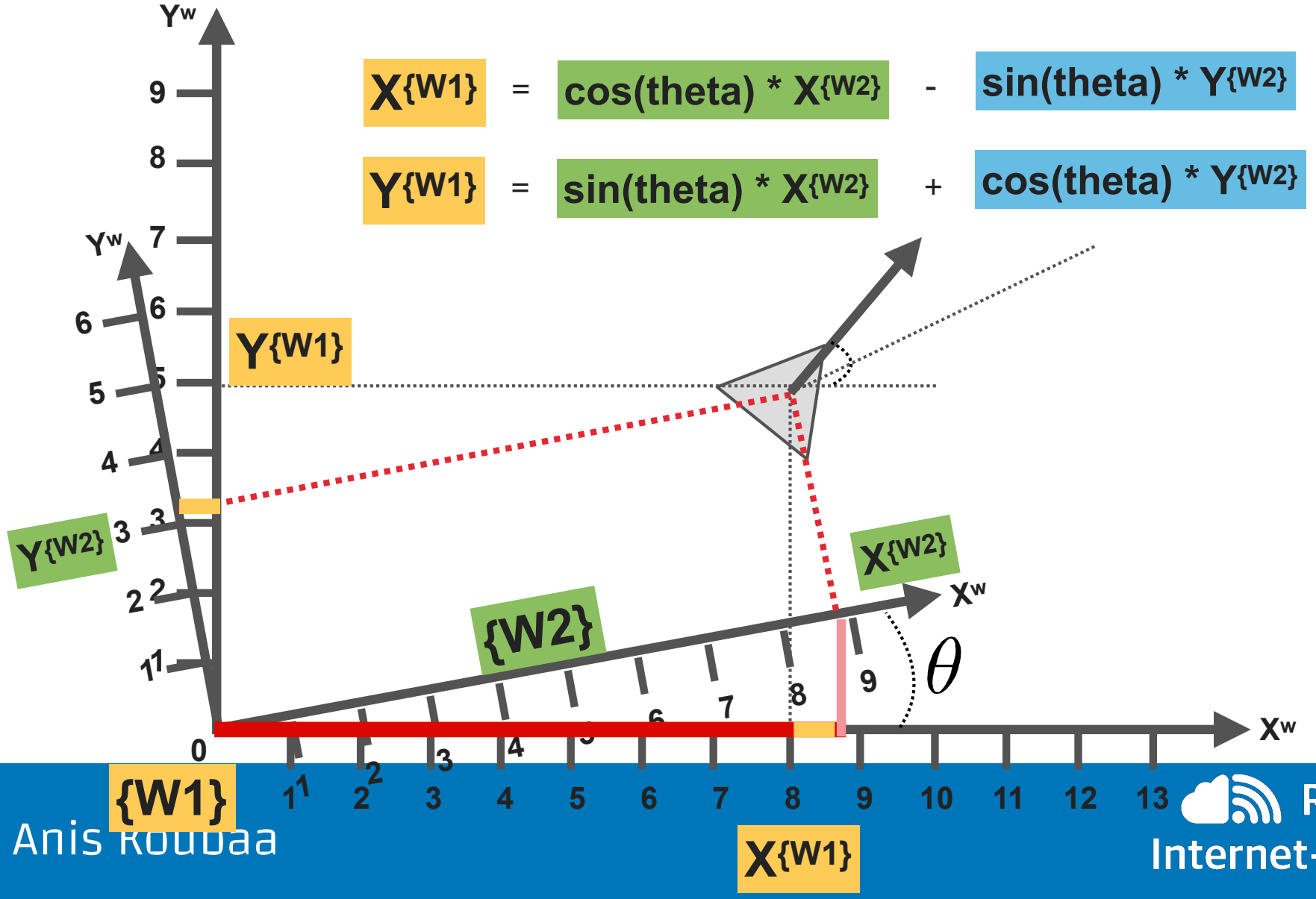
COORDINATE FRAME: ROTATION



COORDINATE FRAME: ROTATION

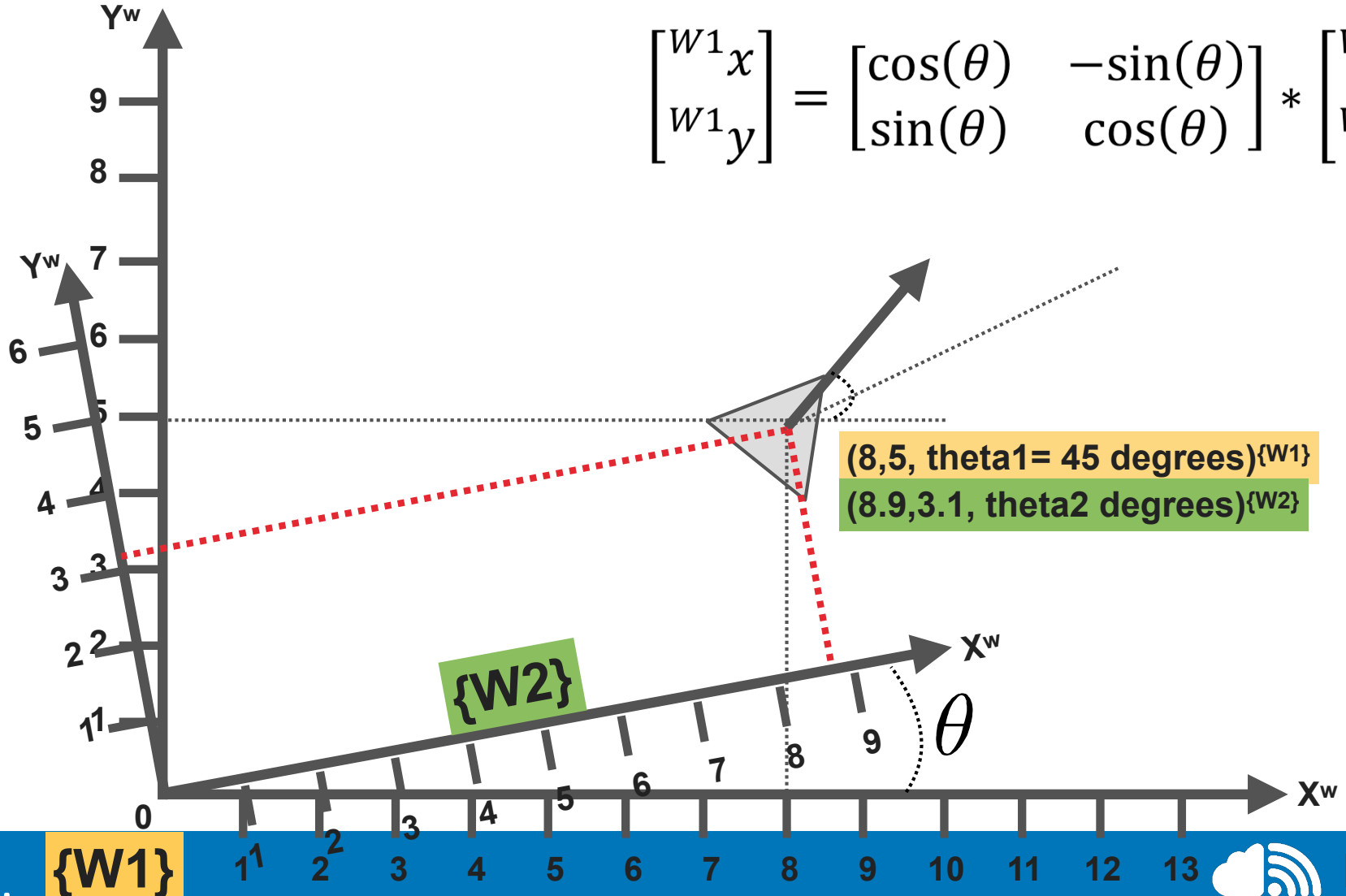


COORDINATE FRAME: ROTATION



COORDINATE FRAME: ROTATION

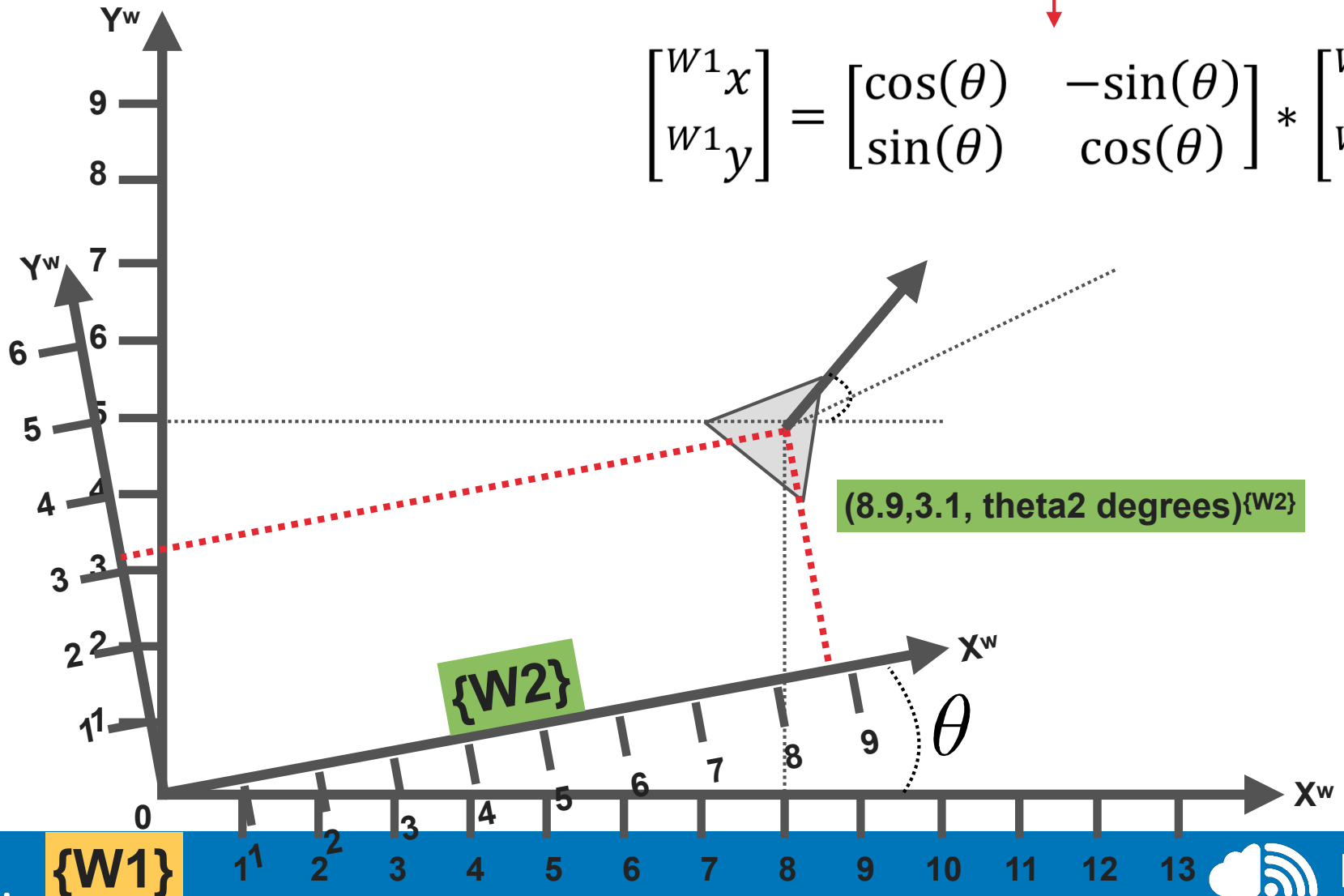
$$\begin{bmatrix} {}^{W1}x \\ {}^{W1}y \end{bmatrix} = \begin{bmatrix} \cos(\theta) & -\sin(\theta) \\ \sin(\theta) & \cos(\theta) \end{bmatrix} * \begin{bmatrix} {}^{W2}x \\ {}^{W2}y \end{bmatrix}$$



COORDINATE FRAME: ROTATION

Rotation Matrix

$$\begin{bmatrix} {}^{W1}x \\ {}^{W1}y \end{bmatrix} = \begin{bmatrix} \cos(\theta) & -\sin(\theta) \\ \sin(\theta) & \cos(\theta) \end{bmatrix} * \begin{bmatrix} {}^{W2}x \\ {}^{W2}y \end{bmatrix}$$



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2D Transformation: Translation + Rotation

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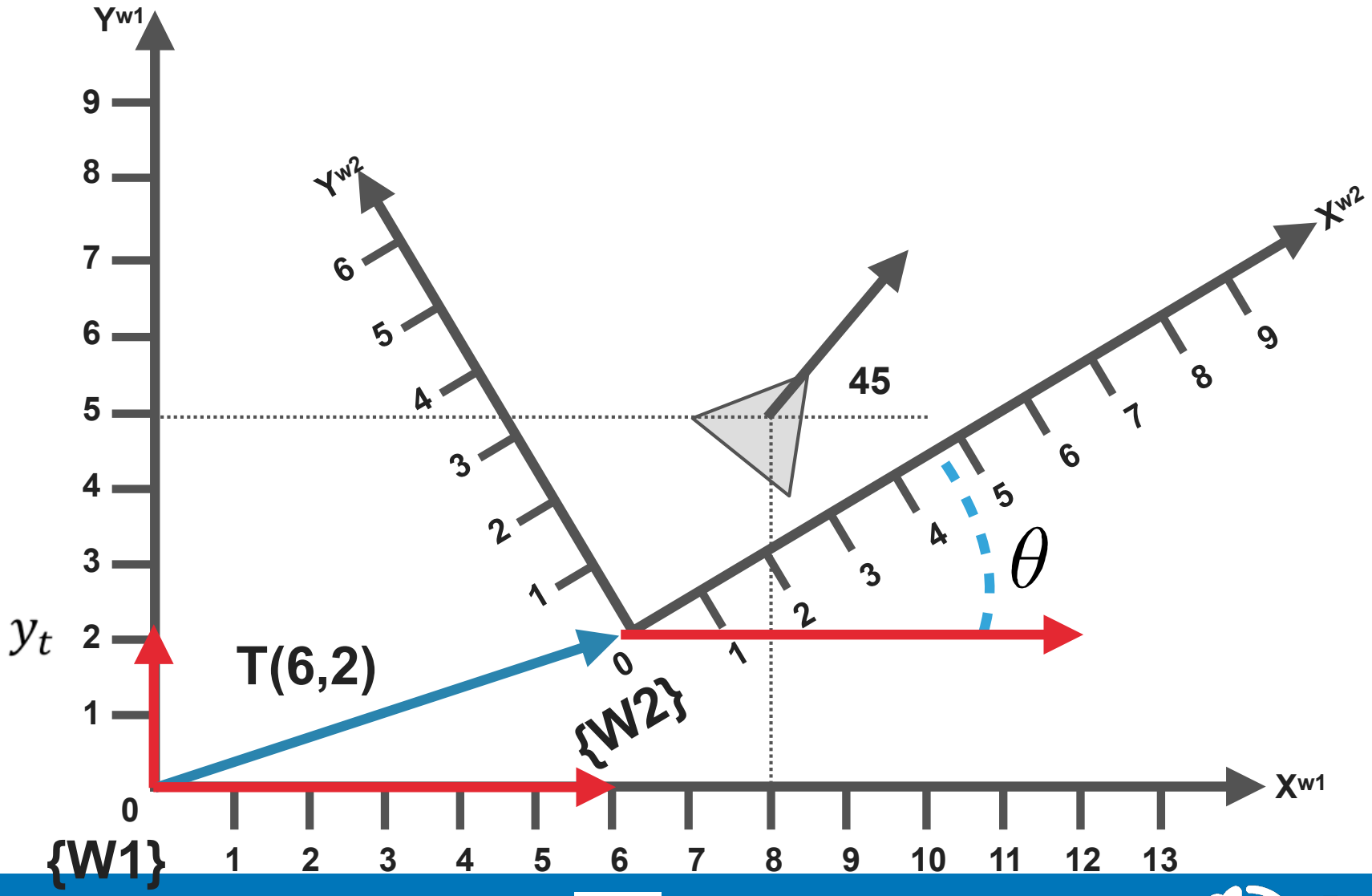
OUTLINE

- 2D Transformation involves
  - one translation
  - one rotation

TRANSFORMATION: TRANSLATION + ROTATION



COORDINATE FRAME 2D TRANSFORMATION

for counter clock wise rotation angle theta

$$\begin{bmatrix} {}^{w1}x \\ {}^{w1}y \\ 1 \end{bmatrix} = \begin{bmatrix} \cos(\theta) & -\sin(\theta) & x_t \\ \sin(\theta) & \cos(\theta) & y_t \\ 0 & 0 & 1 \end{bmatrix} * \begin{bmatrix} {}^{w2}x \\ {}^{w2}y \\ 1 \end{bmatrix}$$

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Transformation Example

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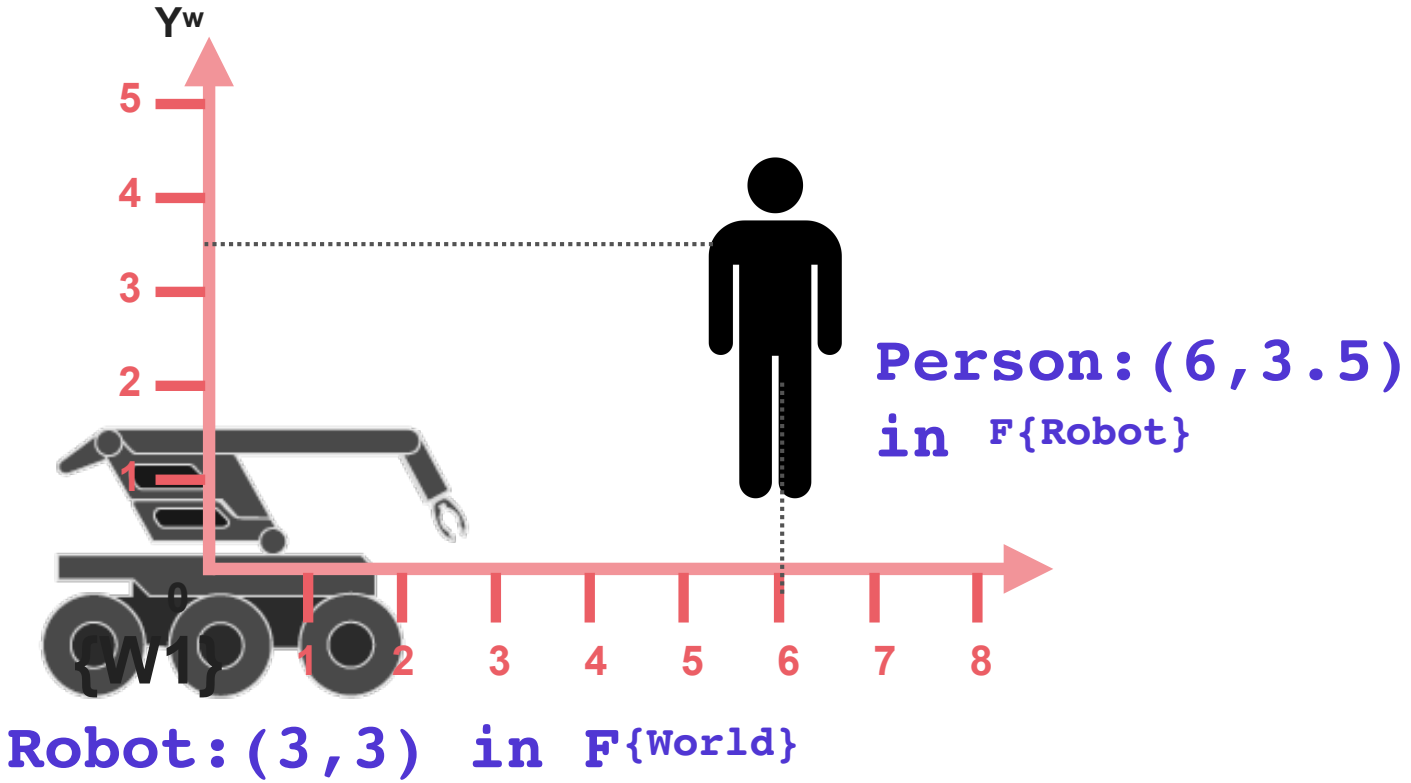
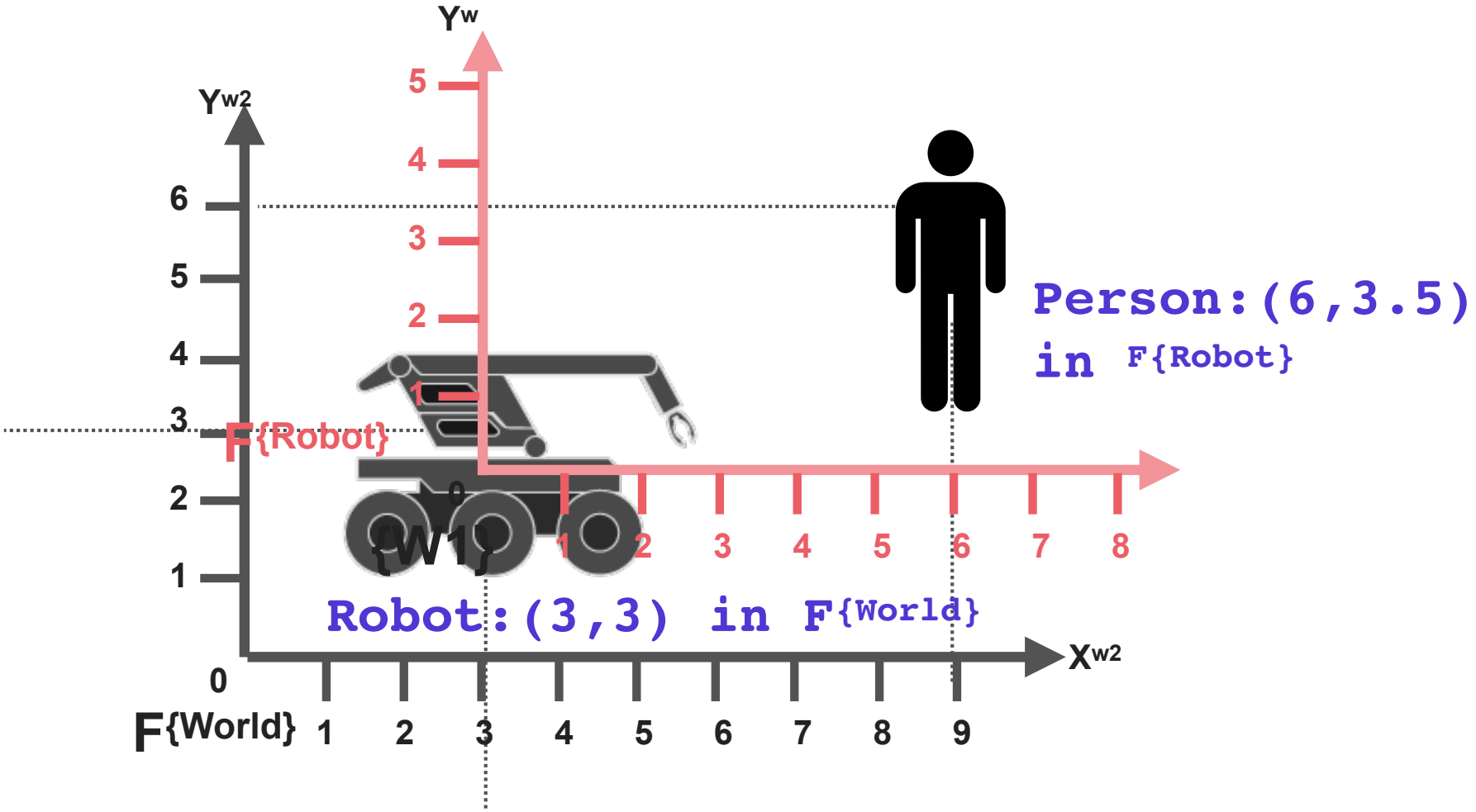
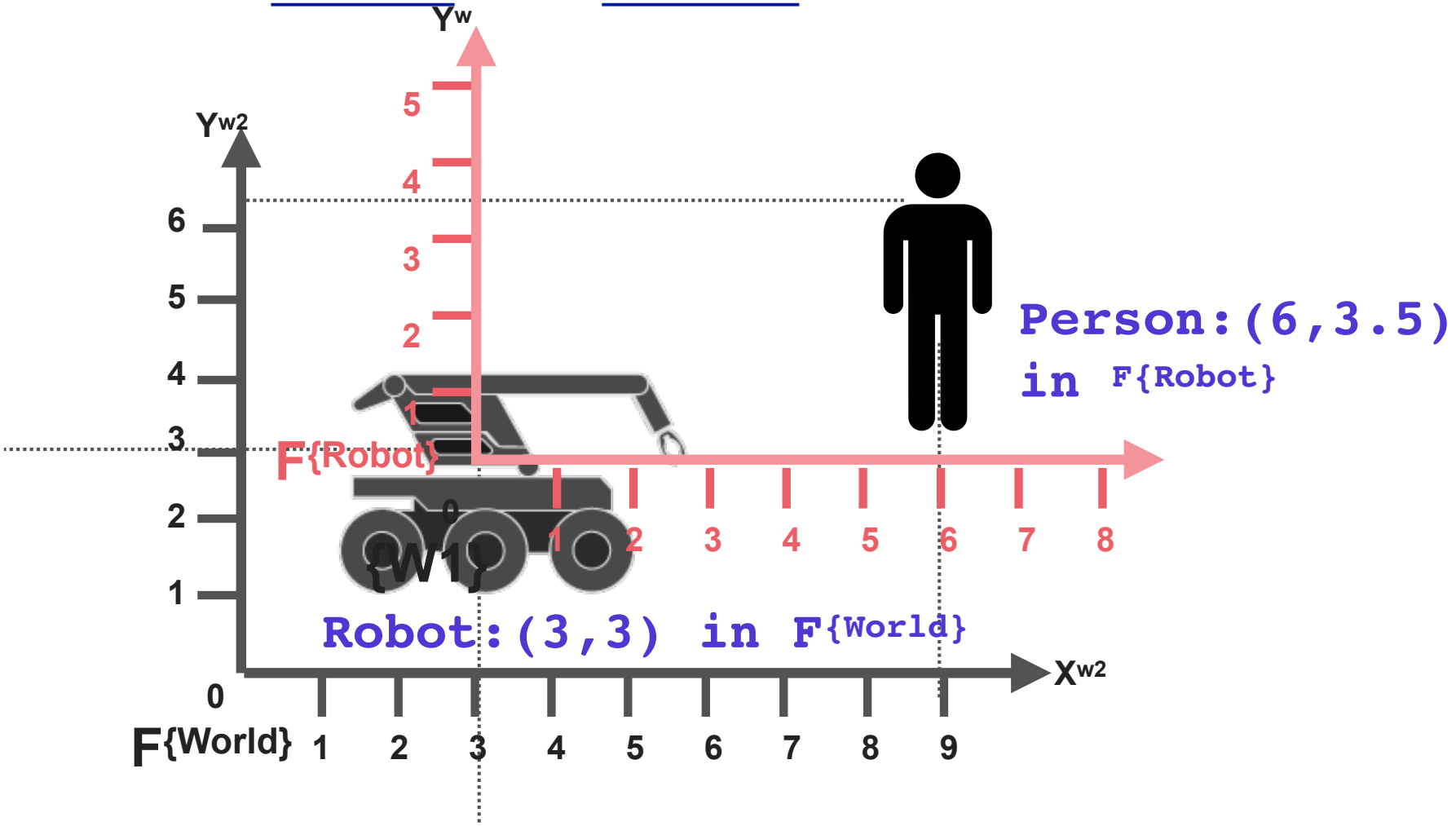
LOCATION IN THE ROBOT AND WORLD COORDINATE FRAMES



LOCATION IN THE ROBOT AND WORLD COORDINATE FRAMES



LOCATION IN THE ROBOT AND WORLD COORDINATE FRAMES



Person in F{world}?

TRANSFORMATION MATRIX

$$\begin{bmatrix} {}^{W1}x \\ {}^{W1}y \\ 1 \end{bmatrix} = \begin{bmatrix} \cos(\theta) & -\sin(\theta) & x_t \\ \sin(\theta) & \cos(\theta) & y_t \\ 0 & 0 & 1 \end{bmatrix} * \begin{bmatrix} {}^{W2}x \\ {}^{W2}y \\ 1 \end{bmatrix}$$

$$\begin{vmatrix} X\{world\} \\ Y\{world\} \\ 1 \end{vmatrix} = \begin{vmatrix} Cos(0) & -Sin(0) & 3 \\ Sin(0) & Cos(0) & 3 \\ 0 & 0 & 1 \end{vmatrix} * \begin{vmatrix} X\{robot\} \\ Y\{robot\} \\ 1 \end{vmatrix}$$

TRANSFORMATION MATRIX

$$\begin{vmatrix} X^{\{world\}} \\ Y^{\{world\}} \\ 1 \end{vmatrix} = \begin{vmatrix} 1 & 0 & 3 \\ 0 & 1 & 3 \\ 0 & 0 & 1 \end{vmatrix} * \begin{vmatrix} X^{\{robot\}} \\ Y^{\{robot\}} \\ 1 \end{vmatrix}$$

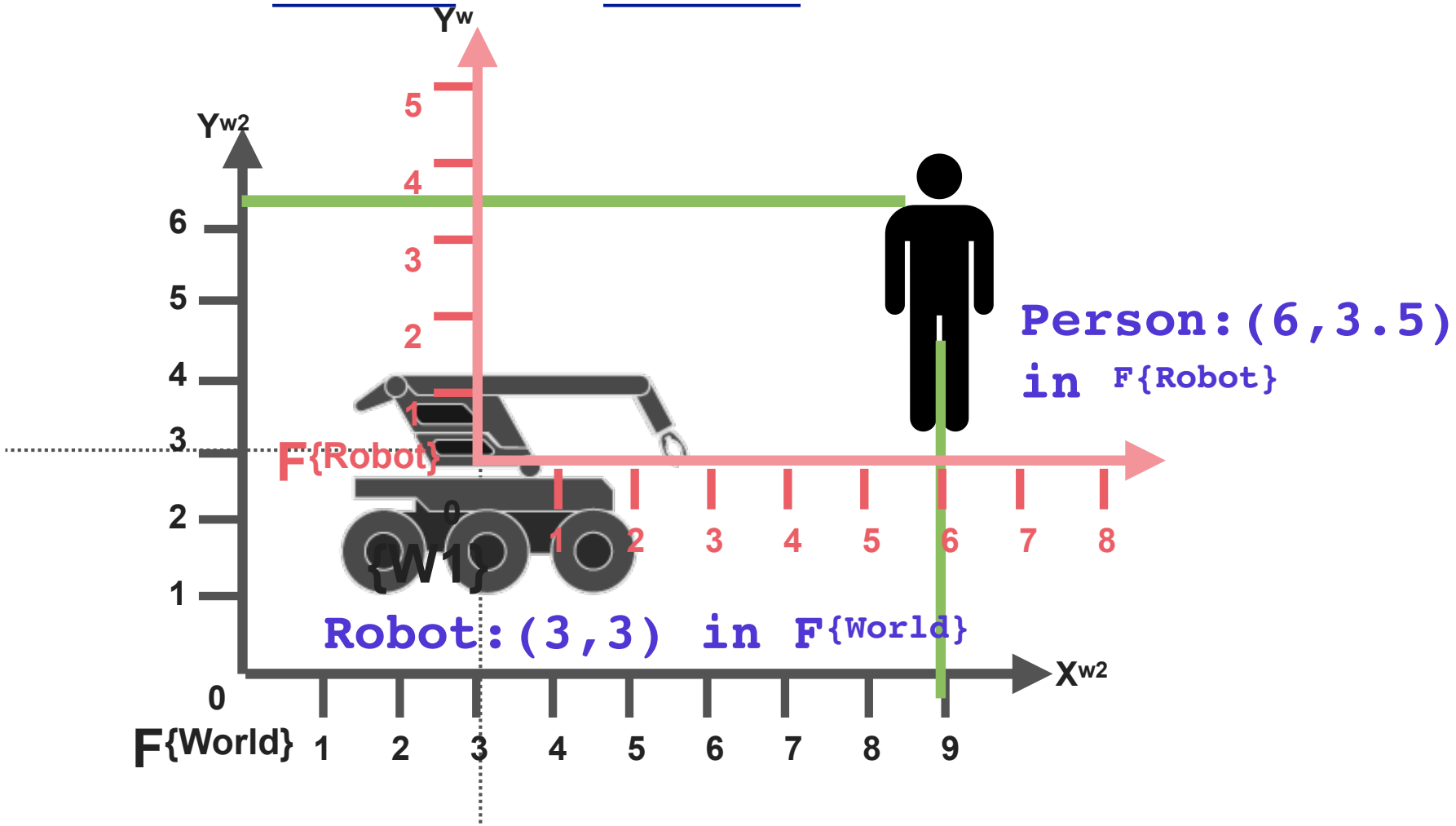
TRANSFORMATION MATRIX

$$\begin{vmatrix} X_{\{world\}} \\ Y_{\{world\}} \\ 1 \end{vmatrix} = \begin{vmatrix} 1 & 0 & 3 \\ 0 & 1 & 3 \\ 0 & 0 & 1 \end{vmatrix} * \begin{vmatrix} 6 \\ 3.5 \\ 1 \end{vmatrix} = \begin{vmatrix} 9 \\ Y_{\{world\}} \\ 1 \end{vmatrix}$$

TRANSFORMATION MATRIX

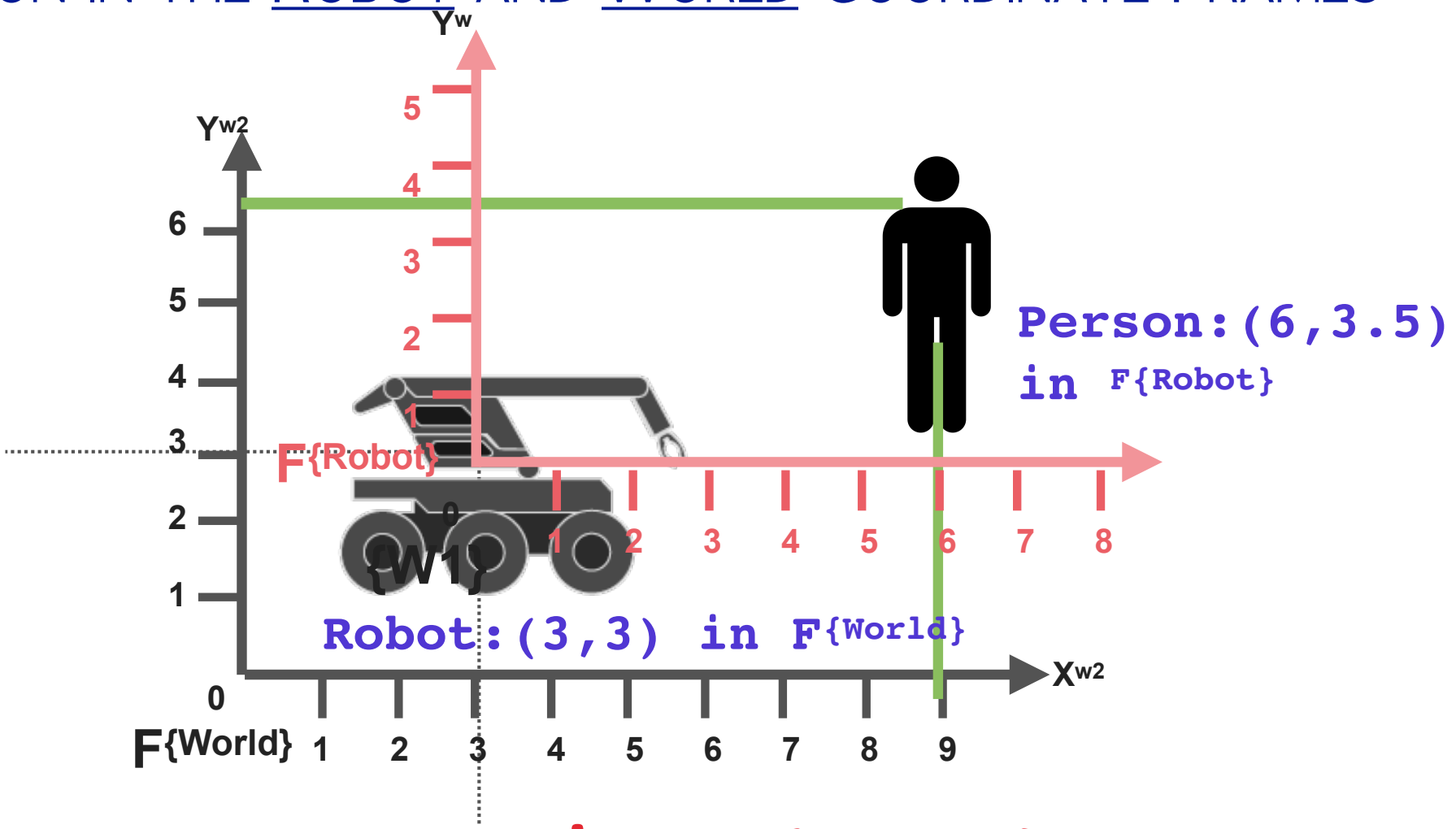
$$\begin{vmatrix} X_{\{world\}} \\ Y_{\{world\}} \\ 1 \end{vmatrix} = \begin{vmatrix} 1 & 0 & 3 \\ 0 & 1 & 3 \\ 0 & 0 & 1 \end{vmatrix} * \begin{vmatrix} 6 \\ 3.5 \\ 1 \end{vmatrix} = \begin{vmatrix} 9 \\ 6.5 \\ 1 \end{vmatrix}$$

LOCATION IN THE ROBOT AND WORLD COORDINATE FRAMES



Person in F{world}?

LOCATION IN THE ROBOT AND WORLD COORDINATE FRAMES



Person in F{world}?