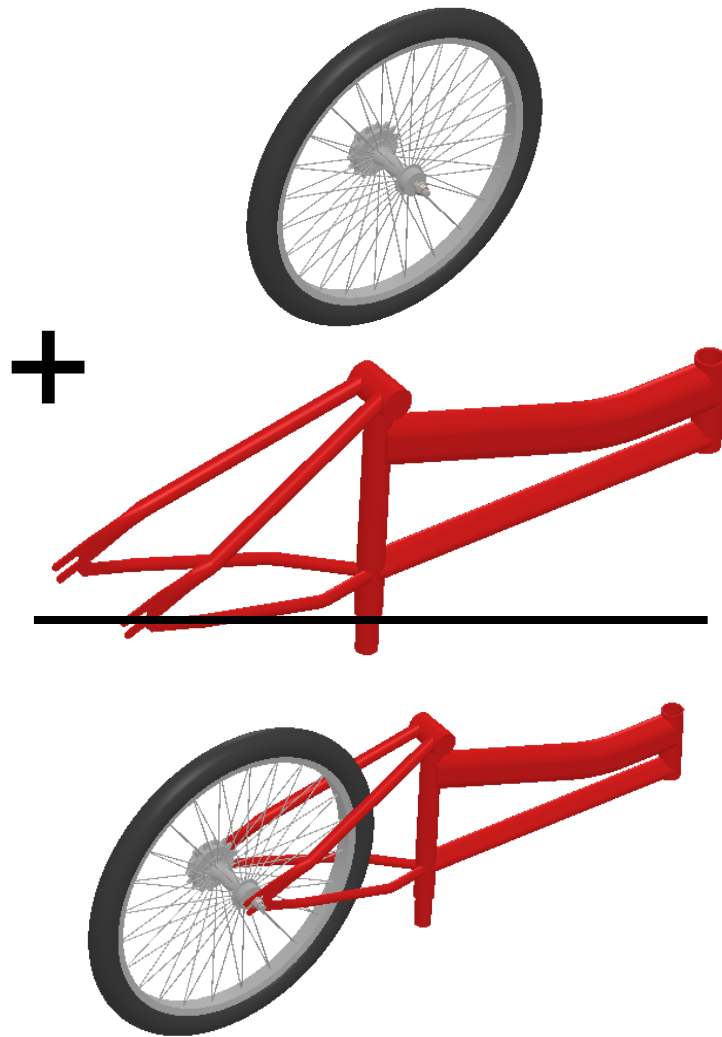


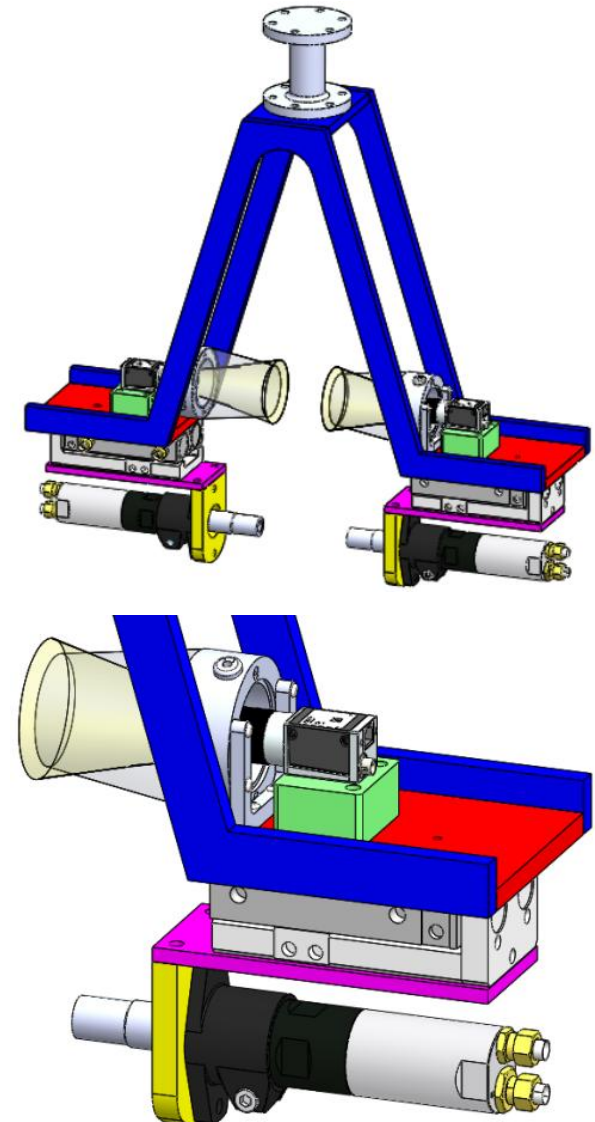
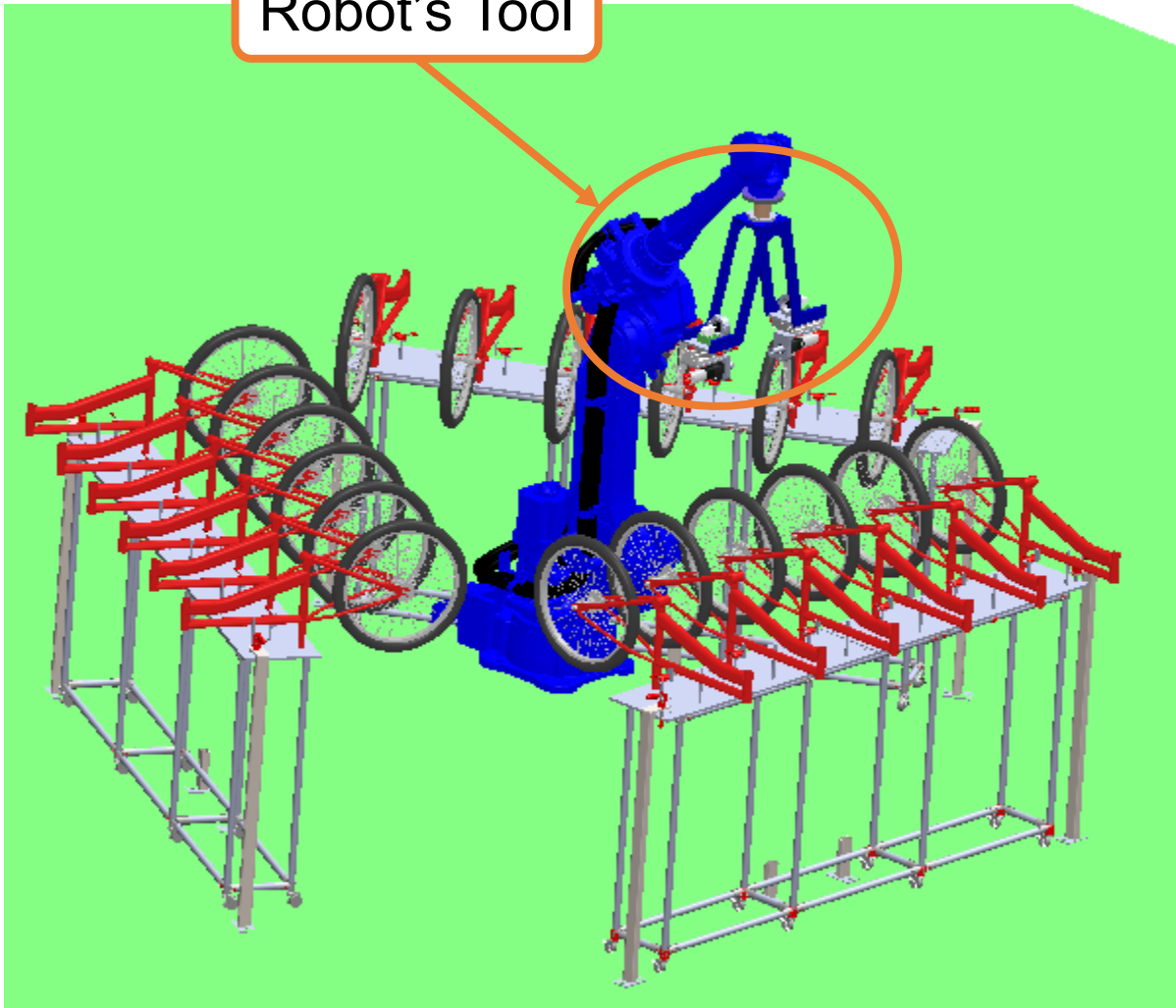
# System



Assembling and tightening the bicycle bolts

# Workspace

Robot's Tool



# Control System Design

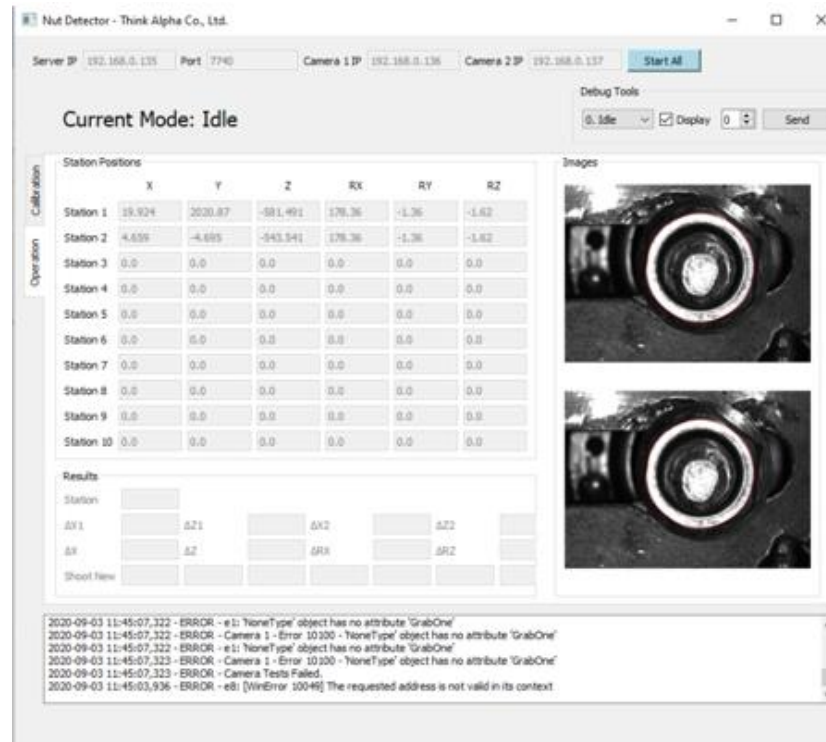
## Control System Design

### Modbus TCP/IP

**HMI (MT8071iP)**  
Receive user's settings.  
Start/stop operation.

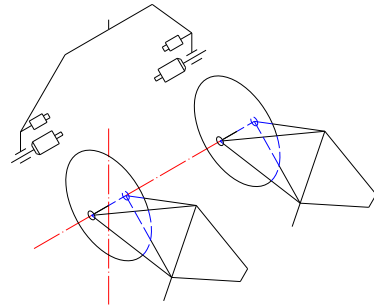
**PLC (S7-1200)**  
Main controller.  
Trigger Robot and Computer operations.  
Manage all sensors in the system.

**Computer**  
Find nuts positions.  
by image processing.  
Do trajectory planning for robot

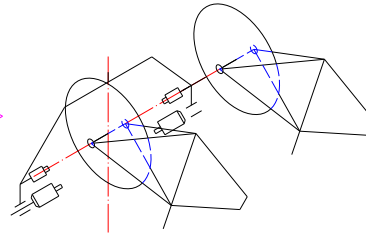
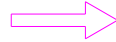


# The Workflow

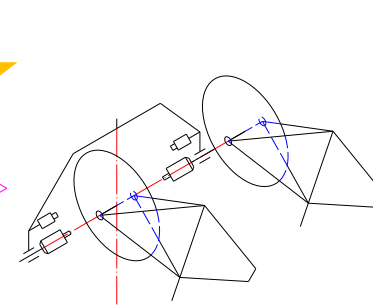
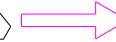
My golden star !!!



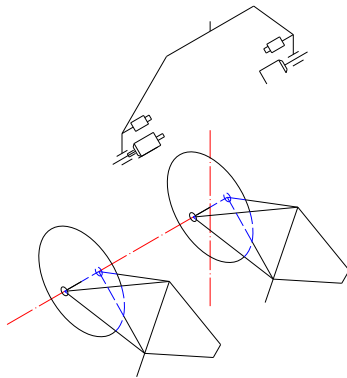
Move to  $P_{\text{prepare}-i}$   
Defined when the bike type is chosen.



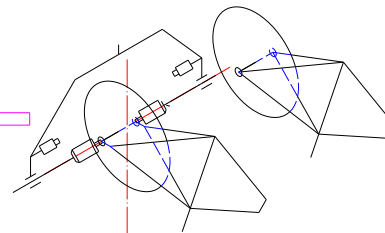
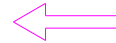
Move to  $P_{\text{capture}-i}$   
Defined when the bike type is chosen.  
Cameras are requested to capture and the img processing started.



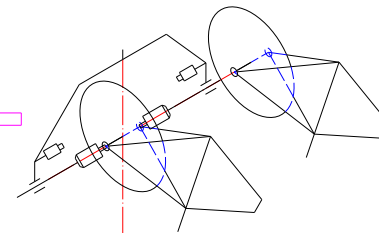
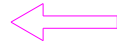
Move to  $P_{\text{hold}-i}$   
Calculated by Image Processing Algorithm  
At this time, the sockets and the shaft are co-axial.



The cylinders retract.  
Move to  $P_{\text{prepare}-i+1}$



Move to  $P_{\text{run}-i}$   
Defined when the bike type is chosen.  
At this position, the motors run to tighten the nuts.



Still at  $P_{\text{hold}-i}$   
The cylinders extract to hold the nuts

# Capture, Run and Ref. Positions

The capture position at station  $i$  is given by

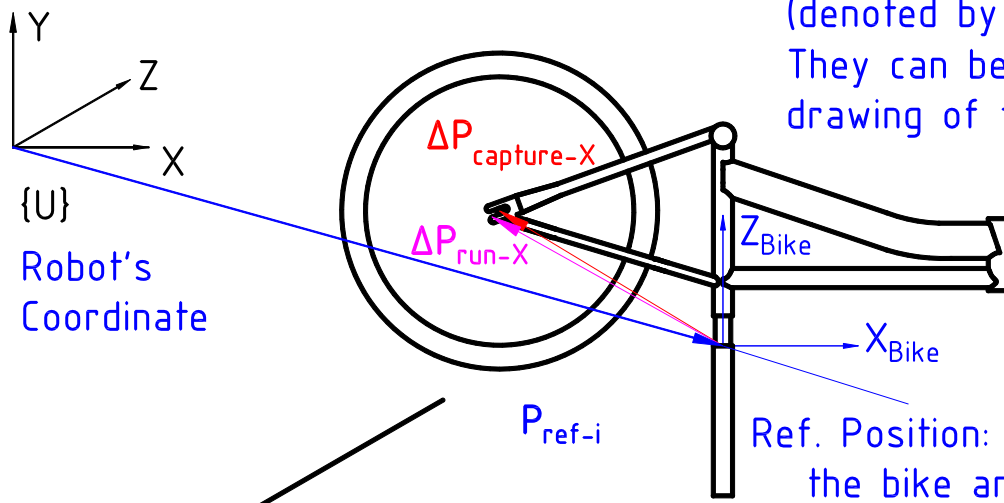
$$\mathbf{P}_{\text{capture}-i} = \mathbf{P}_{\text{ref}-i} + \Delta\mathbf{P}_{\text{capture}-X}$$

The nut running position at station  $i$  is given by

$$\mathbf{P}_{\text{run}-i} = \mathbf{P}_{\text{ref}-i} + \Delta\mathbf{P}_{\text{run}-X}$$

$\Delta\mathbf{P}_{\text{capture}-X}$  and  $\Delta\mathbf{P}_{\text{run}-X}$  vary between the bike types (denoted by  $X$ ).

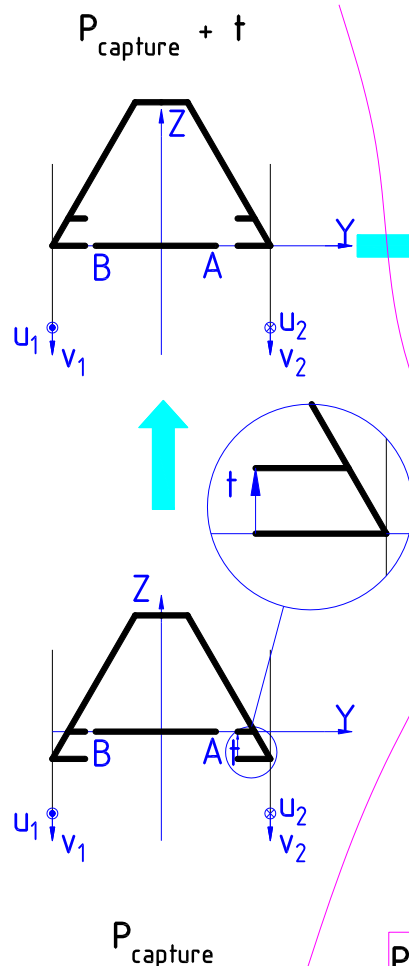
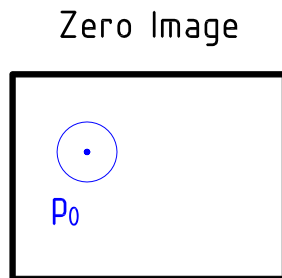
They can be specified by using the technical drawing of the bike or teach the robot directly.



# Image Processing Technique

## Setup Period

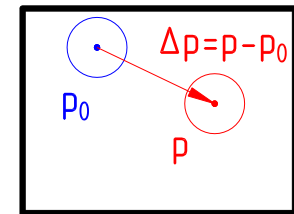
The "zero" data is taken once when first setting up the system!



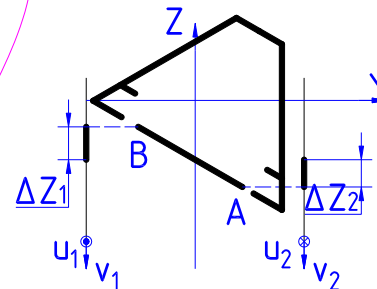
## Operation Period

$$P_{\text{capture}} + t + [\Delta X_1, 0, \Delta Z_1, 0, 0, 0]^T$$

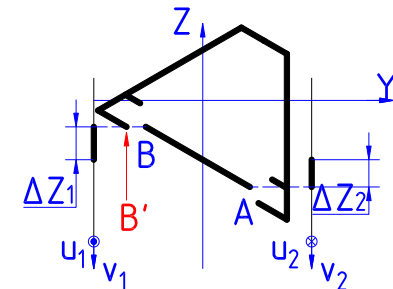
New Image



B as the center of rotation



B' as the center of rotation (more complex)



$$P_{\text{hold}} = P_{\text{capture}} + t + [\Delta X_1, 0, \Delta Z_1, \Delta R X, 0, \Delta R Z]^T$$



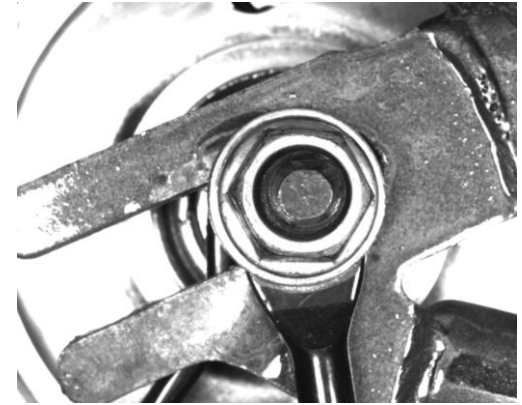
# Detect the Nut in the Image (1/2)



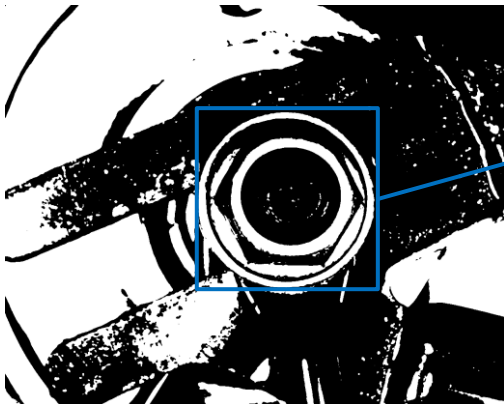
(a) Origin Image



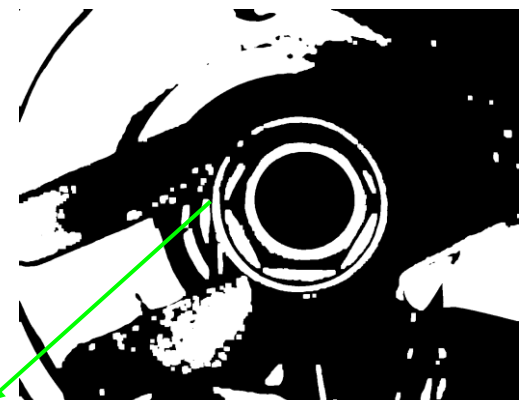
(b) Undistorted



(c) Gaussian blurred

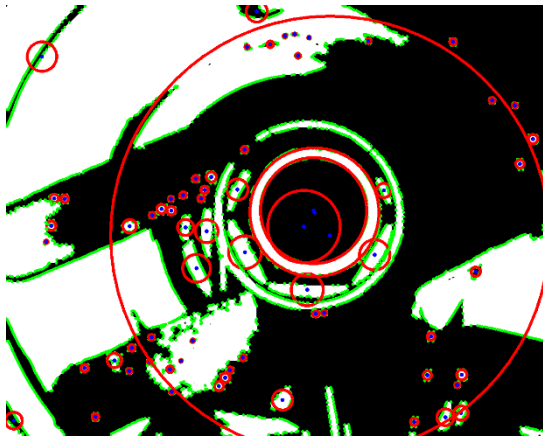


(d) Otsu Thresholded

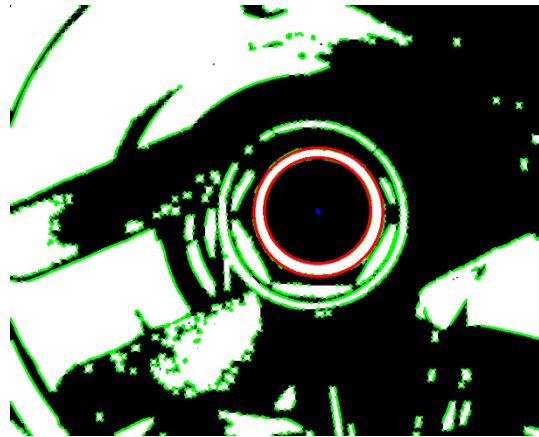


(e) Closing Transformed  
(Inverted Image)  
(Dilation followed by Erosion)

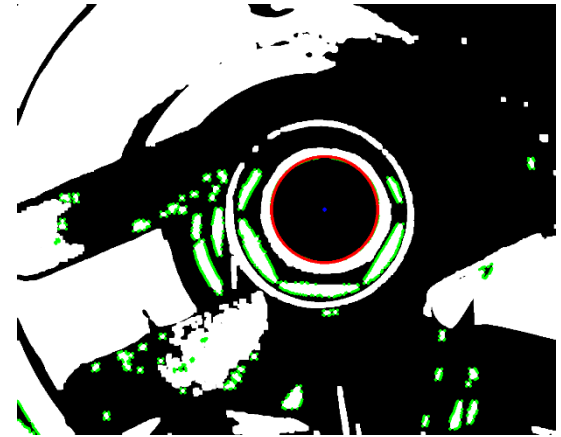
## Detect the Nut in the Image (2/2)



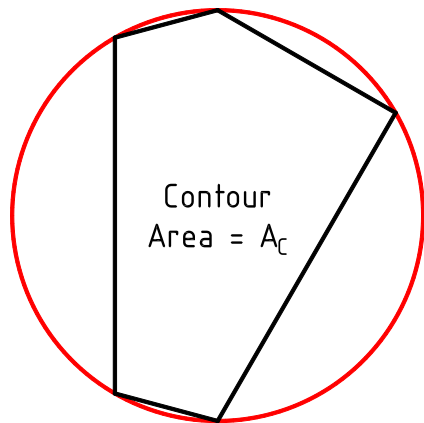
(a) All contours and their min-fitting-circles



(b) Filter out the "not round" contours.



(c) Final contour (using dimensional comparison)



Min Fitting Circle

Min Fitting Circle  
Area =  $A_{MFC}$

**The "round criterion"**

$$\frac{A_c}{A_{MFC}} \in [0.9, 1.1]$$