HO CHI MINH CITY UNIVERSITY OF TECHNOLOGY
FACULTY OF MECHANICAL ENGINEERING
DEPARTMENT OF MECHATRONIC ENGINEERING

FINAL YEAR PROJECT REPORT

DESIGN OF AN AUTOMATED NUT RUNNING SYSTEM FOR BICYCLES

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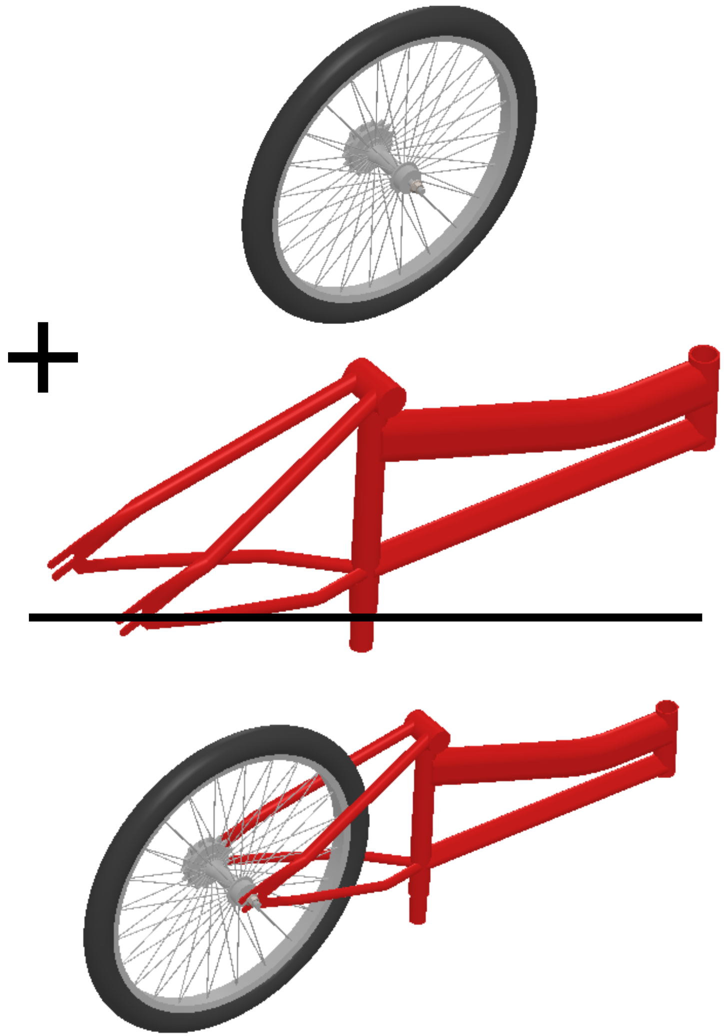
HO CHI MINH CITY, 2020

COVID-19

The Motivation

Why this System?



Lắp ráp và siết ốc cho xe đạp

Design Objective

"Design an

automated nut running system

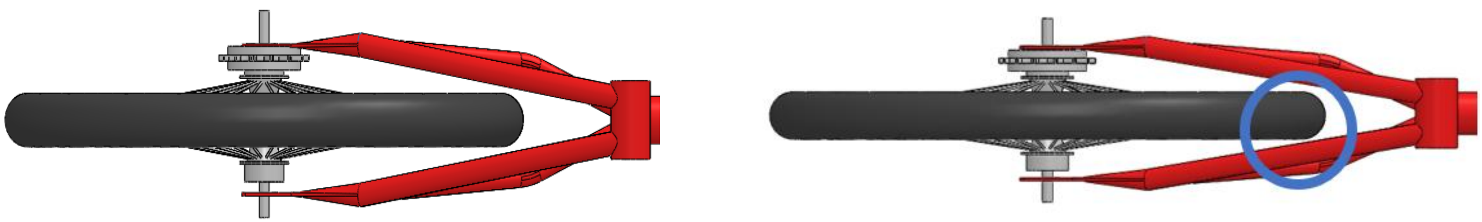
for the back-wheel assembly of bicycles

using robotic arm

and computer vision.."

Design Scope (1/2)

- **Output quality:**
  - The wheel is centered.
  - The chain drive is tensioned.
  - Required tightening force: 46 Nm.
  - Productivity: 30 bikes per hour.

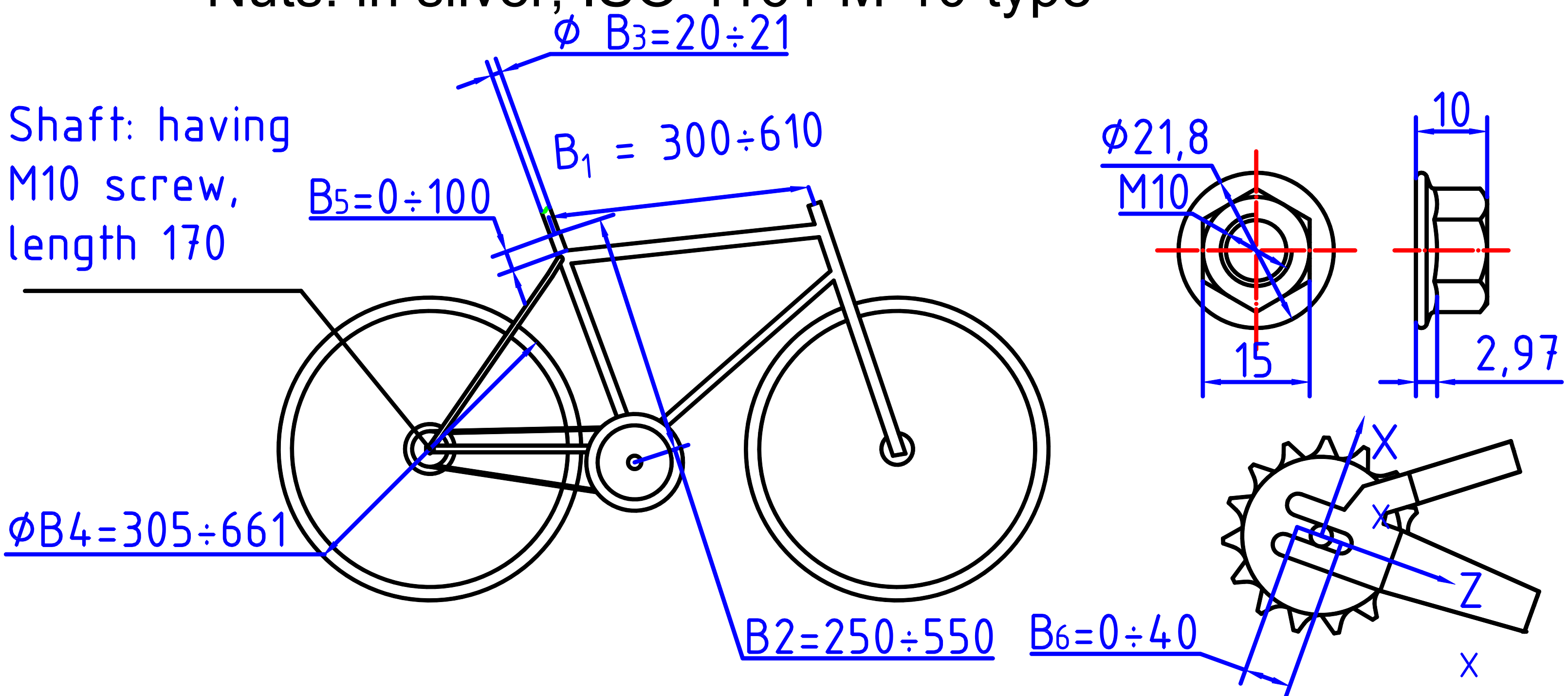


(a) OK (b) NG

Illustration of OK and NG products

Design Scope (2/2)

- **Input data:** Bike's dimensions
- **Notes:**
  - Shaft: in black or silver and has M-10 thread.
  - Nuts: in silver, ISO 4161 M-10 type

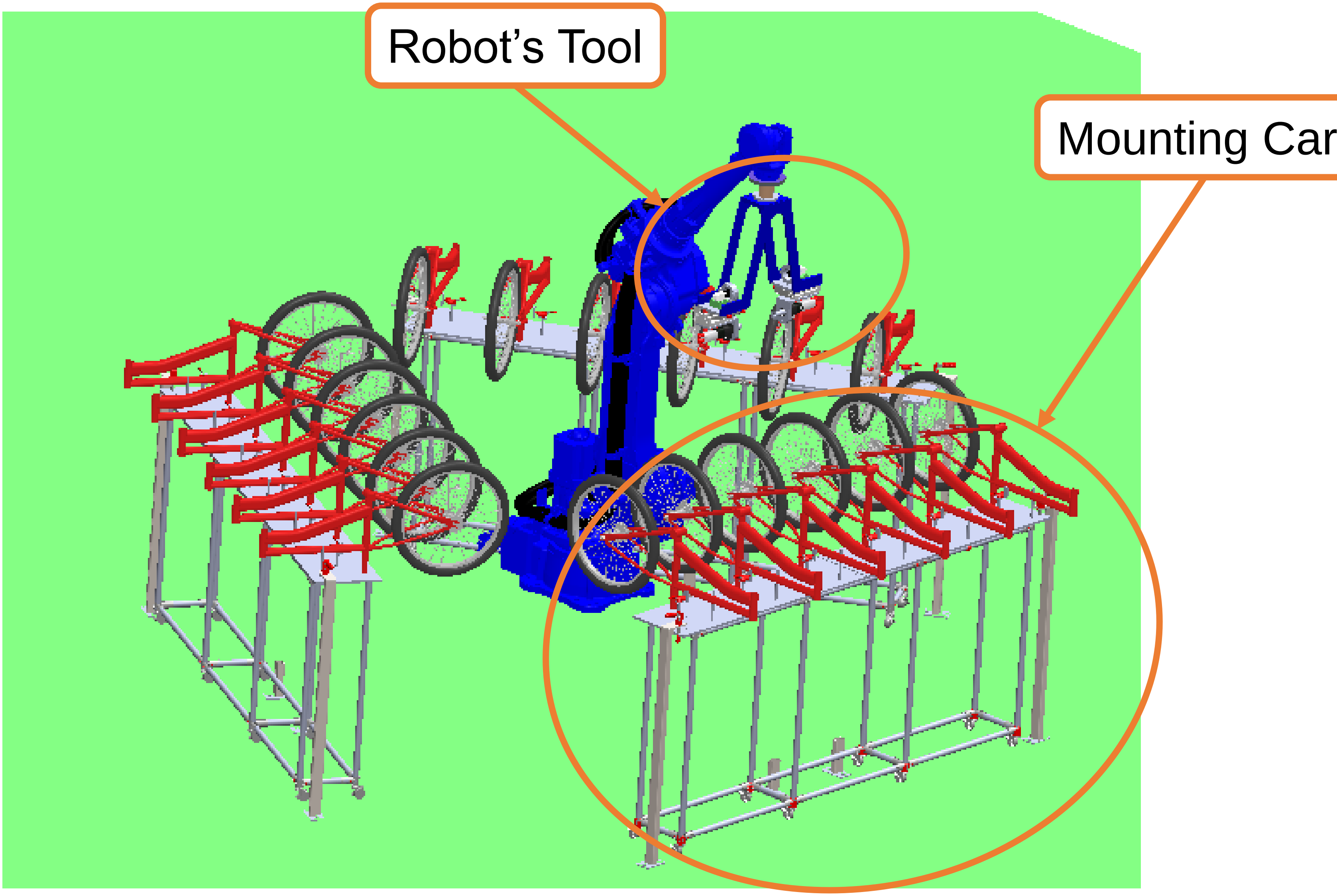


Bike's dimensions

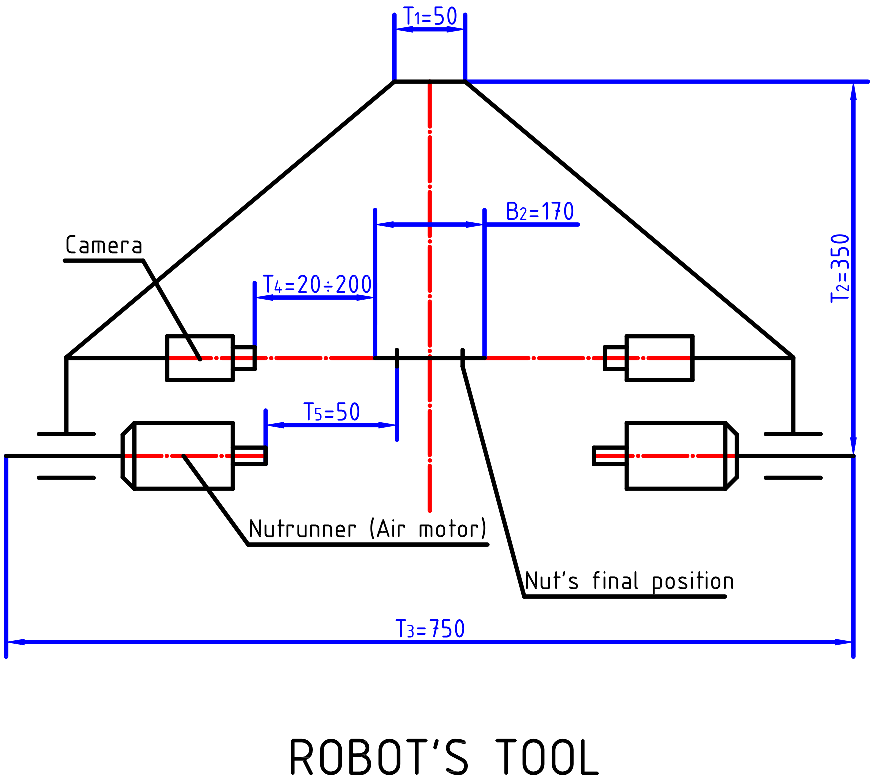
SYSTEM DESIGN

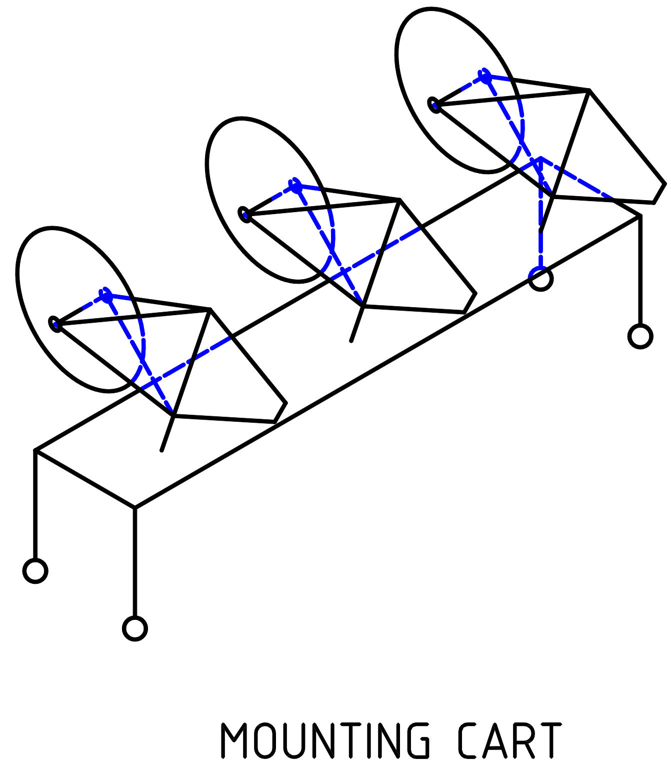
An Overview

Workspace Setup



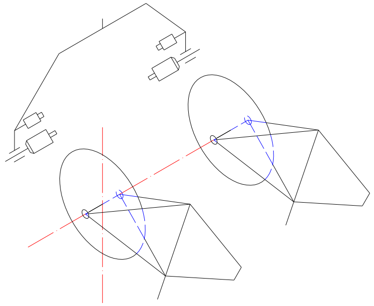
Simplified Diagrams



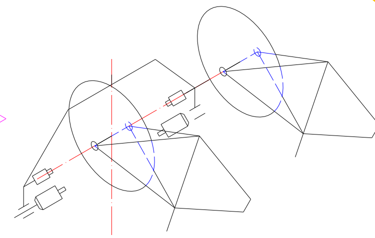


The Workflow

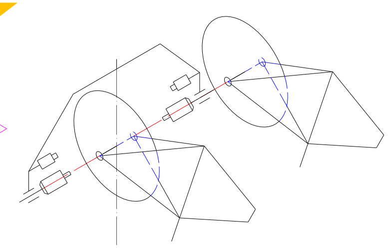
My golden star !!!



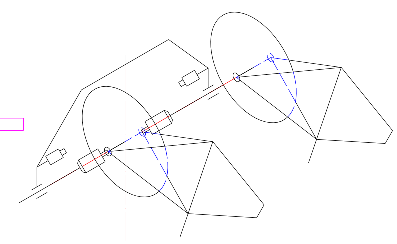
Move to $P_{prepare-i}$
Defined when the bike type is chosen.



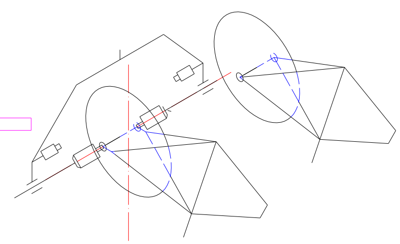
Move to $P_{capture-i}$
Defined when the bike type is chosen.
Cameras are requested to capture and the img processing started.



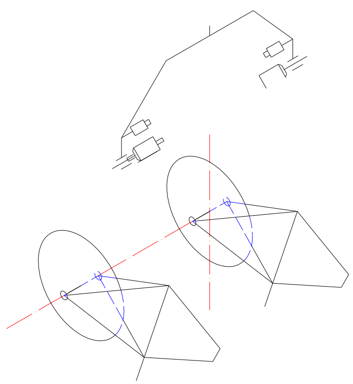
Move to P_{hold-i}
Calculated by Image Processing Algorithm
At this time, the sockets and the shaft are co-axial.



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



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



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

Capture, Run and Ref. Positions

The capture position at station i is given by

$$\mathbf{P_{capture-i}} = \mathbf{P_{ref-i}} + \mathbf{\Delta P_{capture-X}}$$

The nut running position at station i is given by

$$\mathbf{P_{run-i}} = \mathbf{P_{ref-i}} + \mathbf{\Delta P_{run-X}}$$

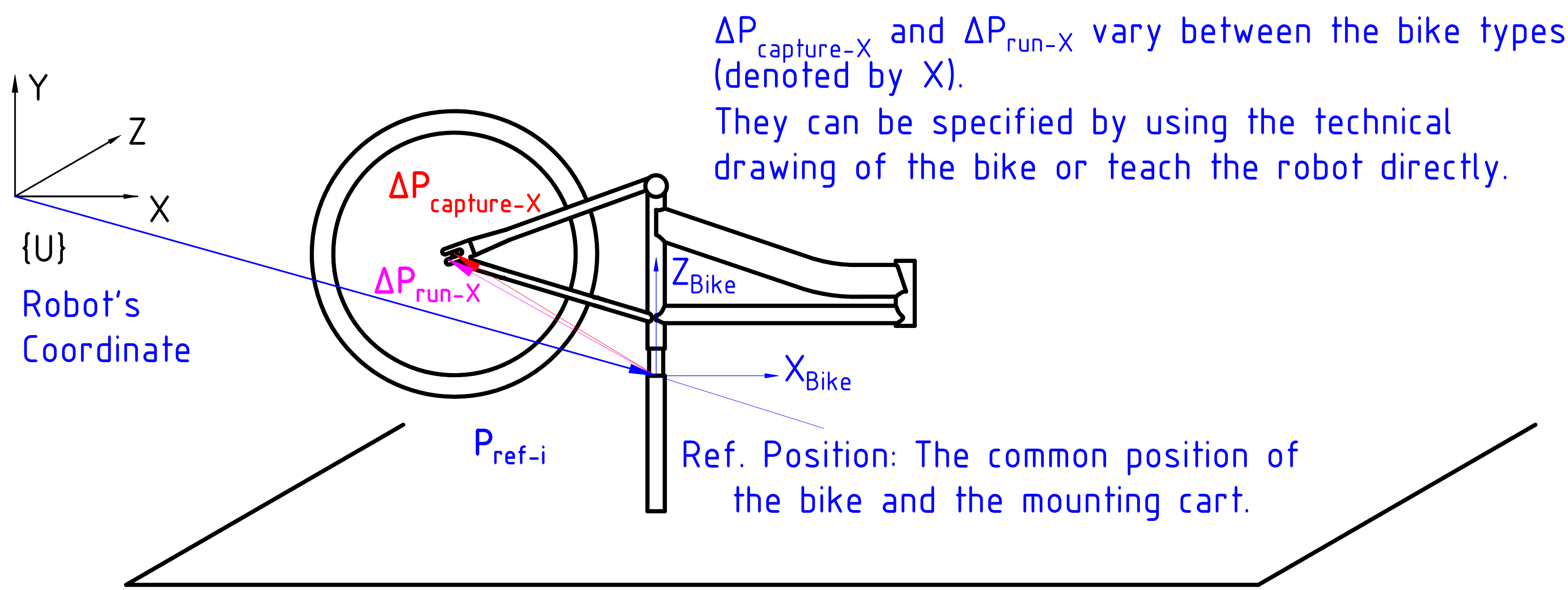
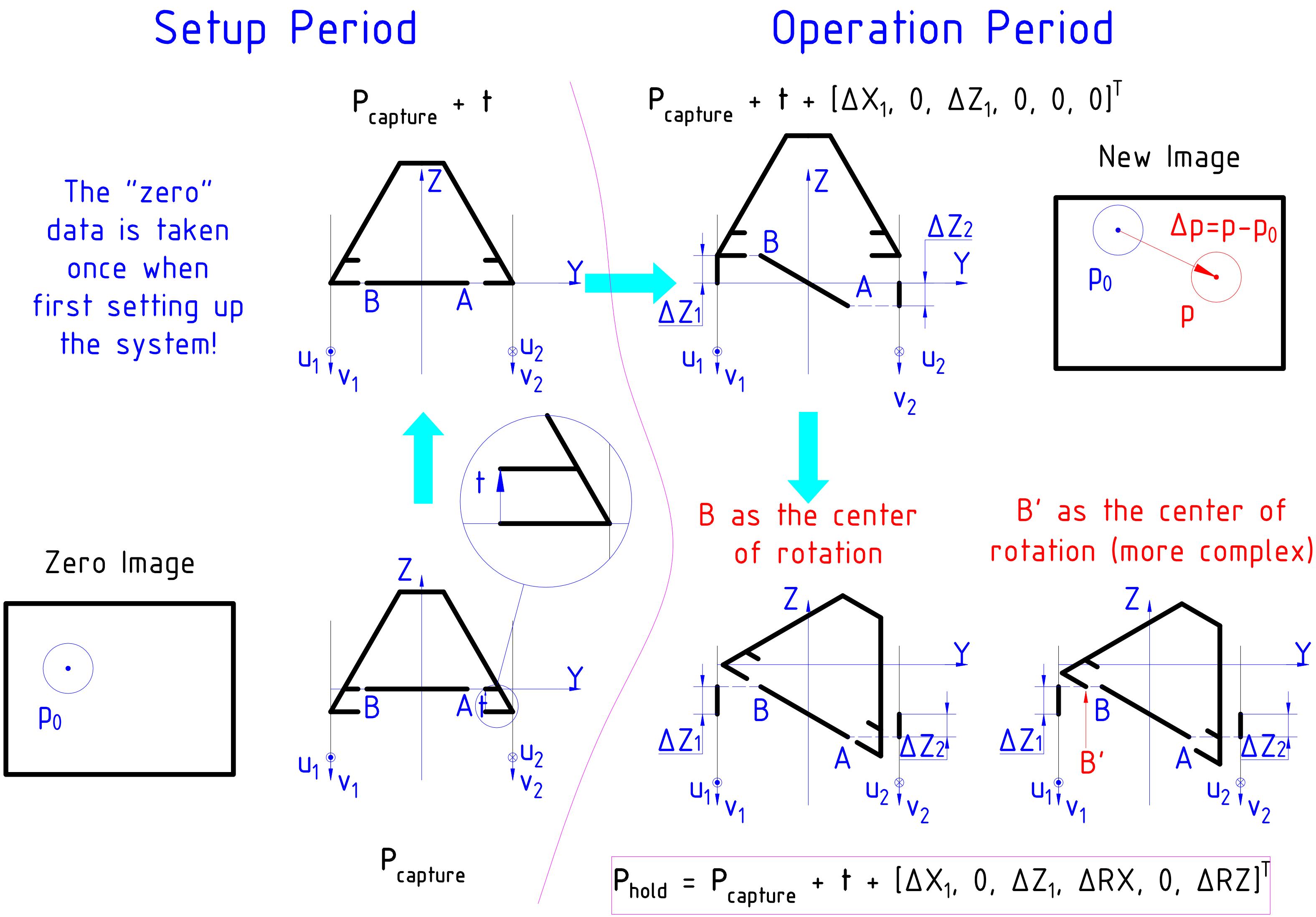


IMAGE PROCESSING ALGORITHM

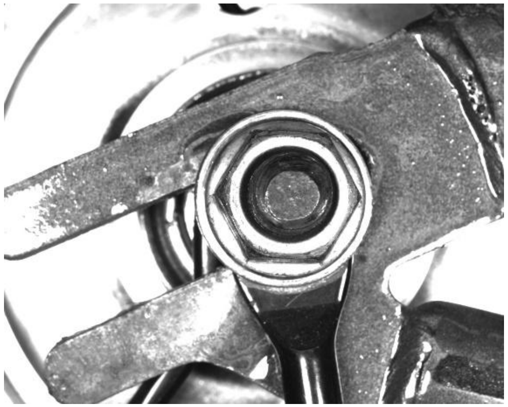
★ My Golden Star ★

How It Works

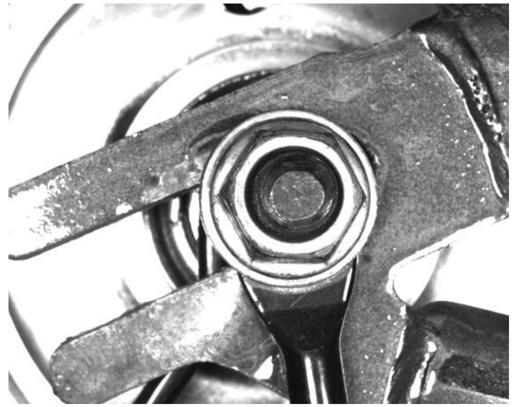


Setup Period
Operation Period
$P_{capture} + t$
$P_{capture} + t + [\Delta X_1, 0, \Delta Z_1, 0, 0, 0]^T$
The "zero" data is taken once when first setting up the system!
New Image
$\Delta p = p - p_0$
p_0
p
Zero Image
p_0
B as the center of rotation
B' as the center of rotation (more complex)
$P_{capture}$
$P_{hold} = P_{capture} + t + [\Delta X_1, 0, \Delta Z_1, \Delta RX, 0, \Delta RZ]^T$

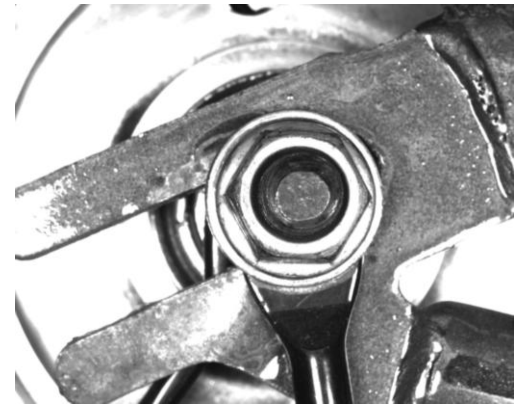
Detect the Nut in the Image (1/2)



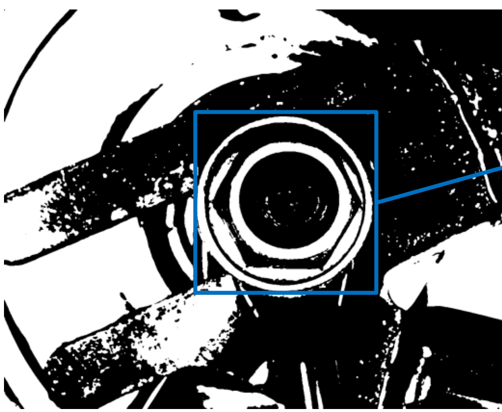
(a) Origin Image



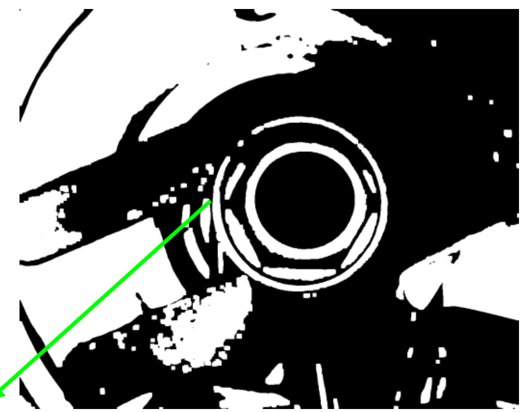
(b) Undistorted



(c) Gaussian blurred



(d) Otsu Thresholed



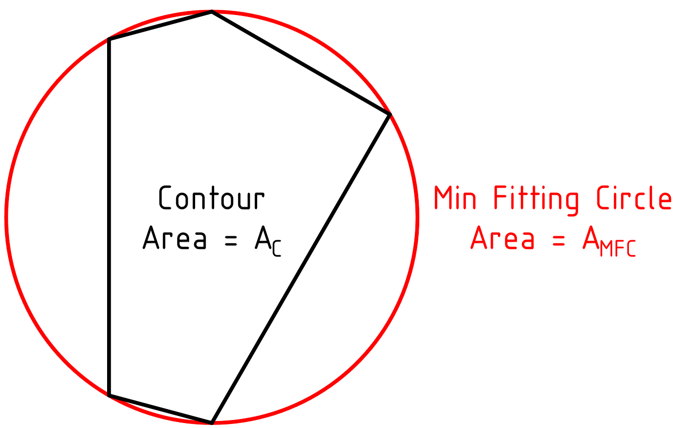
(e) Closing Transformed
(Inverted Image)
(Dilation followed by Erosion)

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 comparision)

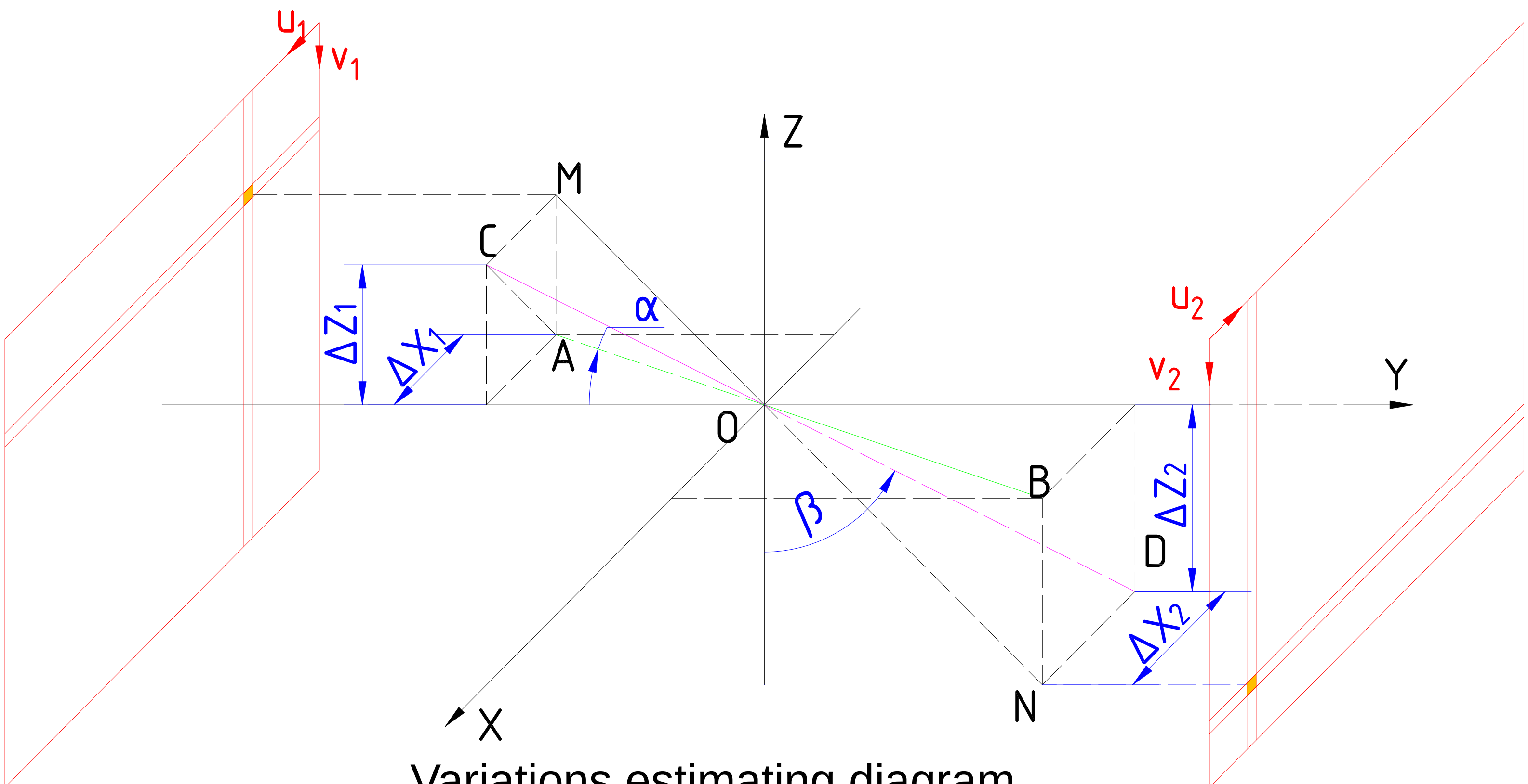


Min Fitting Circle

The "round criterion"

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

Estimate the Variations w.r.t the "Zero" Data.

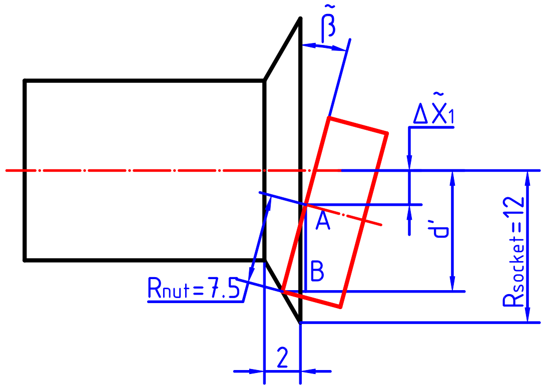


Variations estimating diagram

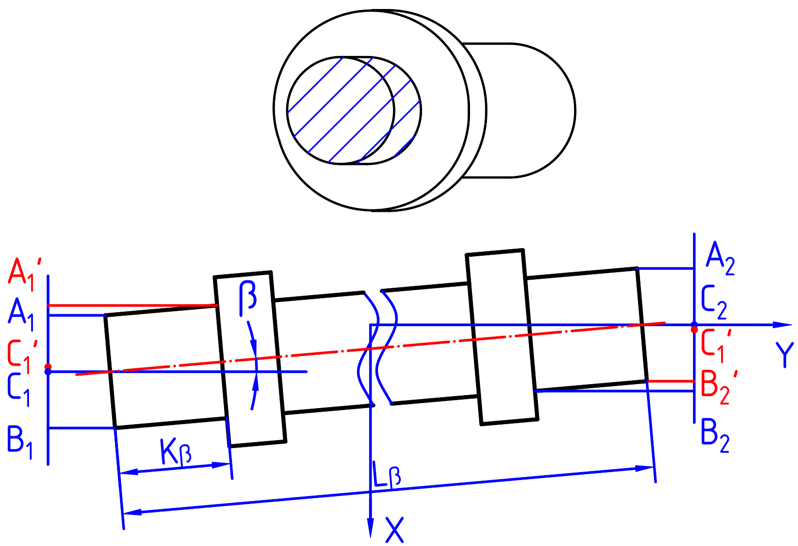
$$\Delta X_1 = r_{11}\Delta u_1$$
$$\Delta Z_1 = -r_{21}\Delta v_1$$
$$\Delta X_2 = -r_{21}\Delta u_2$$
$$\Delta Z_2 = -r_{22}\Delta v_2$$

$$\alpha = \operatorname{asin}\frac{\Delta X_1 - \Delta X_2}{AB}$$
$$\beta = \operatorname{asin}\frac{\Delta Z_1 - \Delta Z_2}{AB}$$
$$AB = \sqrt{L^2 - (\Delta Z_1 - \Delta Z_2)^2}$$

Error Examination



"Nut hold-able criterion" diagram



Errors diagram.

Nut hold-able criterion:

$$d = \sqrt{2}\left(\left|\Delta\tilde{Z}_1\right| + R_{shaft}\cos\tilde{\beta}\right) \leq 9.75$$

Errors:

$$\Delta\tilde{Z}_1 = -1.1 \cdot 0.5K_\beta \sin\beta$$

$$\hat{\beta} = \operatorname{asin}\frac{\left(L_\beta - 1.1K_\beta\right)\sin\beta}{\sqrt{L^2 - \left(L_\beta - 1.1K_\beta\right)^2 \sin^2\beta}}$$

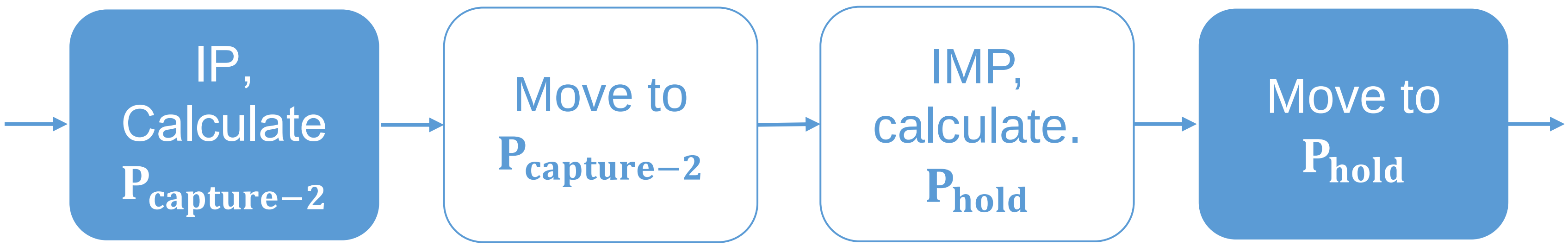
where

$$L_\beta = \sqrt{L^2 - (\Delta Z_1 - \Delta Z_2)^2}$$

$$\Delta Z = \Delta Z_1 - \Delta Z_2 = L_\beta \sin\beta$$

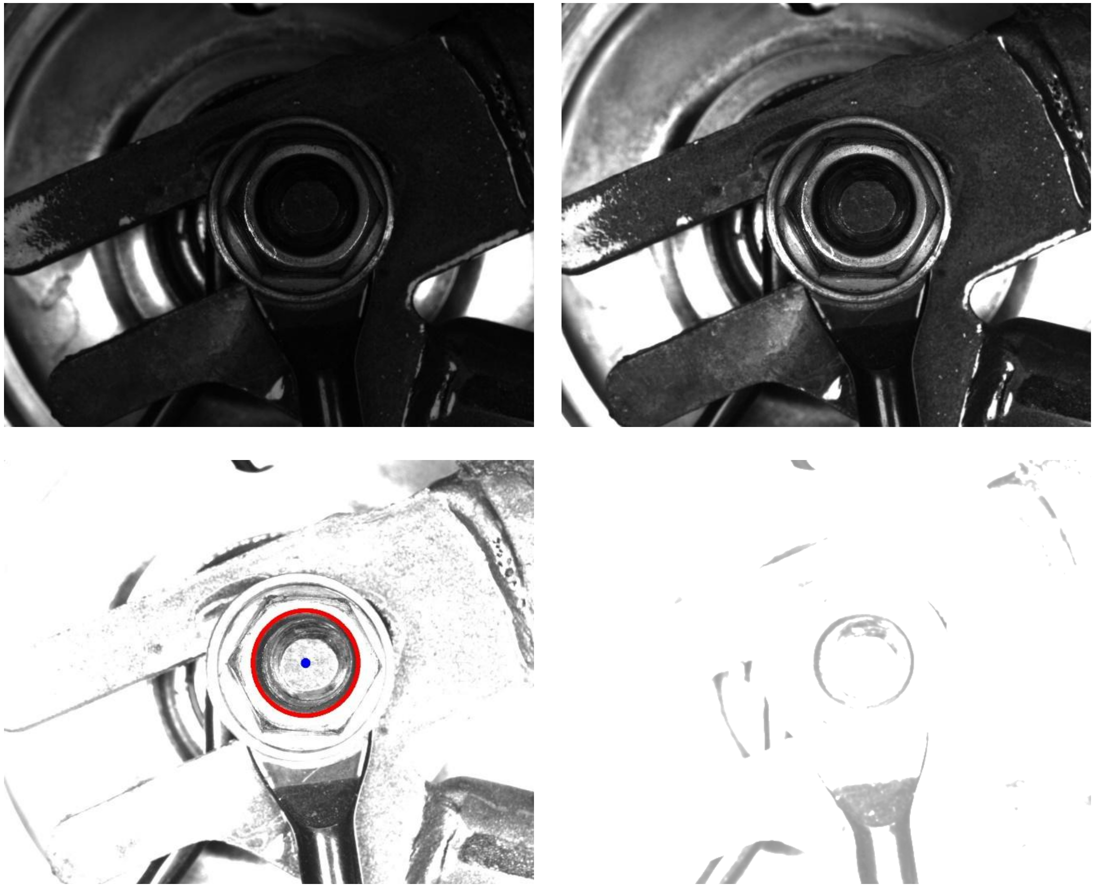
High Error Cases: Double Capturing Solution

IP: Image Processing

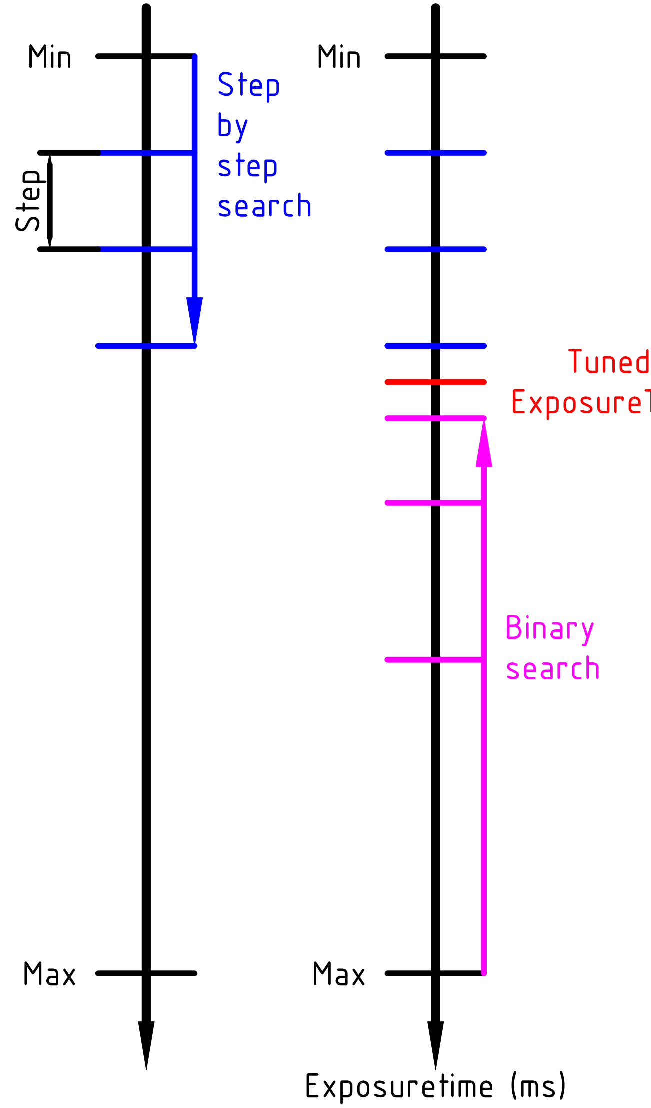


	First Capture	Second Capture
L	$170\ mm$	
β	14^o	2.44^o
$\Delta\tilde{Z}_1$	0.45^o	$-0.47\ mm$
$\tilde{\beta}$	2.44^o	0.31^o
d	$\boxed{10.8\ mm}$	$\boxed{7.73\ mm}$

Auto Tunning Fuction



Lighting effect on nuts detection.



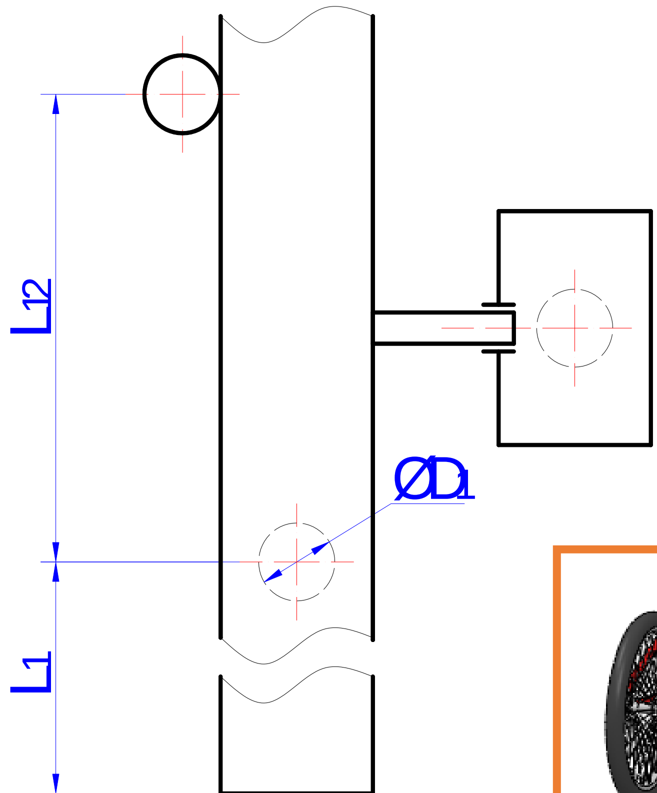
Auto Tunning Algorithm

MECHANICAL AND ELECTRIC/ELECTRICAL DESIGN

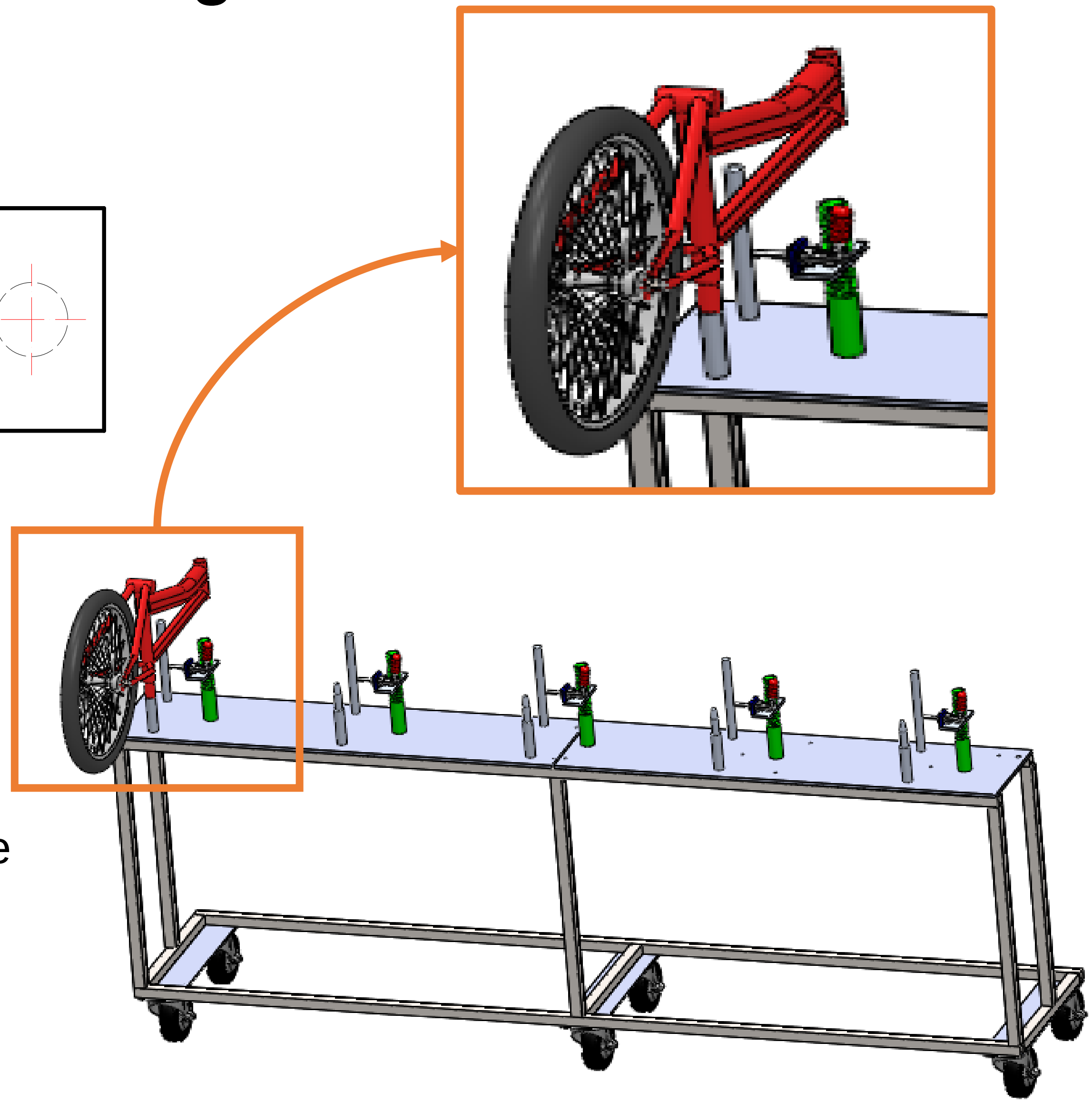
Robot’s Tool – Devices Selection

Device	Requirements	Selection
Motor	Tightening force: $46Nm$. Tightening time: $3s$.	LZB42-L-A005-11 (Atlas Copco)
Linear cylinder	Static moment $46\ Nm$. Working load: $W = 15N$ Stroke: $50mm$.	MXQ25-50 (SMC)
Camera	Min resolution: 800x400 px Industrial standards	acA1300-22gm (Basler)
Lens	Capture widows: 60x30. Working distance: <200	C125-0818-5M-P f6mm (Basler)
Lighting	Working distance: 100 Brightness: >5000 lux	RL1424-WHI-100-XXL-24 (Advanced Illumination)

Mounting Cart Design



Bike Mounting Principle



Electric/Electrical System Design

Device	Requirements	Selection
Compute r	Gigabit Ethernet (RJ45) Avaiable. RAM: 1GB. CPU: 2GHz, multithreading supported. OS supported	IPC-510 (Core i3) (AdvanTech)
PLC	Min: 2 digital inputs and 2 digital outputs Modbus TCP supported	S7-1200 CPU 1211C (Siemens)
HMI	Modbus TCP supported Min resolution: 7”. CPU min speed: 400 MHZ.	MT8071iP (Weintek)
Switch	Minimum 6 ports including: • 2 ports PoE GigE • 2 ports GigE • 2 ports 100Mbps	IPS33064P (ONV)

SYSTEM PERFORMANCE

What do the Experiments Say?

Experiment Objective and Method

Objective

- examine the **stability** of the nut-holding position determination algorithm.
- examine the processing time of the nut-holding position determination algorithm.
- examine the working process to find if any risk might occur.

Phương án tổ chức thực nghiệm

- Gá các xe đạp sao cho vị trí cốt đùm không thay đổi.
- Cho hệ thống chạy tự động trong một thời gian *(không cho xy lanh đi ra/siết ốc)*, **ghi lại các kết quả xử lý ảnh** (logging).

Experimental Video

ĐẠI HỌC QUỐC GIA THÀNH PHỐ HỒ CHÍ MINH
TRƯỜNG ĐẠI HỌC BÁCH KHOA
KHOA CƠ KHÍ – BỘ MÔN CƠ ĐIỆN TỬ

LUẬN VĂN TỐT NGHIỆP

THIẾT KẾ HỆ THỐNG SIẾT ỐC TỰ ĐỘNG CHO CỤM BÁNH SAU XE ĐẠP

Sinh viên thực hiện:	Võ Đức Trí – 1513682
Mã số sinh viên:	1513682
Giảng viên hướng dẫn:	PGS. TS. Nguyễn Quốc Chí

Tp. Hồ Chí Minh, ngày 17 tháng 09 năm 2020

CONCLUSIONS

Conclusions

Research Task:

- The research task was completed, meeting the design requirements.
- The design emphasizes the flexibility of the system.
- Experimental results demonstrate the feasibility of the designed system.

Limitations:

- The issue of automatic material feeding and removal has not been resolved.
- The experiment was not conducted exactly according to the design specifications.
- Cost optimization for the products has not been achieved.
- The system's target audience is relatively small.

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