SOLUTION FOR INDUSTRIAL CAMERA AUTOFOCUSING

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INTRODUCTION

There are two devices:
ROS Robots and Industrial Camera,
and the camera can’t auto focus an object itself.

How about making a moving robot
with auto-focusing industrial camera?

FOCUSED POINTS

MACHINE LEARNING

Image learning using 2000+ images

01

02

ON-BOARD LEARNING

Process with online streaming data with NVIDIA TX2 board

ROS-BASED ROBOT

, which enables to move industrial camera

03

04

HW/SW MODULARIZATION

by developing a ROS package in a docker container

SYSTEM ARCHITECTURE

Robot with Industrial Camera

ROS
Image Crawler

2000+ Captured Images

+

8000+ Rotate/Cropped Images

ROS
Image Analyzer

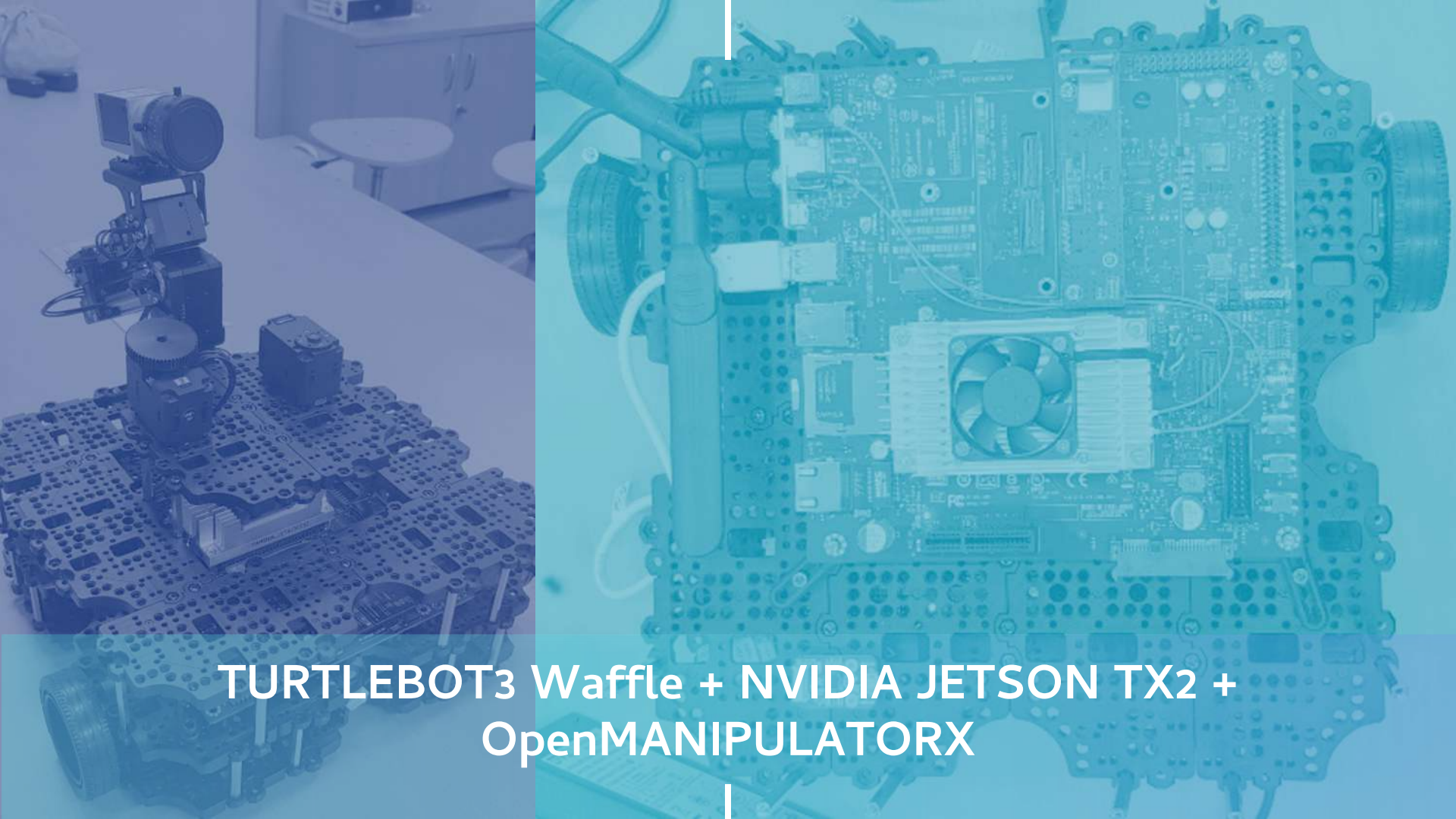
Optimal Values of
- Aperture
- Focal Length
- Moving Distance

THEN, MOVE!

HARDWARE SETUP

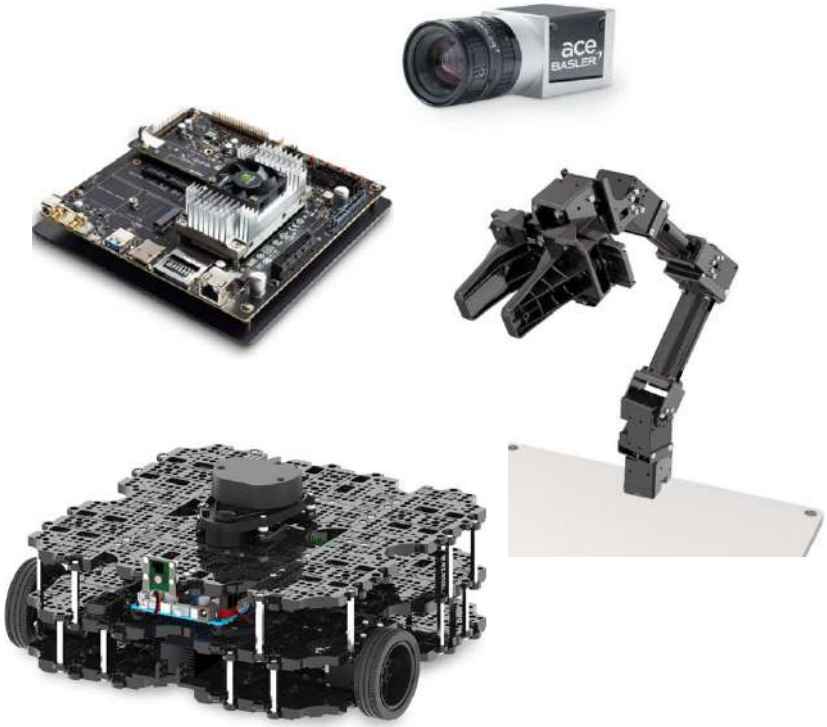
TURTLEBOT3 WAFFLE /
NVIDIA TX2 BOARD

01



TURTLEBOT3 Waffle + NVIDIA JETSON TX2 + OpenMANIPULATORX

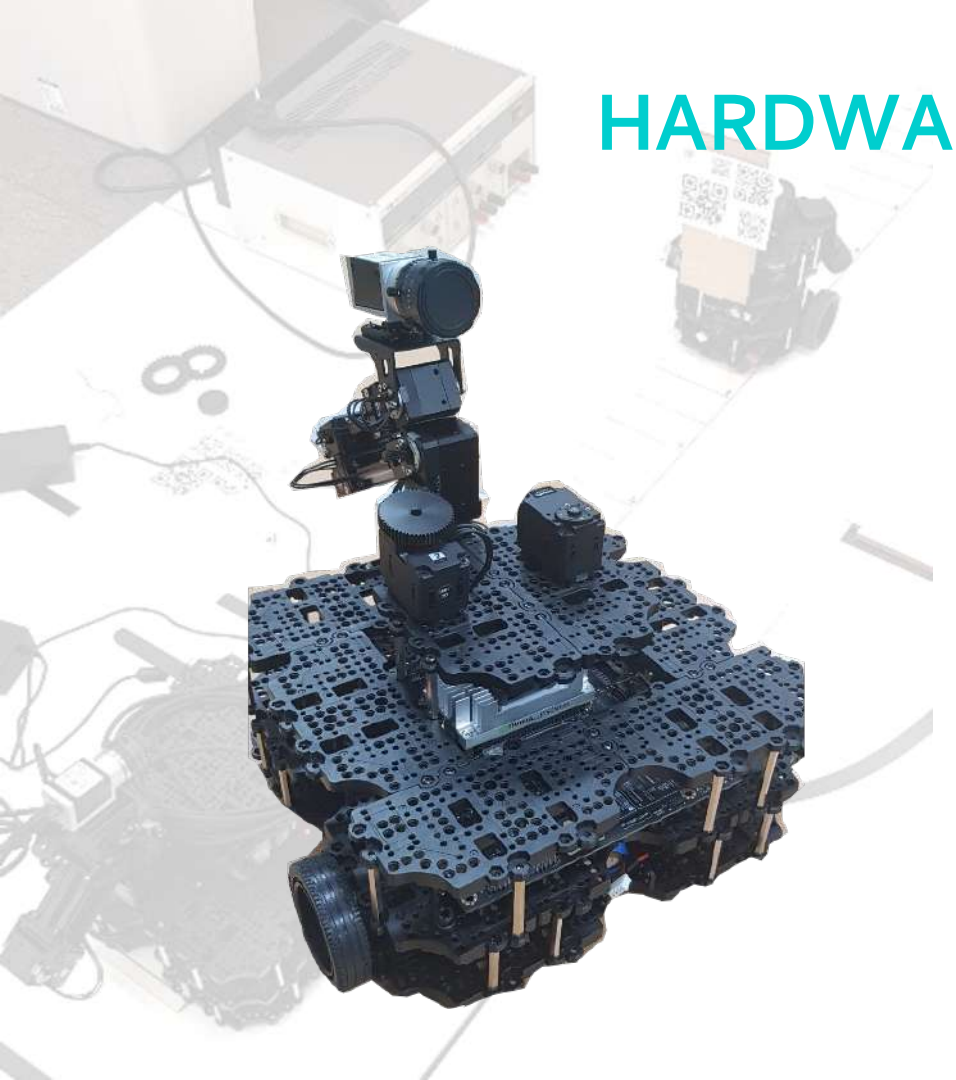
HARDWARE SPECS



Here’s specifications of hardware used:

- Basler ACE acA2500-14gm
  - 2592 x 1944 5MP resolution
  - MONO tone
  - 14fps
- Turtlebot3 Waffle
  - 281 x 306 x 141 mm
  - 30kg maximum payload
  - SBC: Raspberry Pi 3 Model B+
  - OpenCR Arduino + Dynamixel Motor 2EA

HARDWARE SPECS



Here’s specifications of hardware used:

- NVIDIA Jetson TX2
  - ARM A57 with CUDA GPU
  - 8GB DDR + 64GB Flash
  - 32GB eMMC
  - Linux for Tegra
- Open ManipulatorX
  - Injection Molding Parts
  - Aluminum-frame arms

CUSTOM PARTS

1. GEARS
   - various size
     from 5:1 to 10:1
   - MDF / ABS

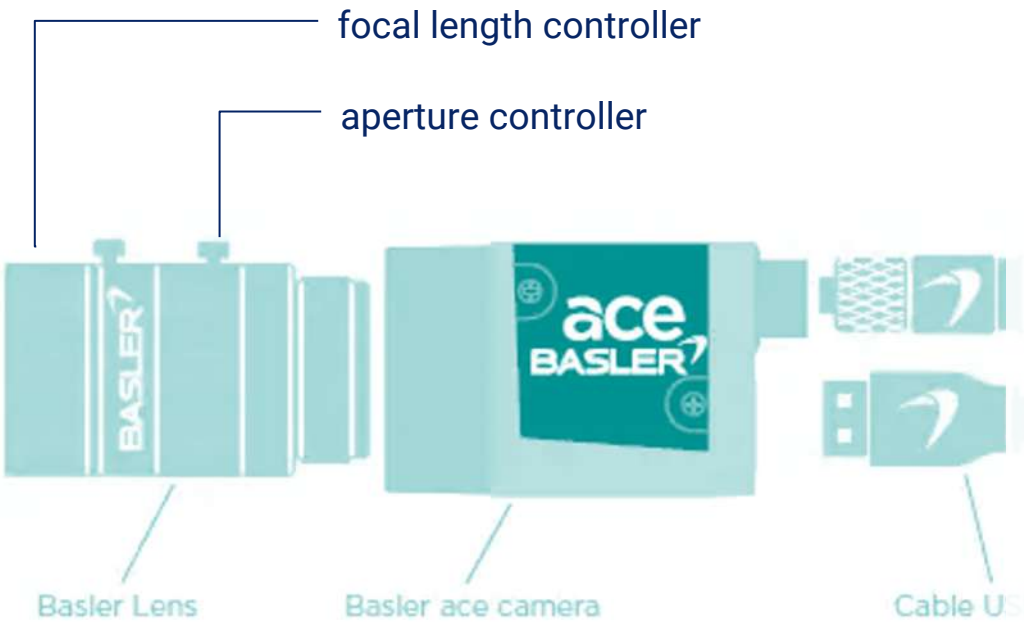
2. Extra Dynamixels
   - to move lens
   - 2EA

LEARNING MODEL DESIGN

with Keras + Scikit Learn

02

OBJECTIVES



01

OPTIMAL APERTURE

by standardizing brightness / contrast histograms

02

OPTIMAL FOCAL LENGTH

by machine learning self-captured pictures

03

DESIRED DISTANCE

with moving arms ± 10cm

CONSTRAINTS

01

ONLINE STREAMING IMAGES

14fps live streaming via gigE + ROS subscribers

02

BUT NOT WHEN CHANGING LENS

stop capturing when changing aperture/focal length values

03

IMPRECISE LENS CONTROLLING

lacking exactness of rolling lens

04

NOT FULLY ROTATING ARMS

openManipulatorX arms lacks fully-rotating angles

INPUT

01

CAPTURED IMAGES

self-captures images from self-designed robot, which contains various size of QR Codes

02

CURRENT VALUES

current aperture and focal length values subscribed by ros packages

```
rospy.Subscriber(“/status”,
get_status, StdMsg)
```

MODELS

- Labeling images & analyze:

INPUTS

- Images w QR codes
- Current aperture
- Current focal_length

IMAGE ANALYZER

- Standard Deviation
- Mean
- Canny-edged histogram

- QR CODE values[5]
- QR CODE sizes[5]
- QR CODE scores btw 0~5

INFORMATION

- differential vaules of histogram – equalized histogram

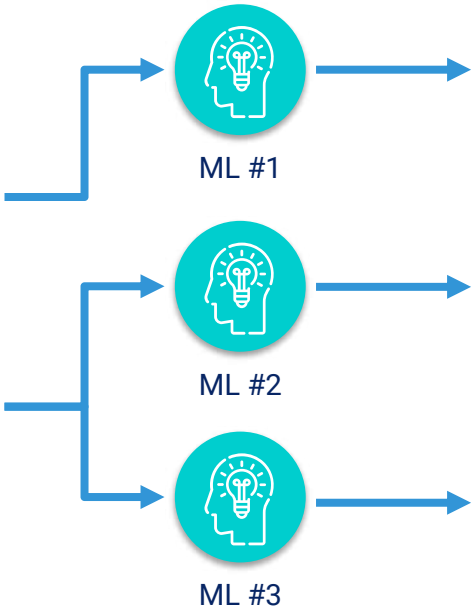
- five discrete values which tells if the image is focused
- ”isOptimized” value == if expected QR score

MODELS

- Getting optimal values by machine learning:

INFORMATION

- differential vaules of histogram – equalized histogram
- five discrete values which tells if the image is focused



OUTPUTS

- Optimal aperture value
- Optimal focal length value
- Desired distance for moving the robot

MODELS

- QR Code Encryption

Version 1 QR Code
(21×21 modules)

The module size
is approx. 0.5mm

The module size is
approx. 1.0mm

QR in Captured images

Each QR_CODE contains

CORMORANT_1cm

CORMORANT_2cm

CORMORANT_3cm

CORMORANT_4cm

CORMORANT_5cm

COMPARISON

- Calculating available detecting distance

	1x1	2x2	3x3	4x4	5x5
Size per dots	0.047mm	0.095mm	1.428mm	1.904mm	2.380mm
Aval. Distance for 3MP Cam	100mm	200mm	300mm	400mm	500mm
Exp. Distance for 5MP Industrial Cam	400mm	800mm	1200mm	1600mm	2000mm

MODELS

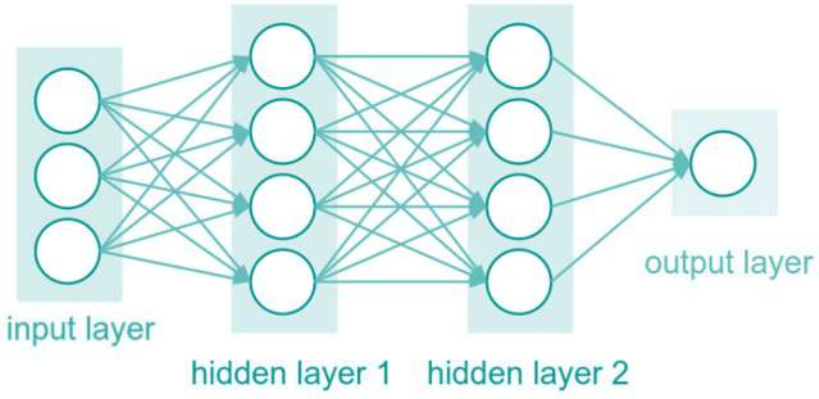
- Getting optimal values by machine learning:

+

- Used for deep learning
- Used for other various machine learning model

MODELS

- Getting optimal values by machine learning:



4 Feed-forward models +
1 Deep learning model

ML #1:
Optimal
Aperture

ML #2:
Optimal
Focal length

ML #3:
Desired
Distance

Each machine learning will use these models:

- Random Forest
- Decision Tree
- k-Nearest Neighbors
- Linear Regression
- Deep Learning with 2 hidden layers

MODELS

- Getting optimal values by machine learning:

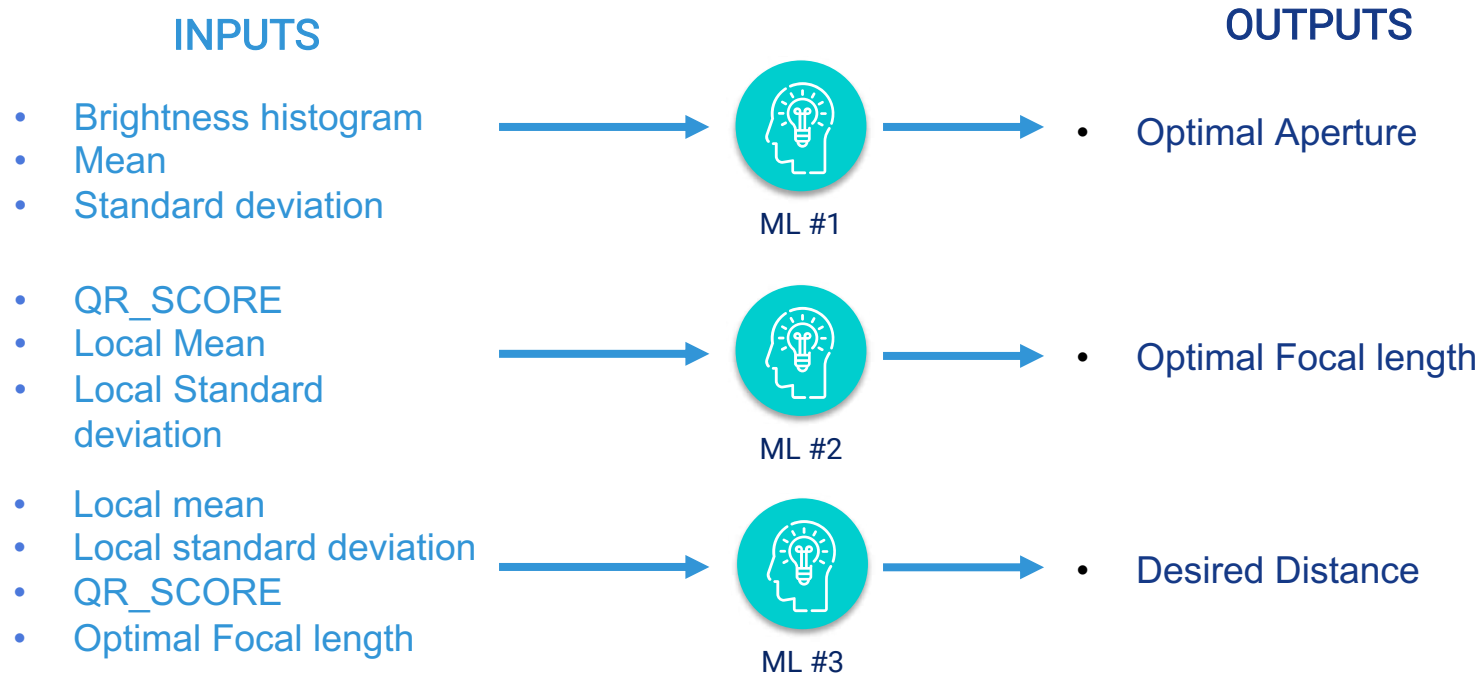
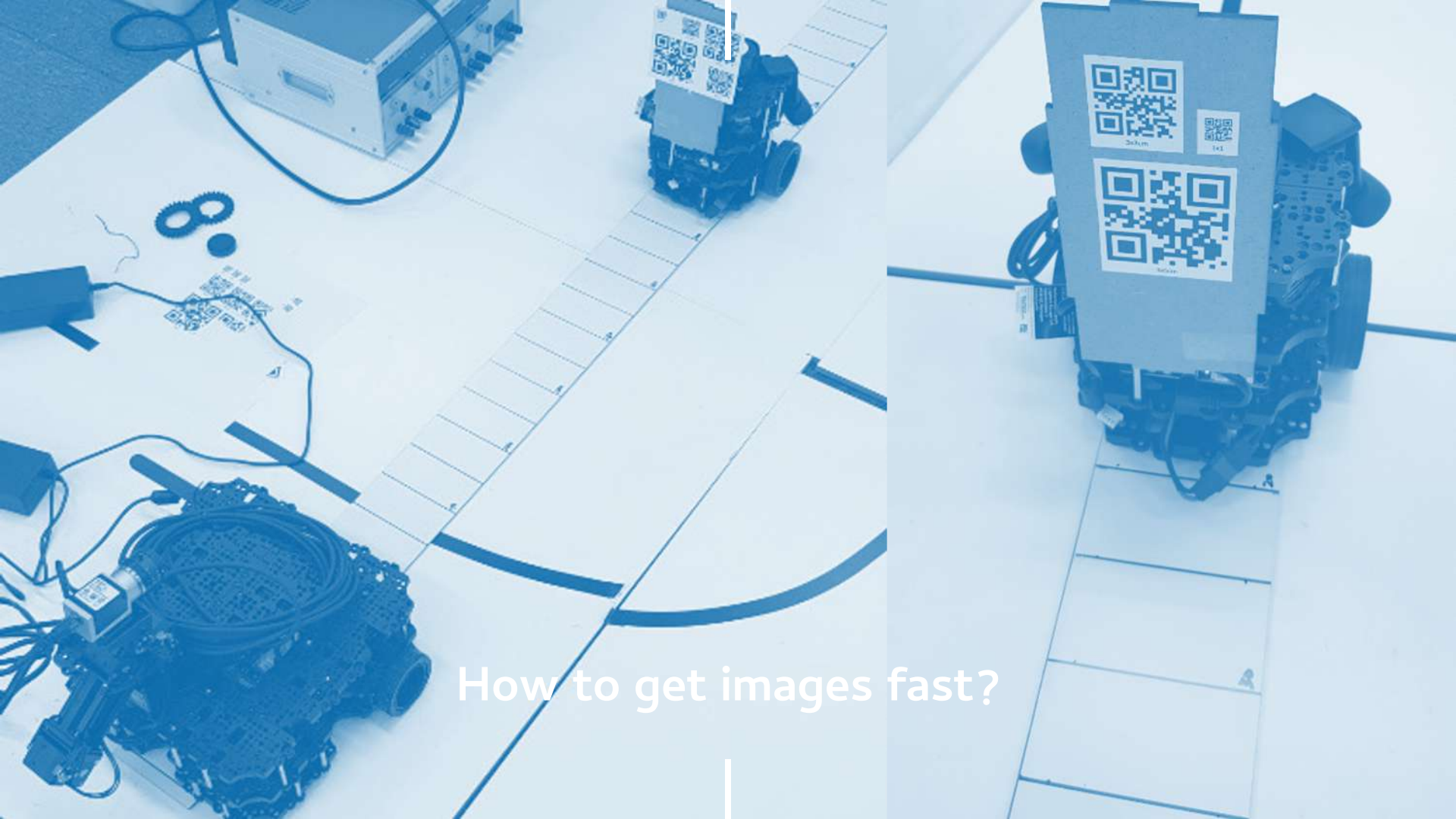


IMAGE CRAWLING & LABELING

03

with custom image crawler



How to get images fast?

OVERVIEW

- A captured image should include:
  - 5 QR Codes
  - Current focal length
  - Current aperture
  - Current distance
  - Environment id

- Almost IMPOSSIBLE to take thousands of images MANUALLY!

MAKE A ROS PACKAGE for CRAWLING!

GITHUB PROJECT

GALAPAGOS CORMORANT

https://github.com/100kimch/galapagos_cormorant

This project includes:

- ROS package for image crawling / data processing
- Docker images for setting the environment (ROS + TF + Jupyter)
- 2000+ Self captured images
- Analyzed CSV files
- Customized Turtlebot3 + openManipulatorX drivers

PROCESS

- Process for image crawling:

1. Put: ‘roslaunch ml-learning image_crawling.roslaunch’ on the industrial camera robot.
2. Put: ‘roslaunch turtlebot3_teleop turtlebot3_teleop_key.launch’ on the QR Codes robot.
3. Place the QR barcodes in the fixed distance away from the industrial camera robot
4. Put the distances, current aperture & focal length values on the ‘ml-learning’ package
5. See rqt images on topic “/cormorant/cam_image” and the robots with the naked eye
6. When the all five QR codes are on the right pose, press space
7. Then the saved image can be seen on topic ”cormorant/saved_image”

PROCESS

- Labeling saved images:

- 5-codes
  - 2r2-2
    - 30-1.png
  - 2r2-inf
  - 4-2
  - ⋮
- 3-codes

- aperture: 2.8 distance: 30
  focal length: 2 environment: 1

DATA PROCESSING

with custom image crawler

04

REVIEW

- Labeling images & analyze:

INPUTS

- Images w QR codes
- Current aperture
- Current focal_length

→

IMAGE ANALYZER

- Standard Deviation
- Mean
- Canny-edged histogram

→

INFORMATION

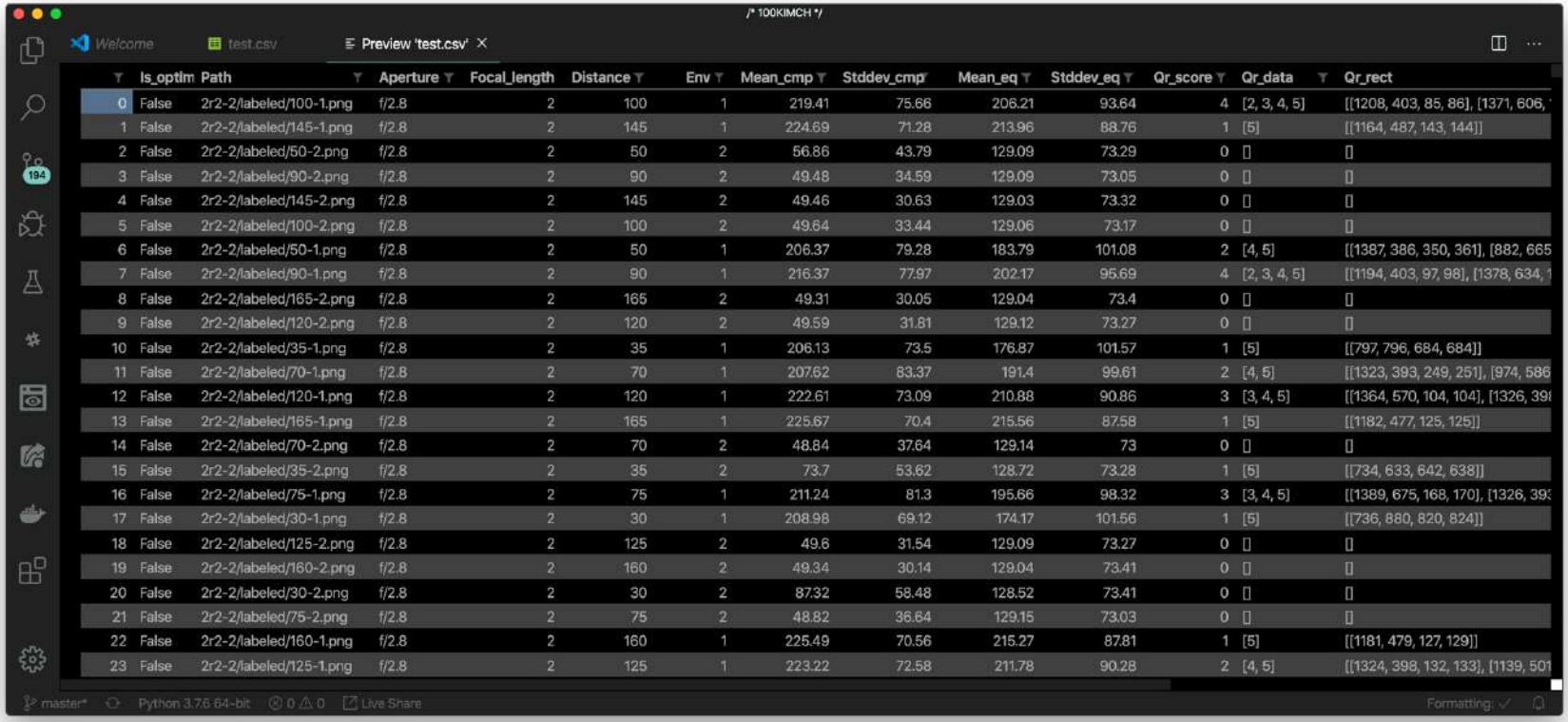
- differential vaules of histogram – equalized histogram

- QR CODE values[5]
- QR CODE sizes[5]
- QR CODE scores btw 0~5

→

- five discrete values which tells if the image is focused
- ”isOptimized” value == if expected QR score

RESULTS



	Is_optim	Path	Aperture	Focal_length	Distance	Env	Mean_cmp	Stddev_cmp	Mean_eq	Stddev_eq	Qr_score	Qr_data	Qr_rect
0	False	2r2-2/labeled/100-1.png	f/2.8	2	100	1	219.41	75.66	206.21	93.64	4	[2, 3, 4, 5]	[[1208, 403, 85, 86], [1371, 606,
1	False	2r2-2/labeled/145-1.png	f/2.8	2	145	1	224.69	71.28	213.96	88.76	1	[5]	[[1164, 487, 143, 144]]
2	False	2r2-2/labeled/50-2.png	f/2.8	2	50	2	56.86	43.79	129.09	73.29	0	[]	[]
3	False	2r2-2/labeled/90-2.png	f/2.8	2	90	2	49.48	34.59	129.09	73.05	0	[]	[]
4	False	2r2-2/labeled/145-2.png	f/2.8	2	145	2	49.46	30.63	129.03	73.32	0	[]	[]
5	False	2r2-2/labeled/100-2.png	f/2.8	2	100	2	49.64	33.44	129.06	73.17	0	[]	[]
6	False	2r2-2/labeled/50-1.png	f/2.8	2	50	1	206.37	79.28	183.79	101.08	2	[4, 5]	[[1387, 386, 350, 361], [882, 665
7	False	2r2-2/labeled/90-1.png	f/2.8	2	90	1	216.37	77.97	202.17	95.69	4	[2, 3, 4, 5]	[[1194, 403, 97, 98], [1378, 634,
8	False	2r2-2/labeled/165-2.png	f/2.8	2	165	2	49.31	30.05	129.04	73.4	0	[]	[]
9	False	2r2-2/labeled/120-2.png	f/2.8	2	120	2	49.59	31.81	129.12	73.27	0	[]	[]
10	False	2r2-2/labeled/35-1.png	f/2.8	2	35	1	206.13	73.5	176.87	101.57	1	[5]	[[797, 796, 684, 684]]
11	False	2r2-2/labeled/70-1.png	f/2.8	2	70	1	207.62	83.37	191.4	99.61	2	[4, 5]	[[1323, 393, 249, 251], [974, 586
12	False	2r2-2/labeled/120-1.png	f/2.8	2	120	1	222.61	73.09	210.88	90.86	3	[3, 4, 5]	[[1364, 570, 104, 104], [1326, 39
13	False	2r2-2/labeled/165-1.png	f/2.8	2	165	1	225.67	70.4	215.56	87.58	1	[5]	[[1182, 477, 125, 125]]
14	False	2r2-2/labeled/70-2.png	f/2.8	2	70	2	48.84	37.64	129.14	73	0	[]	[]
15	False	2r2-2/labeled/35-2.png	f/2.8	2	35	2	73.7	53.62	128.72	73.28	1	[5]	[[734, 633, 642, 638]]
16	False	2r2-2/labeled/75-1.png	f/2.8	2	75	1	211.24	81.3	195.66	98.32	3	[3, 4, 5]	[[1389, 675, 168, 170], [1326, 39
17	False	2r2-2/labeled/30-1.png	f/2.8	2	30	1	208.98	69.12	174.17	101.56	1	[5]	[[736, 880, 820, 824]]
18	False	2r2-2/labeled/125-2.png	f/2.8	2	125	2	49.6	31.54	129.09	73.27	0	[]	[]
19	False	2r2-2/labeled/160-2.png	f/2.8	2	160	2	49.34	30.14	129.04	73.41	0	[]	[]
20	False	2r2-2/labeled/30-2.png	f/2.8	2	30	2	87.32	58.48	128.52	73.41	0	[]	[]
21	False	2r2-2/labeled/75-2.png	f/2.8	2	75	2	48.82	36.64	129.15	73.03	0	[]	[]
22	False	2r2-2/labeled/160-1.png	f/2.8	2	160	1	225.49	70.56	215.27	87.81	1	[5]	[[1181, 479, 127, 129]]
23	False	2r2-2/labeled/125-1.png	f/2.8	2	125	1	223.22	72.58	211.78	90.28	2	[4, 5]	[[1324, 398, 132, 133], [1139, 501

RESULTS

- Labeling images & analyze:

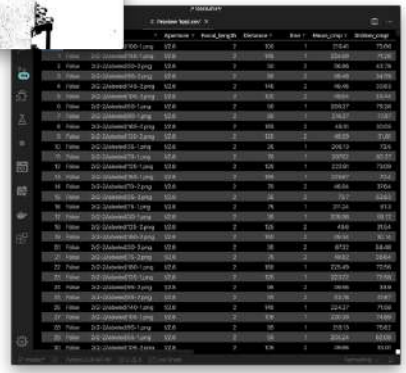
INPUTS

- aperture: f/2.8
- focal length: 5
- distance: 45

IMAGE ANALYZER

- mean: 217.67
- stddev: 65.75

INFORMATION



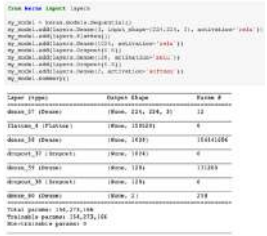
- stddev_eq: 100.69
- QR_score: 4

MACHINE LEARNING

with custom image crawler

05

PROGRESS CHECKLISTS



with 10000+ self images
& rotated/cropped images
in five models

LEARNING

distances to move robot
with desired distance
value

ESTIMATE

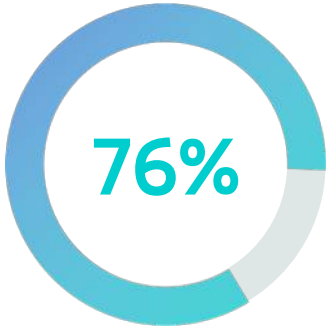
LEARNING

with 2000+ self
captured images
in five models

IMPROVING

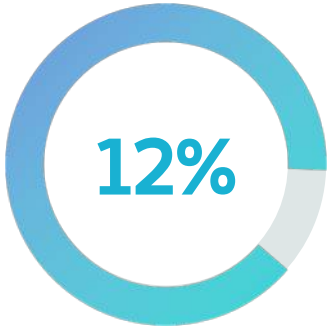
models' accuracy and
redesign data models

BRIEF RESULTS



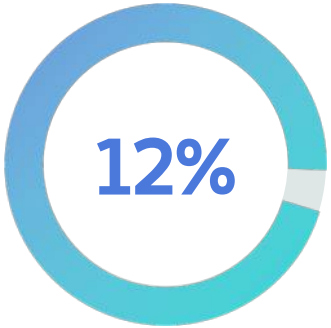
VALIDATION ACCURACY

on 25 epoches, in Deep Learning Model



VALIDATION LOSS

on 25 epoches, in Deep Learning Model



IMPROVEMENT

on 10000+ images compared to 2000+ images

COMPARISON

	2000+ IMG	10000+ IMG
Random Forest	58.12	66.76
Decision Tree	54.24	66.76
k-Nearest Neighbors	57.34	59.12
Linear Regression	65.35	70.12
Deep Learning	69.12	76.12

ROBOT CONTROL

06

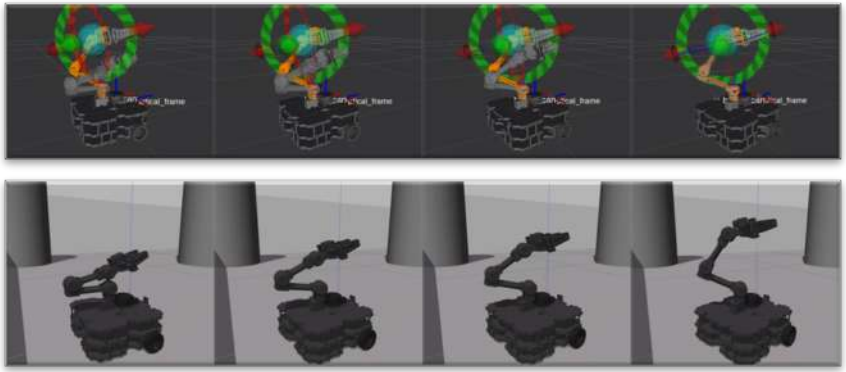
with custom image crawler

WHAT TO CONTROL

- 2 Dynamixel Motors for moving wheels
- 4 Dynamixel Motors for moving openMANIPULATORX arms
- 2 Dynamixel Motors for moving industrial camera aperture & focal length

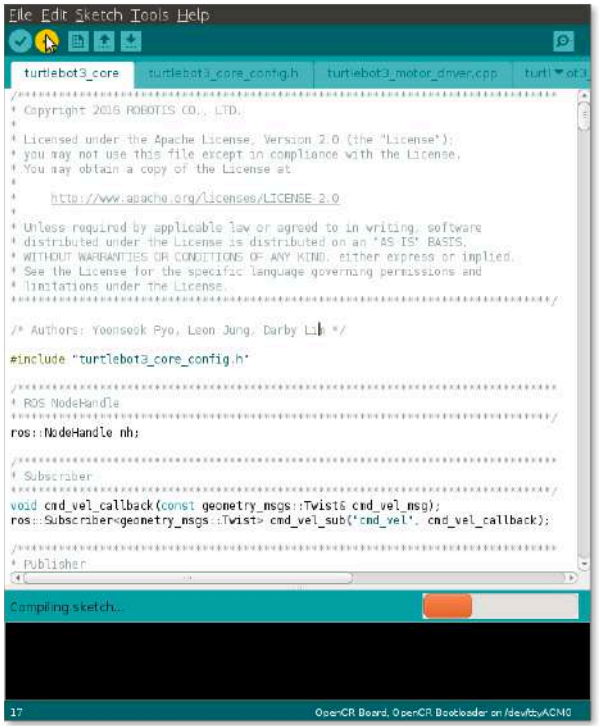
WHAT TO USE

- ROBOTIS OpenManipulator-X e-Manual
- ROBOTIS Turtlebot3 > Manipulation e-Manual
- Moveit + Gazebo Simulator



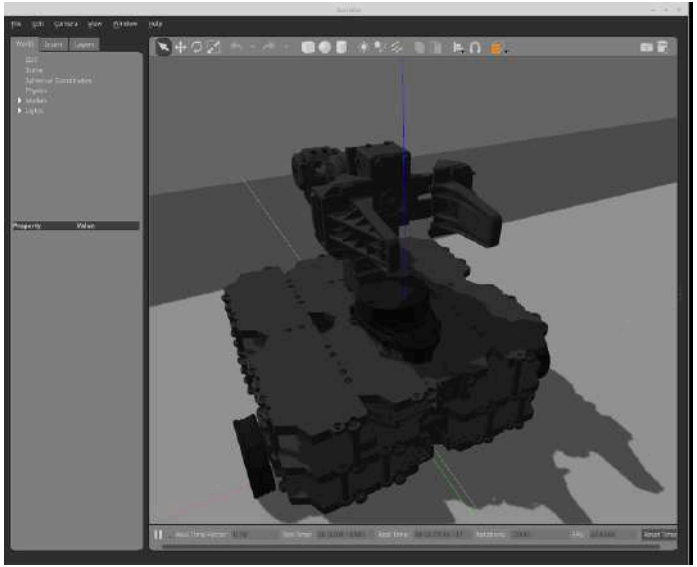
- http://emanual.robotis.com/docs/en/platform/turtlebot3/manipulation/#manipulation
- http://emanual.robotis.com/docs/en/platform/openmanipulator_x/mobile_manipulation/#mobile-manipulation

CUSTOMIZE DRIVERS



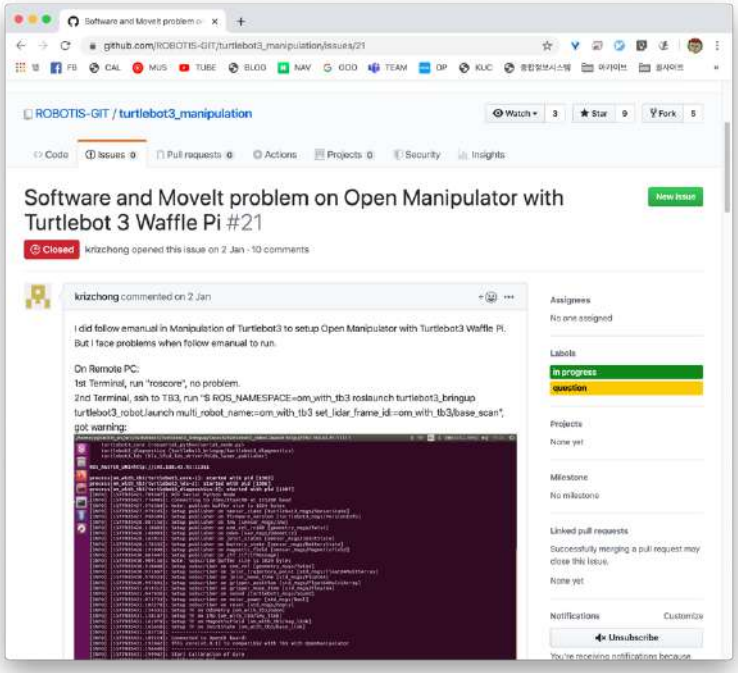
- Based on the driver of “turtlebot3_with_open_manipulator_core”:
  - removed gripper motor
  - added 2 extra motors to control lens
  - added 2 wheeling motors by adding codes of ”turtlebot3_core”

PROBLEMS



- eManual documents of openManipulator-X is outdated!
- cannot launched emanual’s ROS package due to the differences of version 1 & 2 of openManipulatorX!

SOLVING PROBLEMS



https://github.com/ROBOTIS-GIT/turtlebot3_manipulation/issues/21

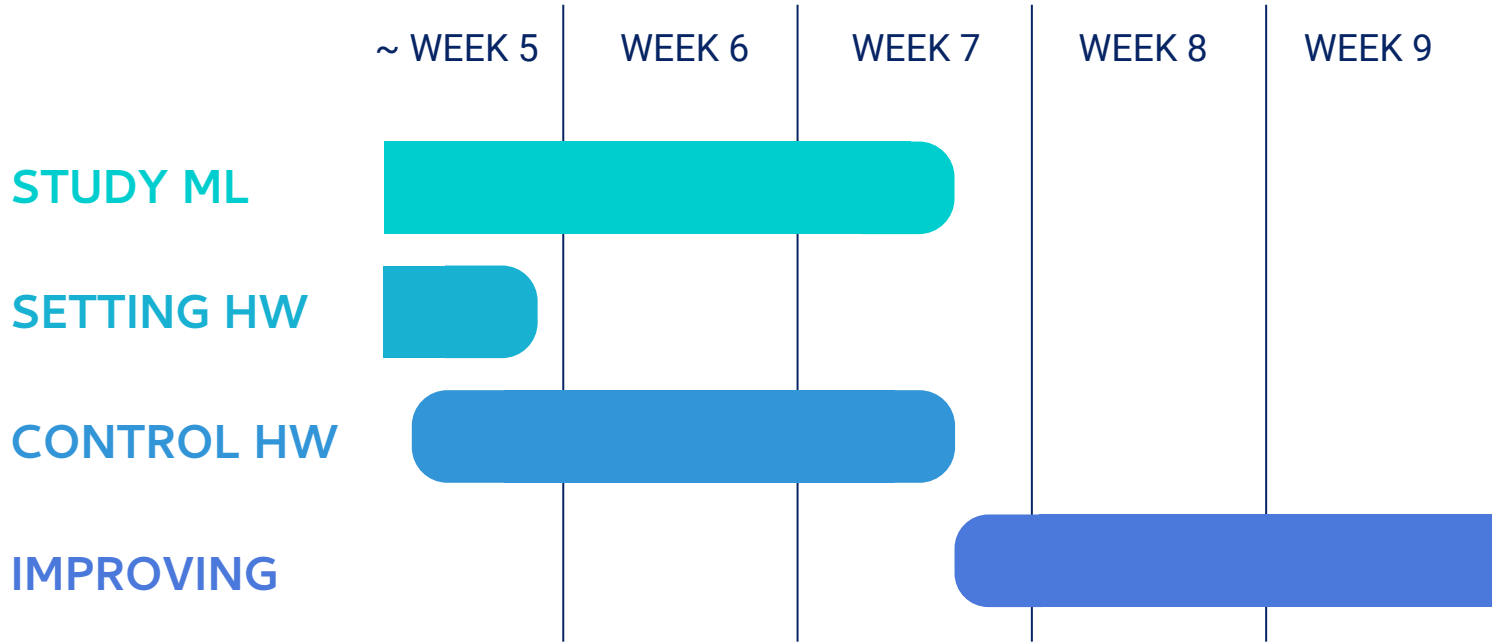
- This issue was in progress
  (2020. Jan. 02 ~ 2020. Feb. 14)
- This issue seemed to be solved by the maintainer's comment in Feb. 14, but I haven't enough time to apply this method.

SUMMARY

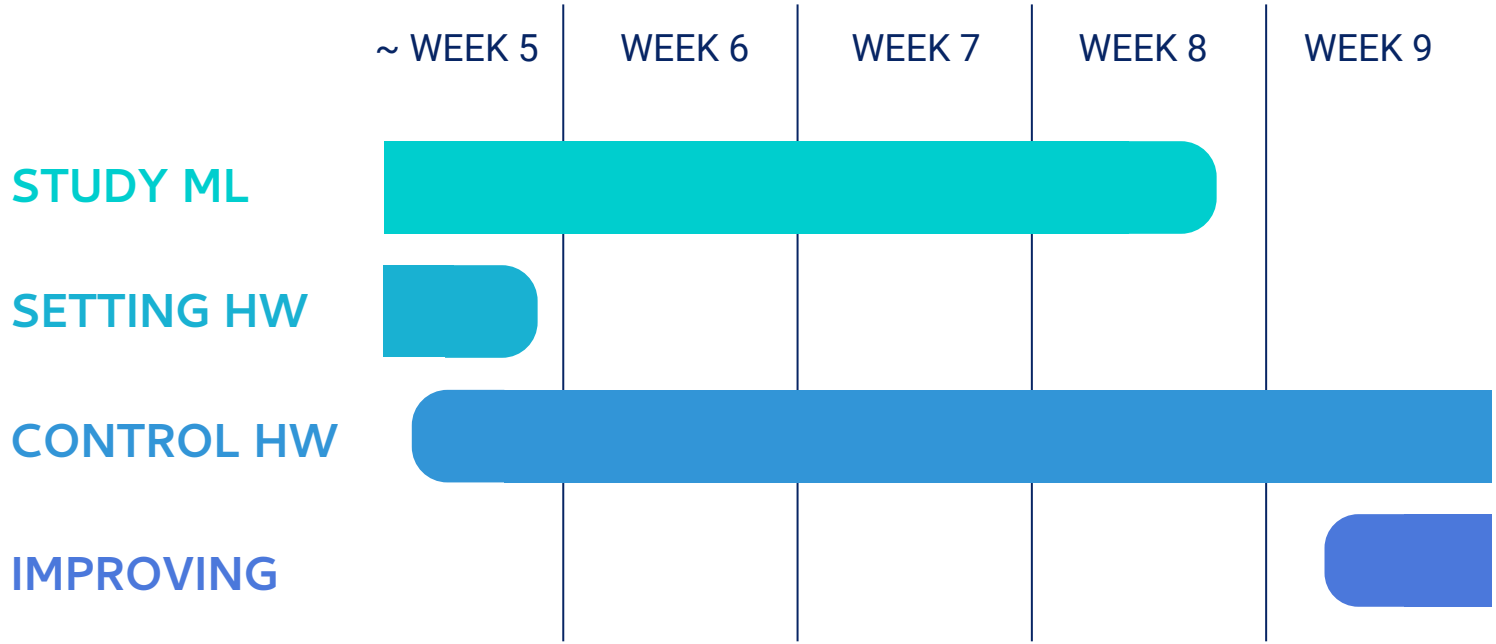
of this project

07

DESIRED TIMELINE



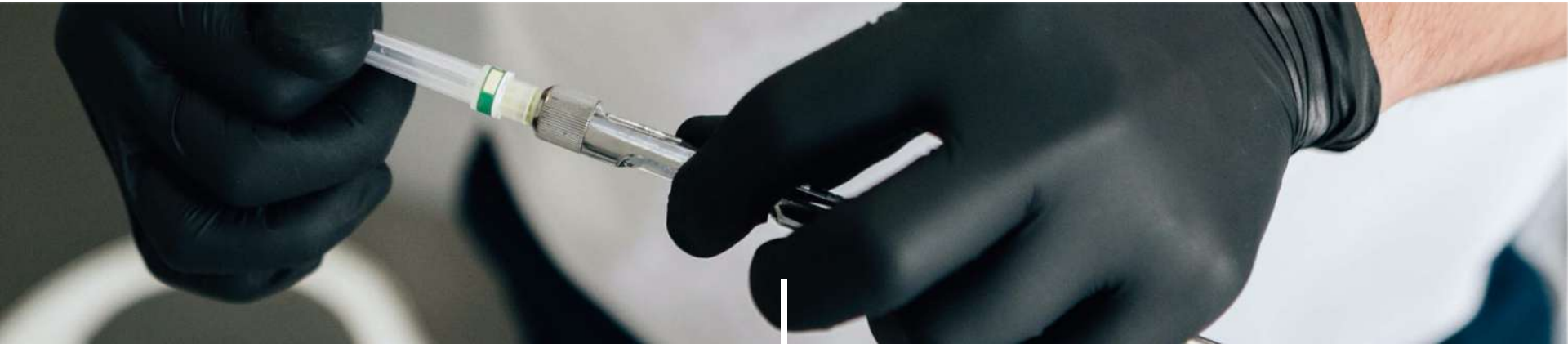
ACCOMPLISHED TIMELINE



THERE ISN'T ENOUGH TIME TO IMROVE!

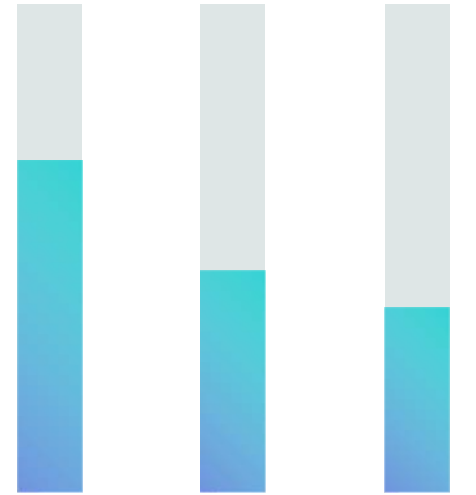
Slidesgo Flaticon

Freepik

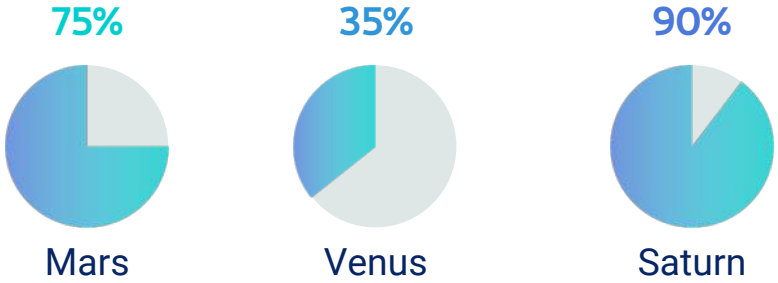


PATIENT MONITORING

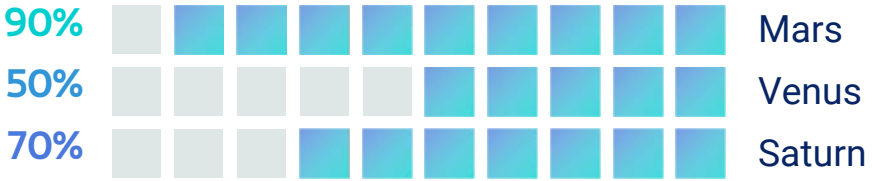
WEEK 1



WEEK 2



WEEK 3



PROCESS

- Process for controlling robot:

1. Put: ‘roslaunch ml-learning image_crawling.roslaunch’ on the industrial camera robot.
2. Put: ‘roslaunch turtlebot3_teleop turtlebot3_teleop_key.launch’ on the QR Codes robot.
3. Place the QR barcodes in the fixed distance away from the industrial camera robot
4. Put the distances, current aperture & focal length values on the ‘ml-learning’ package
5. See rqt images on topic “/cormorant/cam_image” and the robots with the naked eye
6. When the all five QR codes are on the right pose, press space
7. Then the saved image can be seen on topic ”cormorant/saved_image”

IDENTIFYING INFORMATION

01

MERCURY

Mercury is the closest planet to the Sun and the smallest one in the Solar System—it's only a bit larger than the Moon

02

VENUS

Venus has a beautiful name and is the second planet from the Sun. It's terribly hot—even hotter than Mercury

PATIENT MEDICAL HISTORY

TERRY MCGUIRE

AGE
22

GENDER
Male

LOCATION
France

SYMPTOMS

Mars — 60%

Venus — 75%

2015
MERCURY
Mercury is the closest planet to the Sun

2017
MARS
Despite being red, Mars is actually a cold place

2019
NEPTUNE
Neptune is the farthest planet from the Sun

ABOUT THE PATIENT

01

You could enter a subtitle here if you need it

REVIEW OF SYSTEMS

JUPITER

It’s the biggest planet in the Solar System

VENUS

Venus has a beautiful name, but it’s terribly hot

MERCURY

Mercury is the closest planet to the Sun

NEPTUNE

Neptune is the farthest planet from the Sun

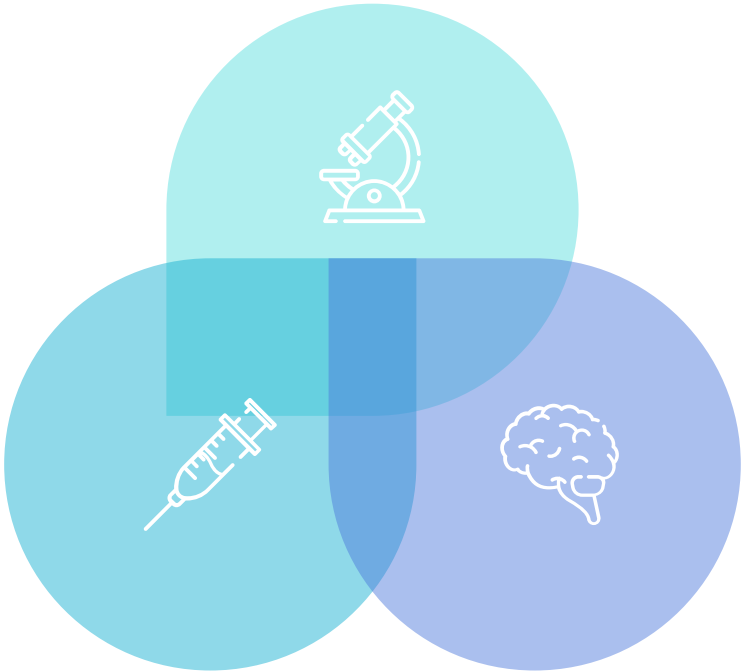
SATURN

Saturn is composed of hydrogen and helium

MARS

Despite being red, Mars is actually a cold place

PHYSICAL EXAMINATION



01

MERCURY

Mercury is the closest planet to the Sun

02

MARS

Despite being red, it’s actually a cold place

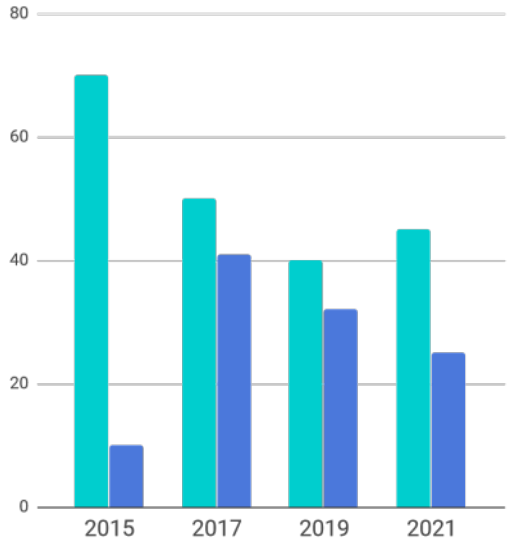
03

NEPTUNE

It’s the farthest planet from the Sun


A Picture Is Worth a Thousand Words

FINDINGS



To modify this graphs, click on it, follow the link, change the data and paste the resulting graph here

8,000

Saturn is the ringed one and a gas giant

44,000

Mercury is the closest planet to the Sun

DISCUSSION

Venus has a beautiful name and is the second planet from the Sun

—Dr. HILDA BLUE

Jupiter is a gas giant and the biggest planet in the Solar System

—Dr. JOHN DOE

Despite being red, Mars is actually a cold place full of iron oxide dust

—Dr. INGRID ROE

AWESOME WORDS

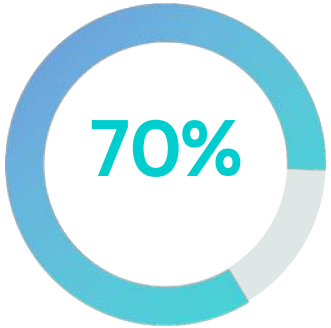
DISCUSSION SUMMARY

1. Mercury is the smallest planet in the Solar System
2. Saturn is composed of hydrogen and helium
3. Venus has a beautiful name, but it’s terribly hot

COMPARISON

	JUPITER	MERCURY	VENUS	MARS
Case 01	✗	✓	✗	✗
Case 02	✗	✗	✓	✓
Case 03	✗	✗	✗	✓
Case 04	✓	✓	✗	✗

DIAGNOSIS

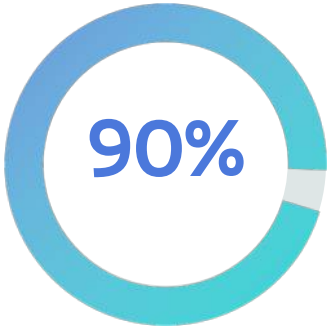


NEPTUNE

Neptune is the farthest planet from the Sun

MERCURY

Mercury is the closest planet to the Sun



VENUS

Venus is the second planet from the Sun

TREATMENT

01

SATURN

It’s composed mostly of hydrogen and helium

02

MARS

Despite being red, Mars is actually a cold place

03

NEPTUNE

It’s the farthest planet from the Sun

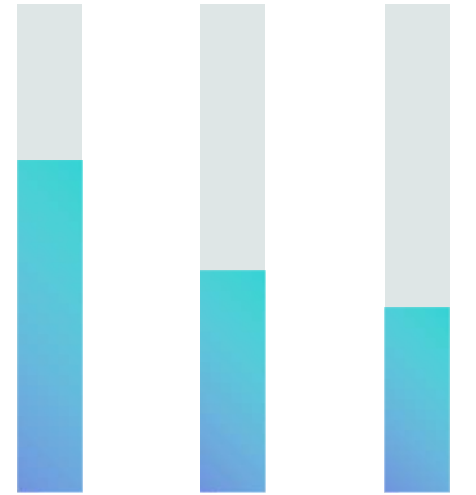
04

VENUS

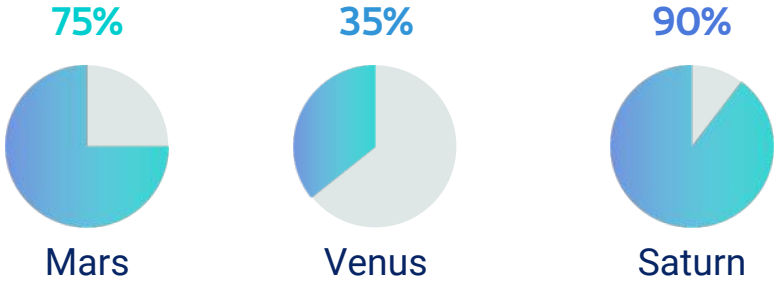
Venus is the second planet from the Sun

PATIENT MONITORING

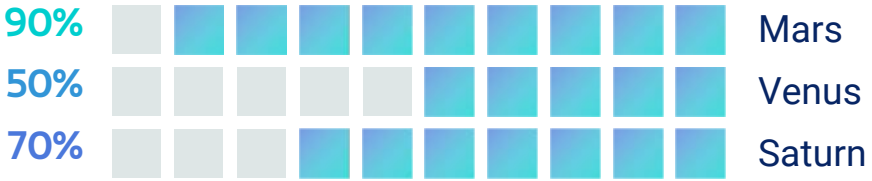
WEEK 1



WEEK 2



WEEK 3



PREVALENCE

Try editing this text according to your own needs

CONTRAINDICATIONS & INDICATIONS

01

Here you can describe a reason to start the treatment

02

Here you can describe a reason to start the treatment

03

Here you can describe a reason to start the treatment

01

Here you can describe the reason to stop the treatment

02

Here you can describe the reason to stop the treatment

03

Here you can describe the reason to stop the treatment

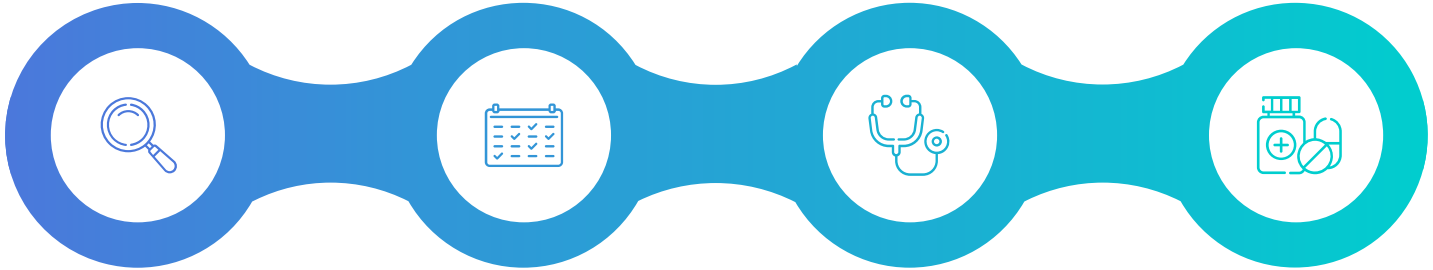
CASE TIMELINE A

It’s the biggest planet in the Solar System

JUPITER

Saturn is composed of hydrogen and helium

SATURN



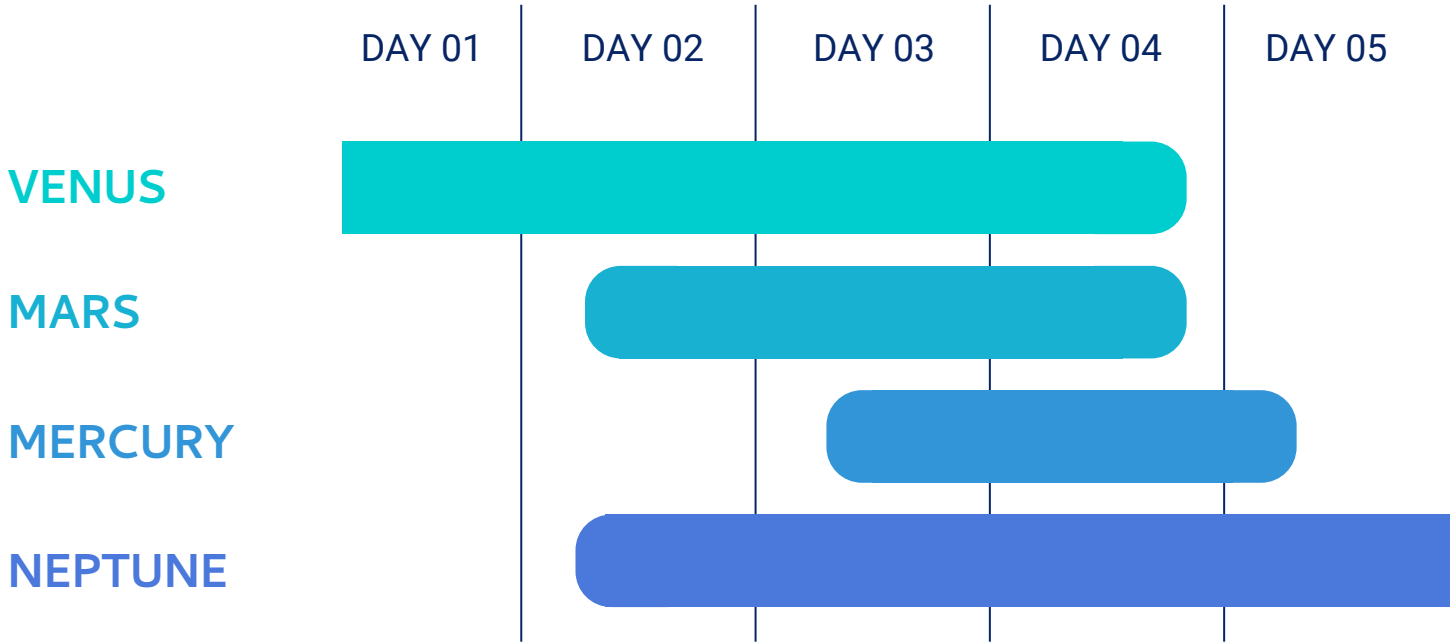
MERCURY

Neptune is the farthest planet from the Sun

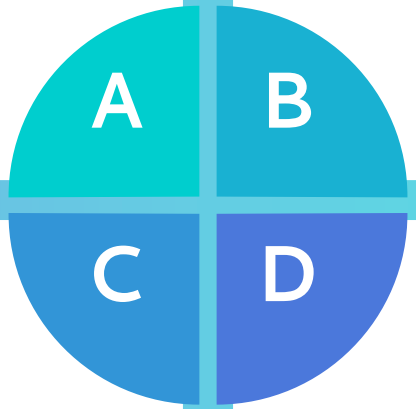
VENUS

Venus has a beautiful name, but it’s hot

CASE TIMELINE B



POST-PREVENTION



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Despite being red, Mars is actually a cold place

VENUS

Venus has a beautiful name, but it’s terribly hot

CONCLUSIONS

Venus has a beautiful name and is the second planet from the Sun. It’s terribly hot—even hotter than Mercury—and its atmosphere is extremely poisonous. It’s the second-brightest natural object in the night sky after the Moon

REFERENCES

- AUTHOR (YEAR). *Title of the publication*. Publisher
- AUTHOR (YEAR). *Title of the publication*. Publisher
- AUTHOR (YEAR). *Title of the publication*. Publisher
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- AUTHOR (YEAR). *Title of the publication*. Publisher

OUR TEAM

Everett Jamison

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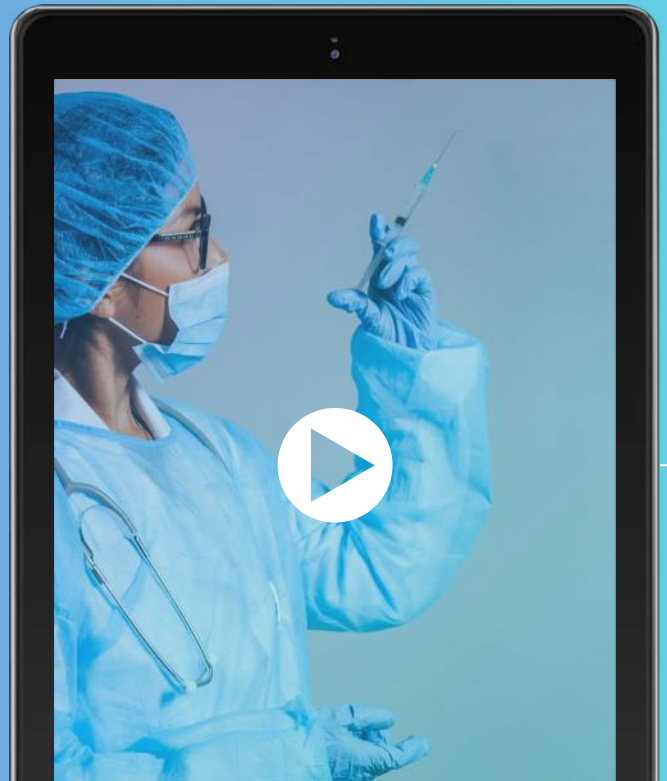
Laura Fisher

You can replace the image on the screen with your own

SNEAK PEEK



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