Plant Objects Detection Considering Environmental Noise

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Background

- In disaster sites or plants, there are many dangerous places. (e.g., debris, radiation)
  - High demand for automatic inspection by robots.
  - It needs automatic valve or lever operation.

Figure 1: Inclined course in World Robot Summit

Research purpose

- To automate this…
  - Automatic object detection is needed.

- Previous study … Detection with color-based segmentation [S.Keito, 2021]

However,

  - Affected environmental noise (e.g., light reflection)

Research purpose

On the other hand,

- Object detection with deep learning is effective to noises.[Y.Funayama et al, 2020]

- My goal is …
  - **Implement object detection effective to environmental noise with deep learning**

Proposed method

- There are no learning data of valve or lever.
  - We create the learning data.

1. Take image of object.
   - Take for each angle.
     - 0^o, $\pm 30^o$, $\pm 60^o$, $\pm 90^o$

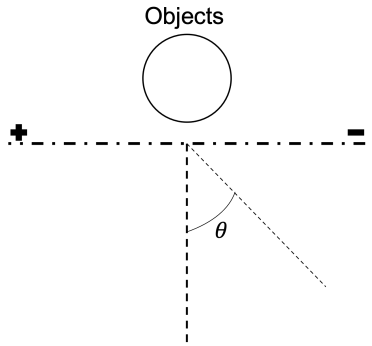


Figure 2: How to measure degree of object

2. Argument the images with adding noise.
   - Add noise and change the scale.
   - OpenCV is used for argumentation.

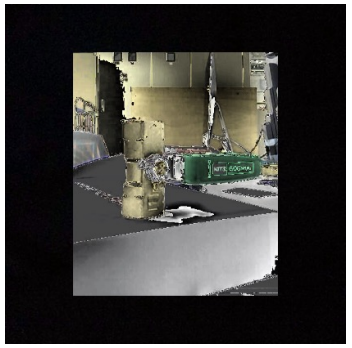


Figure 3: Example of argumentation

Proposed method

3. Classify and learn to DNN

- Darknet / YOLOv3 is used.
- Total images is 65,000 and learning time is 9.5 hours.

Table 1: Classification of YOLO learning

valve / lever degree	class
[-90, -80)	valve_-90 / lever_-90
[-80, -50)	valve_-60 / lever_-60
[-50, -20)	valve_-30 / lever_-30
[-20, 20)	valve_0 / lever_0
[20, 50)	valve_30 / lever_30
[50, 80)	valve_60 / lever_60
[80, 90]	valve_90 / lever_90

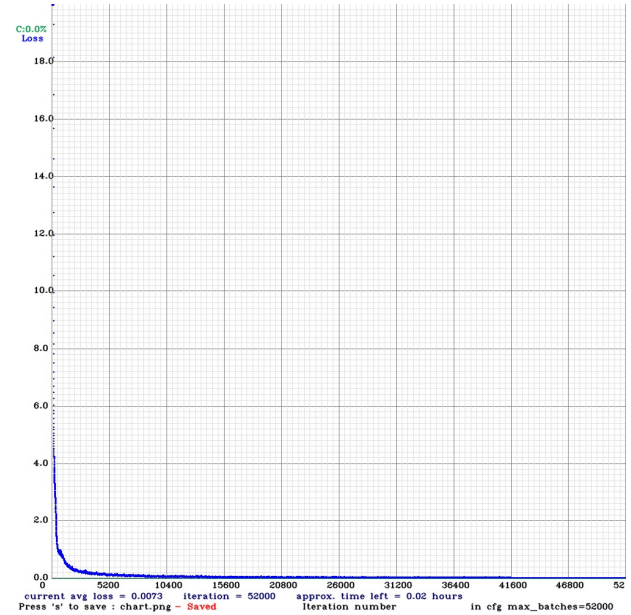


Figure 4: Relation between accuracy and loss

Verification of experiment

- Prepare other background's image and collect the result of detection.

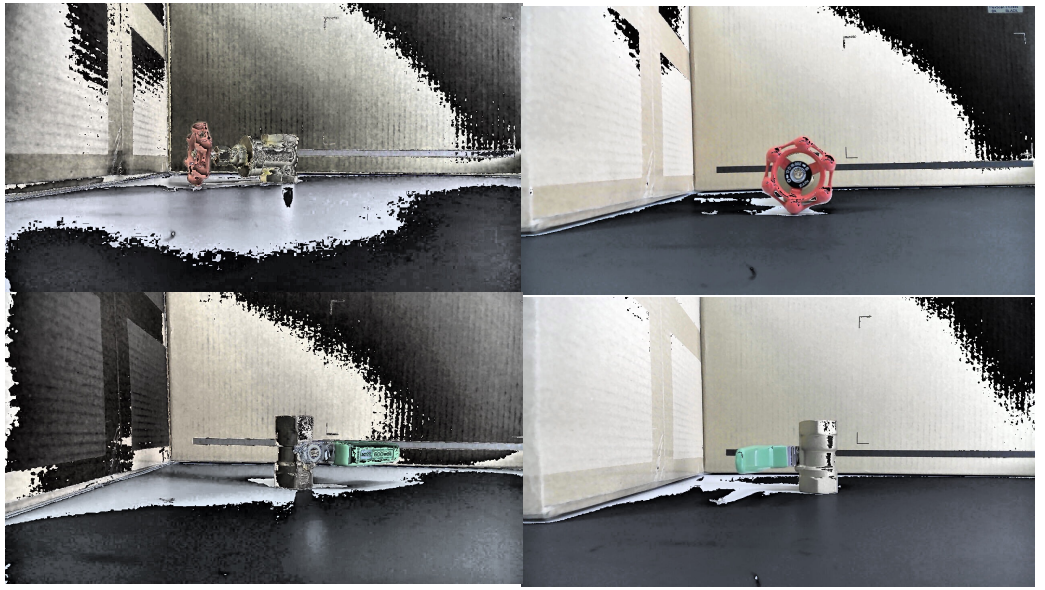


Figure 5: Example of images used in verification

Verification of experiment

- Evaluations

1. Detect 30 image per each angles.

2. Collect the result.
   If nothing is detected, count it as “None”.

3. Summarize to tables.

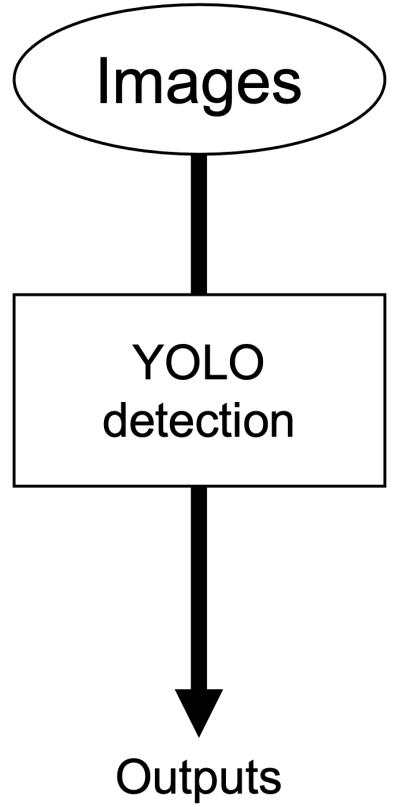


Figure 6: Flow of verification

Expected degree
Nearest degree
Opposite degree

Table 2.1: Detection result of lever

lever		Detection result							
		90	60	30	0	-30	-60	-90	NONE
Input	90	15	0	0	0	0	0	0	15
	60	28	0	0	0	0	0	0	2
	30	0	0	0	3	27	0	0	0
	0	0	0	0	30	0	0	0	0
	-30	0	0	0	0	25	0	0	5
	-60	0	0	0	0	0	1	0	29
	-90	11	0	0	0	11	0	4	4

Expected degree
Nearest degree
Opposite degree

Table 2.2: Detection result of valve

valve		Detection result							
		90	60	30	0	-30	-60	-90	NONE
Input	90	29	0	0	0	0	0	1	0
	60	0	30	0	0	0	0	0	0
	30	0	0	0	0	30	0	0	0
	0	0	0	0	30	0	0	0	0
	-30	0	0	0	0	30	0	0	0
	-60	8	2	0	0	0	0	0	20
	-90	4	0	0	0	0	0	15	11

Discussion

Results show…

- High accuracy almost whole degree.

- It could not discriminate the orientation of right or left
  - lever or valve = 30^{o}, lever = -90^{o}

- There are a lot of None
  - lever = 90^{o}, -60^{o}, valve = -60^{o}, -90^{o}

Additional experiment

- Only YOLO, it could not determine the orientation.
- Previous study… Place QR code to determine the orientation[G.Pitteri et al, 2020]
  - There is no QR code in real situation.

↓ To improve,

- Combine YOLO and ResNet detection.
  - Object detection … YOLO
  - Orientation detection … ResNet

Additional experiment

- Classify images used in previous experiment and learning YOLO and finetuned ResNet50 pretrained ImageNet.

Table 3.1: Classification of YOLO learning

valve / lever degree		class
[0, 20)	[-20, 0)	valve_0 / lever_0
[20, 50)	[-50, -20)	valve_30 / lever_30
[50, 80)	[-80, -50)	valve_60 / lever_60
[80, 90]	[-90, -80]	valve_90 / lever_90

Table 3.2: Classification of ResNet learning for levers

lever degree	class
[-90, 0]	left
[0, 90]	right

Table 3.3: Classification of ResNet learning for valves

valve degree	class
[-90, 0]	left
[0, 90]	right

Additional experiment

- The total image number is 14,000.
- The learning time is 4.1 hours for YOLO

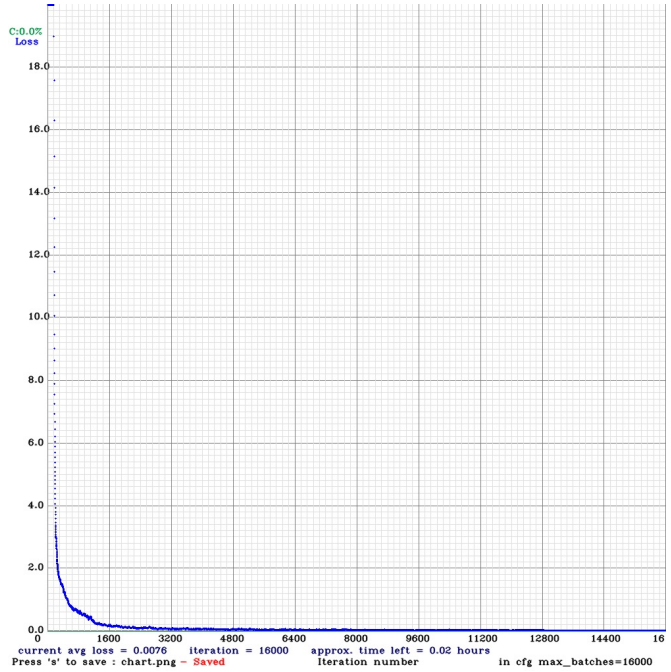


Figure 7: Relation between accuracy and loss in Yolo

Additional experiment

- The total image number is 6,000 per training for ResNet
- The learning time is 30 minutes per training.

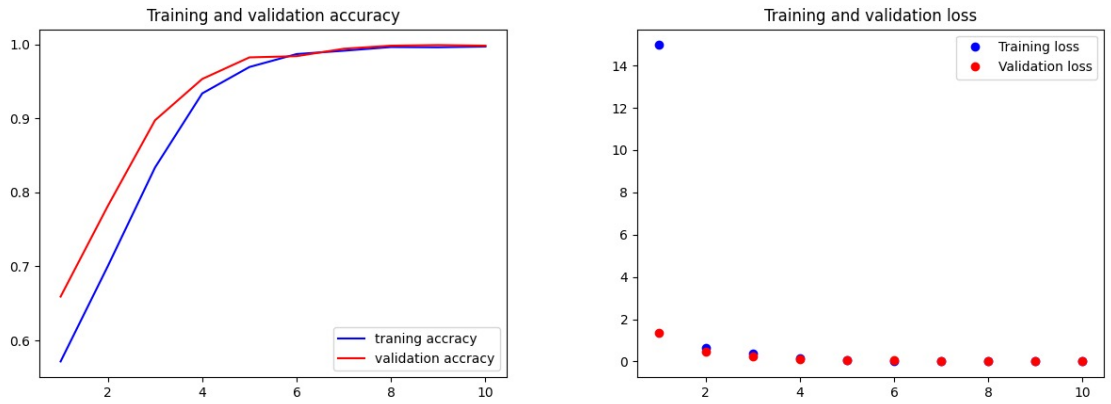


Figure 8.1: Relation between accuracy or loss of ResNet in lever training

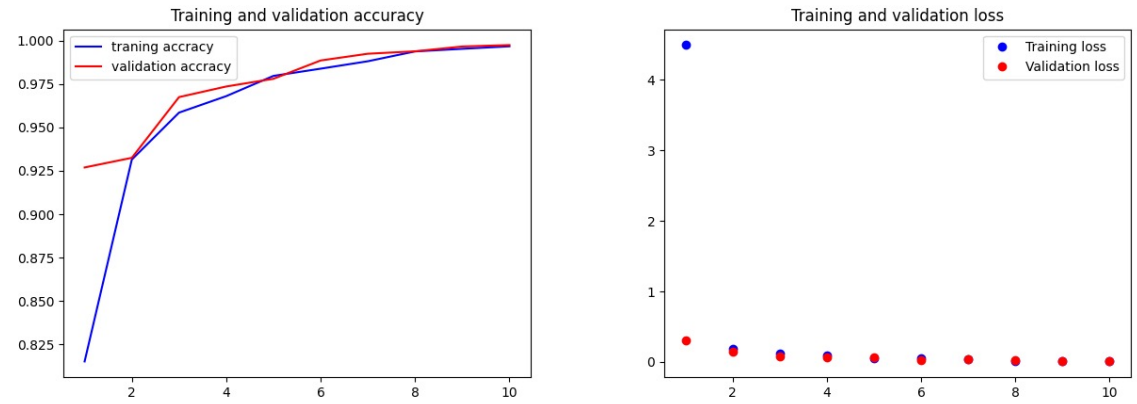


Figure 8.2: Relation between accuracy or loss of ResNet in valve training

Evaluations

- Evaluations

1. Detect 30 image per each angles.

2. Collect the result.
   If nothing is detected, count it as “None”.

3. Summarize to tables.

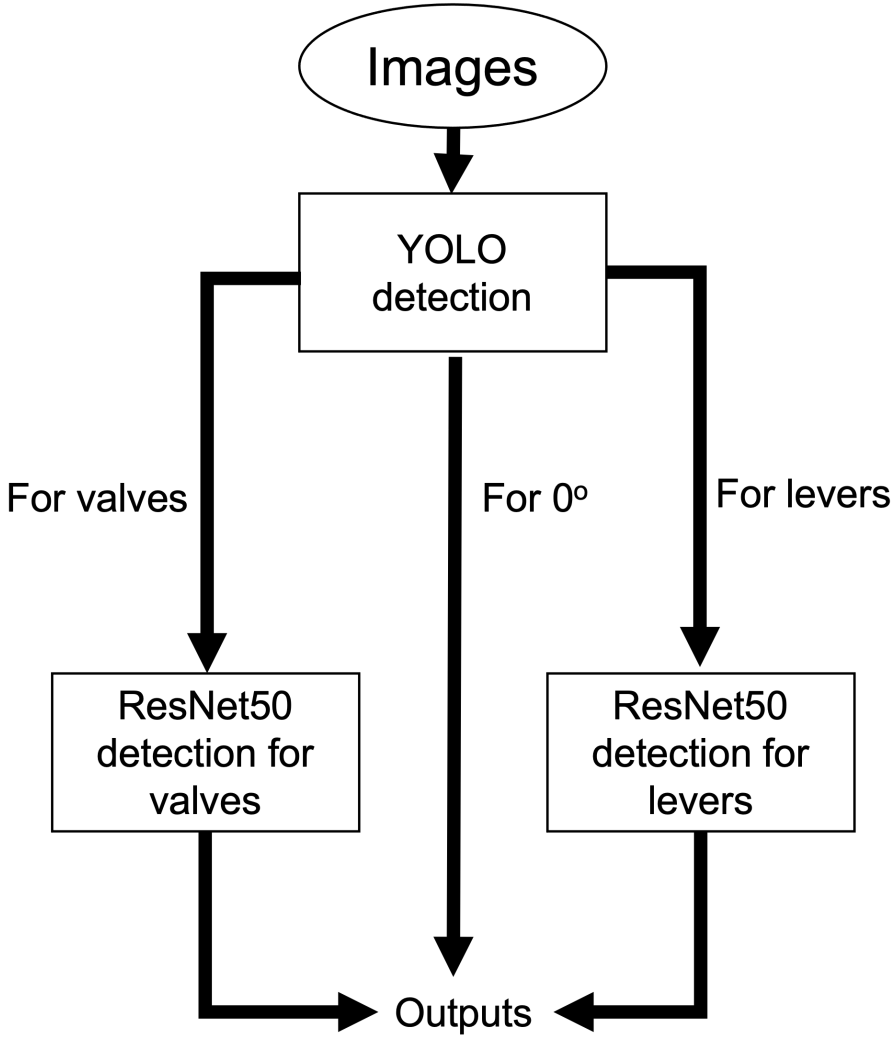


Figure 9: Flow of verification

Expected degree
Nearest degree
Opposite degree

Table 4.1: Detection result of lever

lever			YOLO detection						ResNet detection	
			90	60	30	0	NONE		left (-)	right (+)
Input	right	90	30	0	0	0	0		4	26
		60	0	30	0	0	0		0	30
		30	0	0	30	0	0		0	30
		0	0	0	0	6	24	0		-	-
	left	-30	0	0	30	0	0		28	2
		-60	0	30	0	0	0		30	0
		-90	0	0	15	15	0		30	0

Expected degree
Nearest degree
Opposite degree

Table 4.2: Detection result of valve

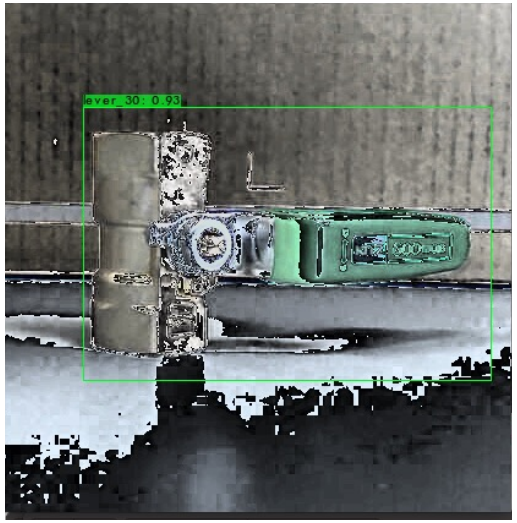
valve			YOLO detection						ResNet detection	
			90	60	30	0	NONE		left (-)	right (+)
Input	right	90	30	0	0	0	0		5	25
		60	0	30	0	0	0		0	30
		30	0	0	30	0	0		24	6
		0	0	0	0	30	0		-	-
	left	-30	0	0	30	0	0		11	19
		-60	28	0	0	0	2		26	4
		-90	30	0	0	0	0		15	15

Additional discussion

- Through experiment…
  - The number of None decrease.
  - Accuracy of detection increase.
  - High accuracy of orientation detection.

On the other hand,

  - Some detection result is not sufficient.
    - Object: lever = -90°, valve = -60°
    - Orientation: valve = 30°, all negative degree



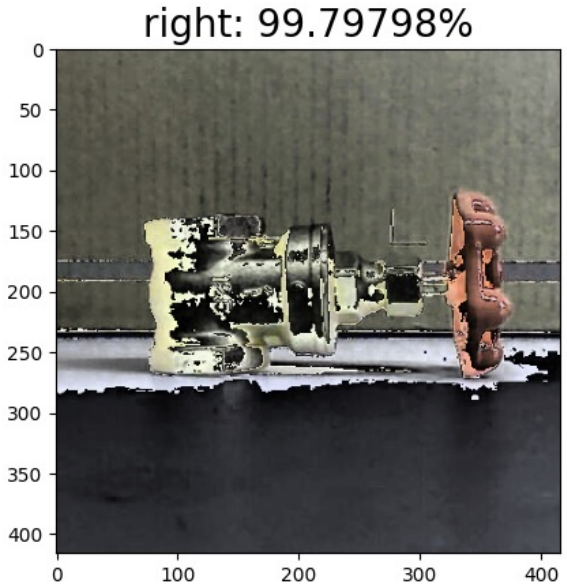


Figure 10: Example of detection result

Conclusion and future work

- We attempted to implement object detection using two deep learning model.
  - Realize high accuracy of detection of object and orientation.
  - There is still room to improve detections.

- In the future…
  - Improve detections
  - Implement in our disaster robot Spider2020