Project for Enhancement of Engineering Higher Education in Myanmar

JICA EEHE Project (FY 2019)

Mandalay Technological University

# A DEEP NEURAL NETWORK BASED HUMAN FOLLOWING ROBOT WITH FUZZY CONTROL

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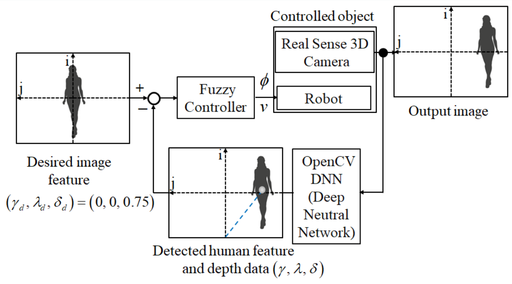
**This research built a human following robot system based on a deep neural network algorithm in which a fuzzy controller controls the robot velocity and keeps the target person in the centre position of robot's view. Firstly, the system utilized the deep neural network algorithm to detect a target person in the video sequence captured from a real sense D435 depth camera mounted on the mobile robot. Then, the system calculated the centre position of the target human and acquires the depth value of target human. Finally, these data are used as the inputs of a fuzzy controller to control the velocity and steering of the robot during tracking. Especially, the velocity of the robot which is normally limited as a constant in most existing human following robot systems is controlled by a fuzzy controller in this research.**

## Problem Setting




$\gamma, \lambda$ = the slope and intercept of the desired target line, $v$ = the velocity of the robot, $\phi$ = the steering angle of the robot, $x$, $y$, $\theta$ = the position and orientation of the robot

## Human Detection Using a Deep Neural Network

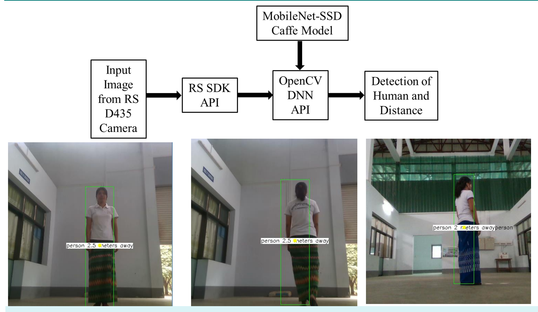
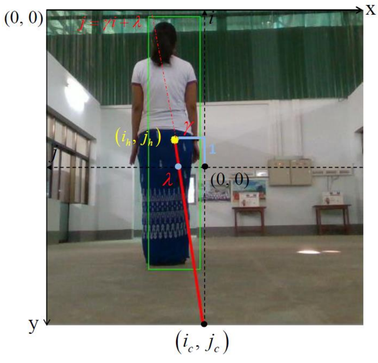



**Figure 1: Detected human (a) front view, (b) back view, (c) side view**

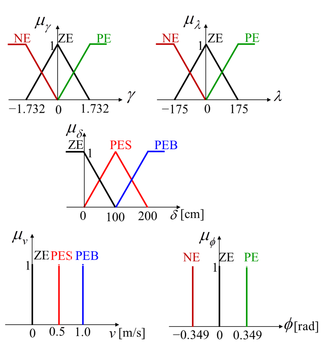
## Generation of Target Line in an Image




$$\gamma = \frac{-j_h}{i_c - i_h}$$

$$\lambda = \frac{i_c j_h - i_h}{i_c - i_h}$$

## Fuzzy Logic Control




| No. | $\gamma$ | $\lambda$ | $\phi$ |
|---|---|---|---|
| 1 | NE | NE | NE |
| 2 | | ZE | NE |
| 3 | | PE | ZE |
| 4 | ZE | NE | NE |
| 5 | | ZE | ZE |
| 6 | | PE | PE |
| 7 | PE | NE | ZE |
| 8 | | ZE | PE |
| 9 | | PE | PE |

| No. | $\delta$ | $\phi$ | $v$ |
|---|---|---|---|
| 1 | ZE | | ZE |
| 2 | PES | | PES |
| 3 | PEB | NE | PES |
| 4 | | ZE | PEB |
| 5 | | PE | PES |

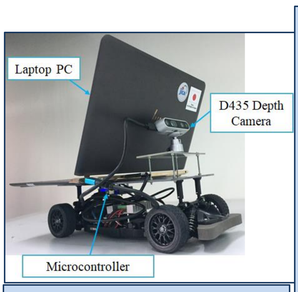



**Figure 3: Experimental Robot**

- D435 Depth Camera
  - Look forward
- Laptop PC
  - Image processing
  - Send control inputs to the microcontroller
- Microcontroller
  - Control the steering angle and velocity
- Mobile Robot
  - Utilize the modified remote control car
  - Utilize one DC motor for velocity control and one servo motor for steering angle control

$$v = \frac{0 \cdot h_{s,\mathrm{ZE}} + 0.5 \cdot h_{s,\mathrm{PES}} + 1.0 \cdot h_{s,\mathrm{PEB}}}{h_{s,\mathrm{ZE}} + h_{s,\mathrm{PES}} + h_{s,\mathrm{PEB}}}$$

$$\phi = \frac{-0.349 \cdot h_{\phi,\mathrm{NE}} + 0 \cdot h_{\phi,\mathrm{ZE}} + 0.349 \cdot h_{\phi,\mathrm{PE}}}{h_{\phi,\mathrm{NE}} + h_{\phi,\mathrm{ZE}} + h_{\phi,\mathrm{PE}}}$$

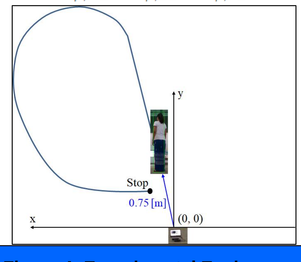



**Figure 4: Experimental Environment**

## Experimental Results for Human Following Robot System

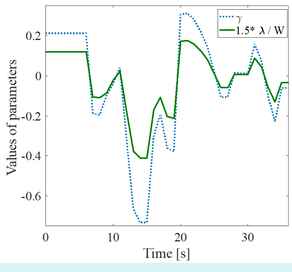



**Figure 5: Amount of parameters, $\gamma$ and $\lambda$, of human tracking**

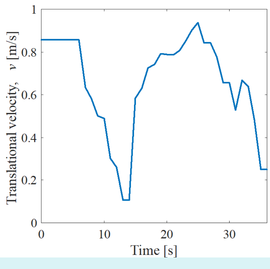



**Figure 6: Amount of the robot velocity**

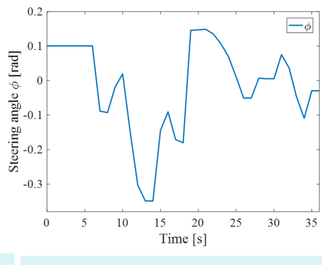



**Figure 7: Amount of the steering angle value**

## Considerations

**Adding the velocity control in this human tracking system improved the turning performing of the robot. Especially, the reduction of velocity can protect the robot from failure tracking the human during the curvature turning. The robot followed the target human well, even if the velocity of human, moving on a straightforward, accelerated. On the other hand, the robot failed to track the human when the human body turned in a corner suddenly. It is attributed to the fact that the OpenCV DNN API utilized in this research can detect the human at least 0.75 [m] away from the 3D camera mounted on the mobile robot.**