A Mobile robot controlled by hand gestures using ToF sensor

Sony SS Report 2022-02-28

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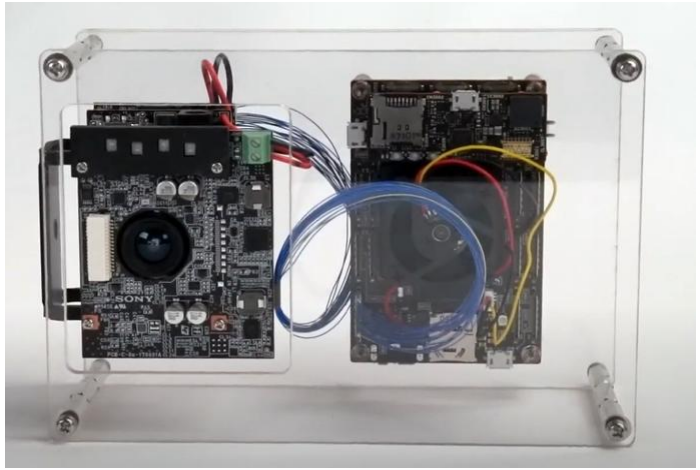
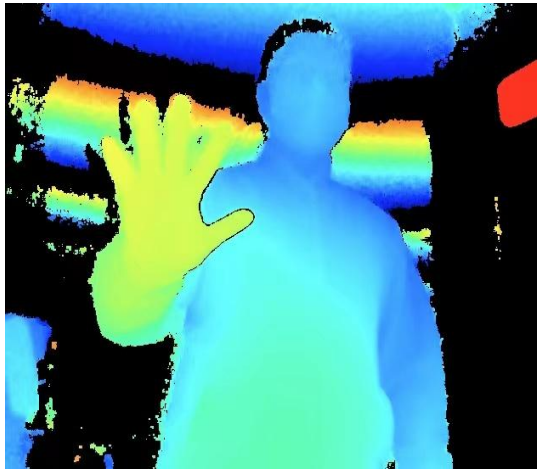
Contents

What is VSP

- Full Name: Visual Sensing Processor
- Function: VSP can help build high-speed, low-power applications
- ToF Module FPS stream point cloud and depth data
- We use ROS-bridge API_Publish Point cloud data
- This picture shows the result of using opencv to visualize depth image.



Time of Flight Camera Module



Depth image

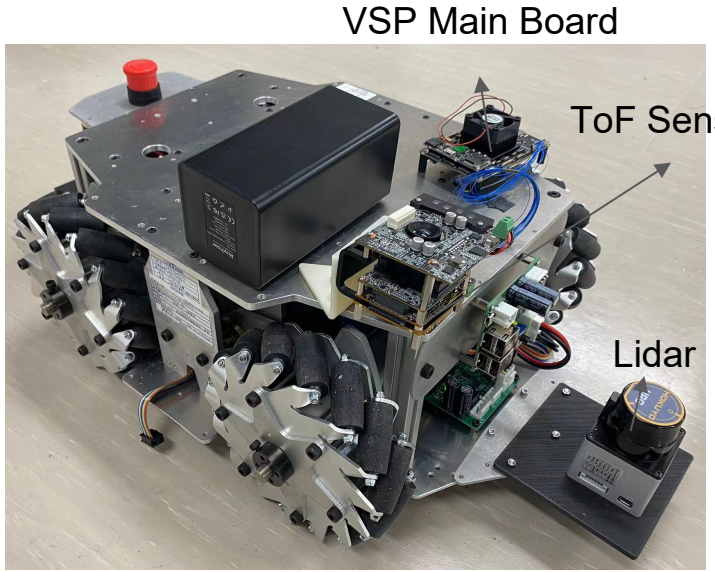
Motivation: A Mobile Robot Controlled by Hand Gestures

- **INDUSTRY**: Lighten the burden of workers and try to make some progress in intelligent manufacturing by introducing systems controlled by hand gestures
- **PUBLIC HEALTH**: Create a system that can reduce direct contact between people & people and people & machines by using hand gesture control
- **ACCOMPANIMENT:** Wish for creating a robot which is capable of interacting with humans

Reference: https://www.bbc.com/news/business-54232563
https://www.interactanalysis.com/20000-autonomous-mobile-robots-shipped-in-2018/
https://www.terabee.com/how-gesture-control-mitigates-hygiene-hazards-smart-buildings/

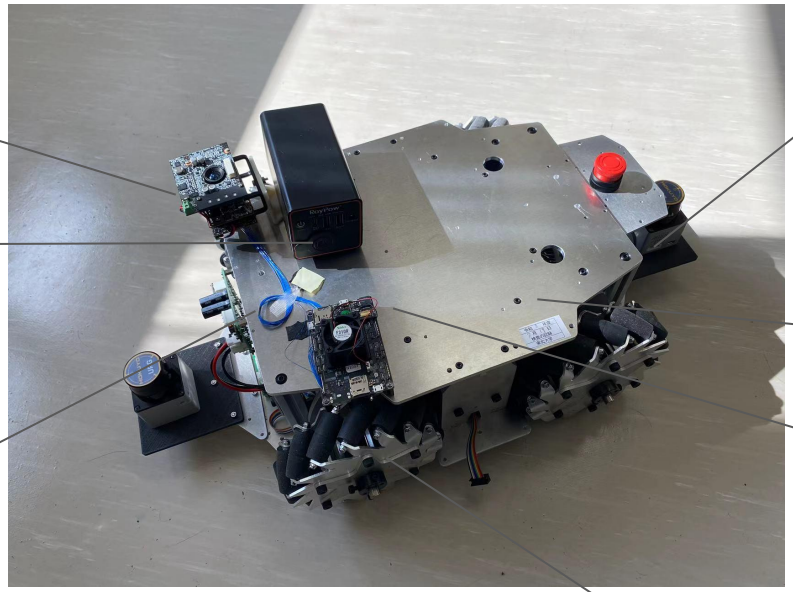
Goal : A Mobile Robot Controlled by Hand Gestures

- **Robot Design**: Design the configuration of the system (sensor and lidar attachment)
- **Hand Recognition**: Recognize our hands and label the joints and fingertips with dots
- **Hand Gesture Control**: Enable the robot to move along with our hand (move the robot with the commands given by hand gestures)
- **Obstacle Avoidance**: Even when there are obstacles around, we can still move the robot safely and smoothly.

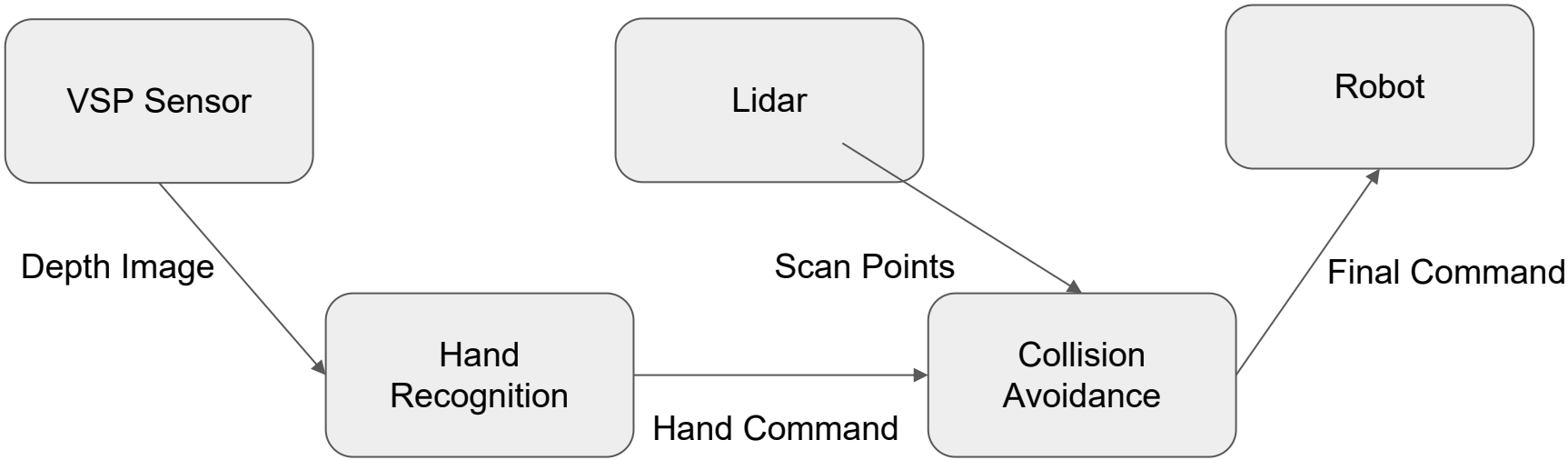


Mobile Robot with ToF Sensor and 2 lidars attached

Overview of the Robot Design

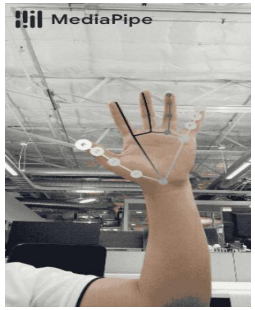


System Integration

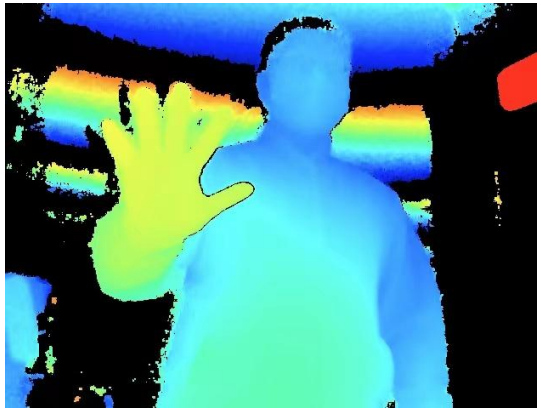


Depth Image: Images that we get from the ToF sensor.
Hand Command: Command that comes out after being processed in the Hand Recognition Node
Scan Points: Point Cloud information we get from the lidar
Final Command: Command that comes out after being processed in the Collision Avoidance Node

Hand Recognition

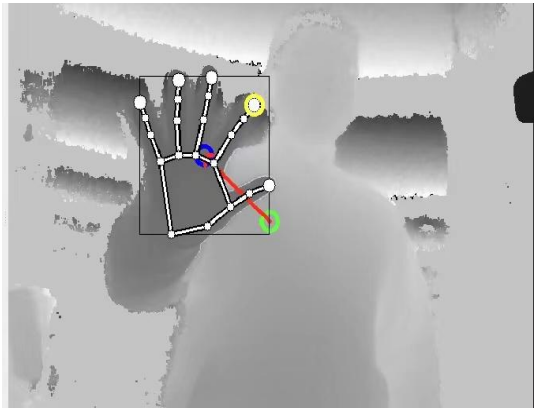


- Hand recognition is performed using MediaPipe.
- Process of Transforming the Image
  Depth image 👉RGB Image 👉Hand recognition.



Depth Image

RGB Image



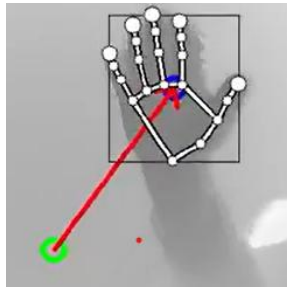
Hand Recognition Image

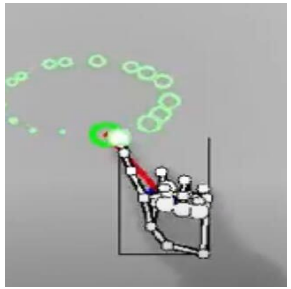
Reference of the library: https://google.github.io/mediapipe/solutions/hands.html

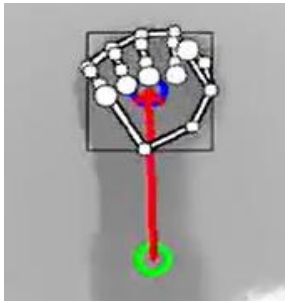
Hand Gesture Control

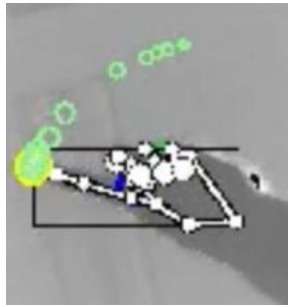
Several Hand Gestures are able to be recognized through model training:

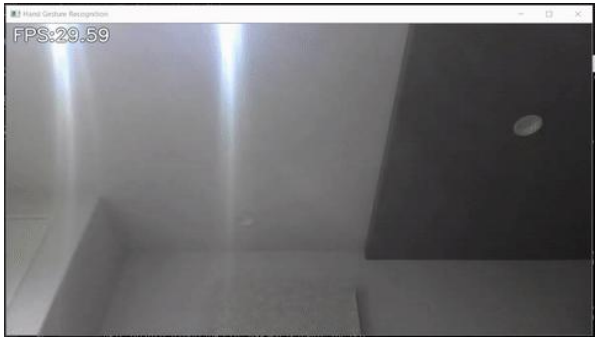
- **With your hand open and moving hands in different directions**
  → You can oparate the robot instinctively
- **With your hand closed or hand disappeared from the screen**
  → The robot stops moving when it recognises the gesture
- **Move your fingers clockwise or counter-clockwise.**
  → You can freely rotate the robot on the spot.
- **Tilt your fingers to different angles**
  → You can rotate the robot to any angle you want and move the robot in the direction of your fingertips











Reference of the library: https://github.com/Kazuhito00/hand-gesture-recognition-using-mediapipe

Robot Linear Movement

- How to get the velocity command?

— Locate the center of the image and our hand, draw a vector between two points

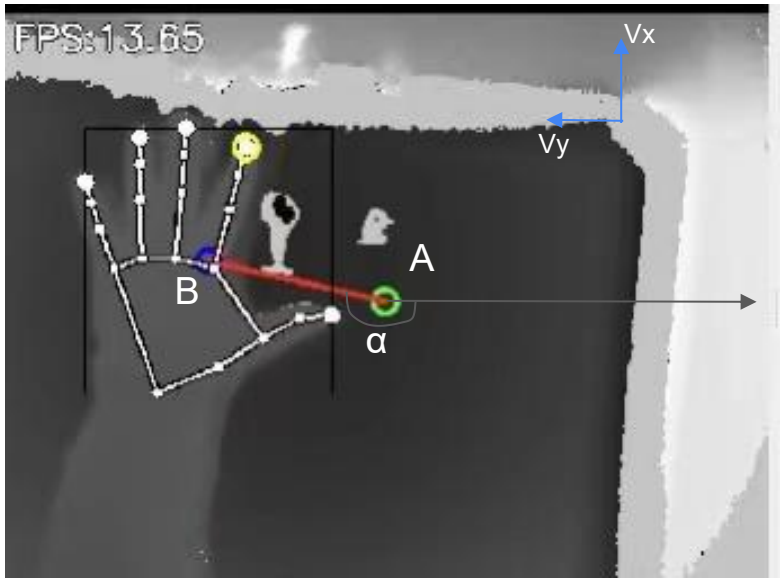
— Figure out the length |AB| and angle α of the vector

— Calculate the velocity of movement of our hand and it direction

($V_x = -|AB|\sin\alpha$; $V_y = -|AB|\cos\alpha$)

— Normalize the velocity range of our hand to obtain the velocity range (V_x' and V_y') of the robot [0,1]

($V_x' = -(|AB|\sin\alpha)/N$; $V_y' = -(|AB|\cos\alpha)/N$)



Center of the Hand : A
Center of the Screen: B
Angle of the Vector: α

Robot Angular Movement

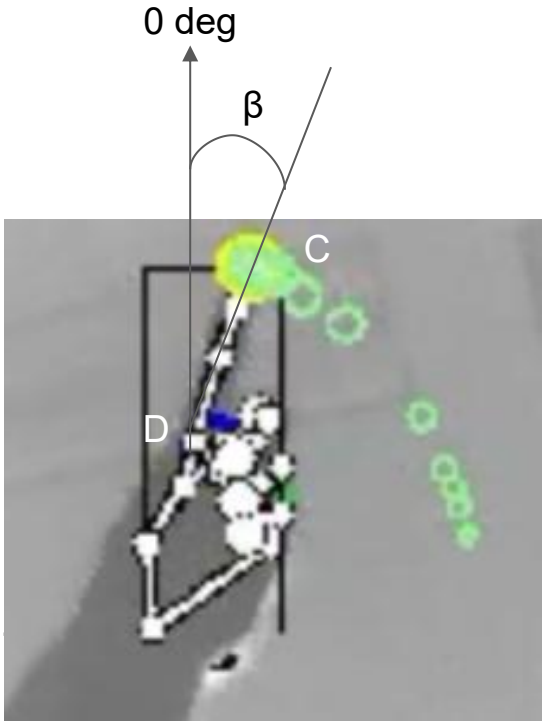
- How to get the angular turning command?
    - Locate the fingertip, the base of the index finger
        - Obtain the vector F from point D to C.

—Calculate the angle β of the vector. ($V_z = \beta$)

B is the angle used to indicate the angular velocity of

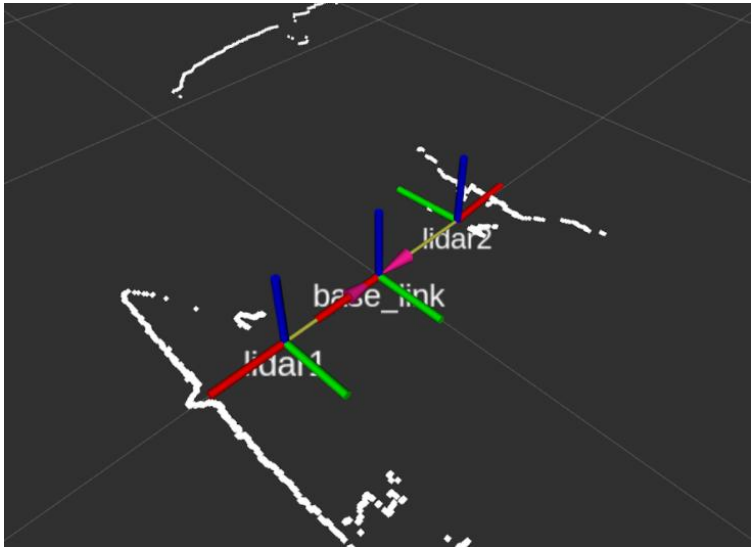
—If we tilt our finger, the robot will rotate at the same angle.

→The larger the angle, the faster the robot will rotate.

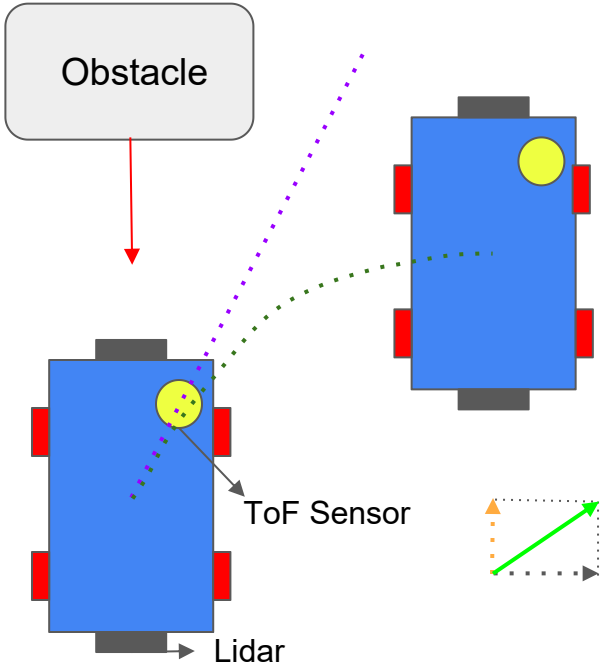


The fingertip: C
The base of the index finger: D
Angle of the Vector: β

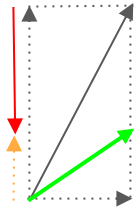
Obstacle Avoidance



Point Cloud information received from the lidars



Black Arrow: Original velocity given by hand commands
Red Arrow: Repulsive velocity given by the lidar commands
Green Arrow: Resulting velocity after processing through the obstacle avoidance node



Purple Dotted Line: Trajectory without processing through the obstacle avoidance node
Green Dotted Line: Trajectory after processing through the obstacle avoidance node

Experimentation (circular path)

In this video demo, we show that we can control the movement of the robot with our hands and the vector that links the center of hand and the center of the screen leads the mobile robot.

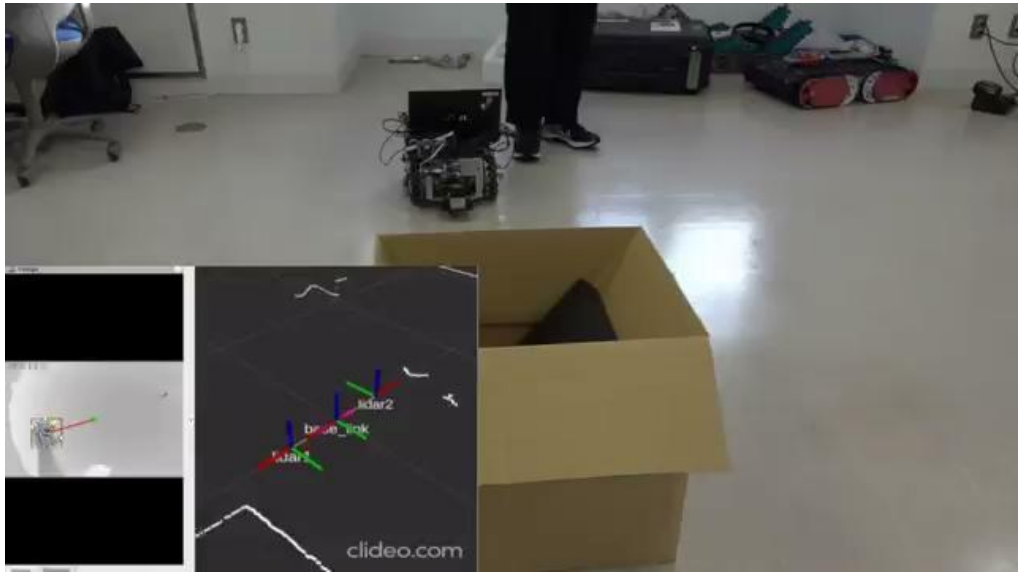
Experimentation
(clockwise turning & counter-clockwise turning)

In this video demo, we show that we can achieve clockwise turning & counter-clockwise turning by moving the fingertips in clockwise or counterclockwise direction.

Experimentation
(Spinning your finger to turn the robot)

In this video demo, we show that we can spin our finger to turn the the direction of the head of our mobile robot.

Experimentation(Obstacle Avoidance)



In this video demo, we show that our robot can escape from the obstacle coming towards it.

Experimentation(In the dark)

In this video demo, we show that we can achieve hand gesture recognition and control the movement of the robot even in a dark situation.

Probable Applications of our System

- Scenario 1: Contactless delivery in a warehouse
- Scenario 2: Transferring books in libraries using mobile robots
- Scenario 3: Autonomous tennis ball collector

Scenario 1

Scenario 2

Scenario 3

Reference: https://www.automate.org/blogs/robot-safety-standards-for-industrial-mobile-robots
https://towardsdatascience.com/the-little-robot-that-lived-at-the-library-90431f34ae2c
https://www.tuvie.com/tennibot-autonomous-tennis-ball-collector-robot-allows-players-and-coaches-to-use-their-time-efficiently/

Thank you for your attention!