ICIEV18, Kitakyushu, Japan

Raspberry Pi for Computer Vision

Case: Vein Visualization

PiLab Tutorial

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- **Major:**
  Electrical & Electronic Engineering
- **Lab:**
  Information Processing Lab
- **Field of Study:**
  Biomedical Informatics.

Takumi Kitajima

- Graduate Student @ Mie University.
- **Major:**

  Public Health, Epidemiology
  (Prev.) Electrical & Electronic Engineering.

- **Lab:**

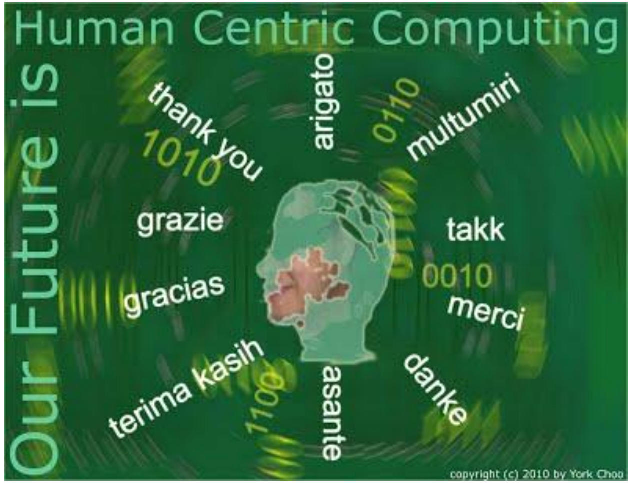
  Dept. of Public Health and Occupational Medicine

- **Field of Study:**

  Public Health, Epidemiology

Atsushi Inoue

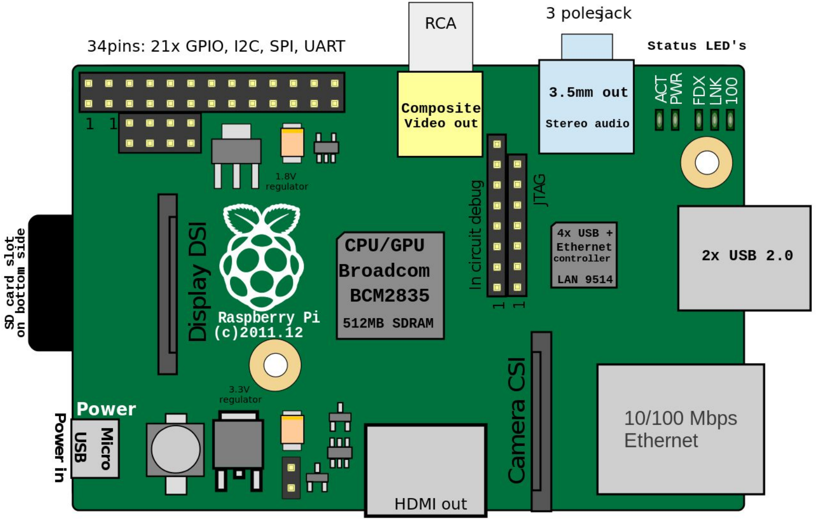
- Human Centric Computing→Perceptual Information Processing
  - **Perceptual Logic Programming (AI platform) & Machine Learning**
  - **Fuzzy Logic**
- Intelligent Informatics Initiative (I3)
  - Digital Entrepreneurship & E-Business
  - Information Security Management
  - Medical Informatics
- PiLab@EWU
  - Raspberry Pi, LINUX

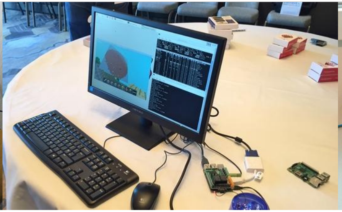
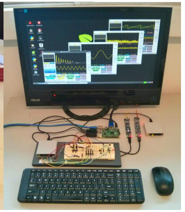


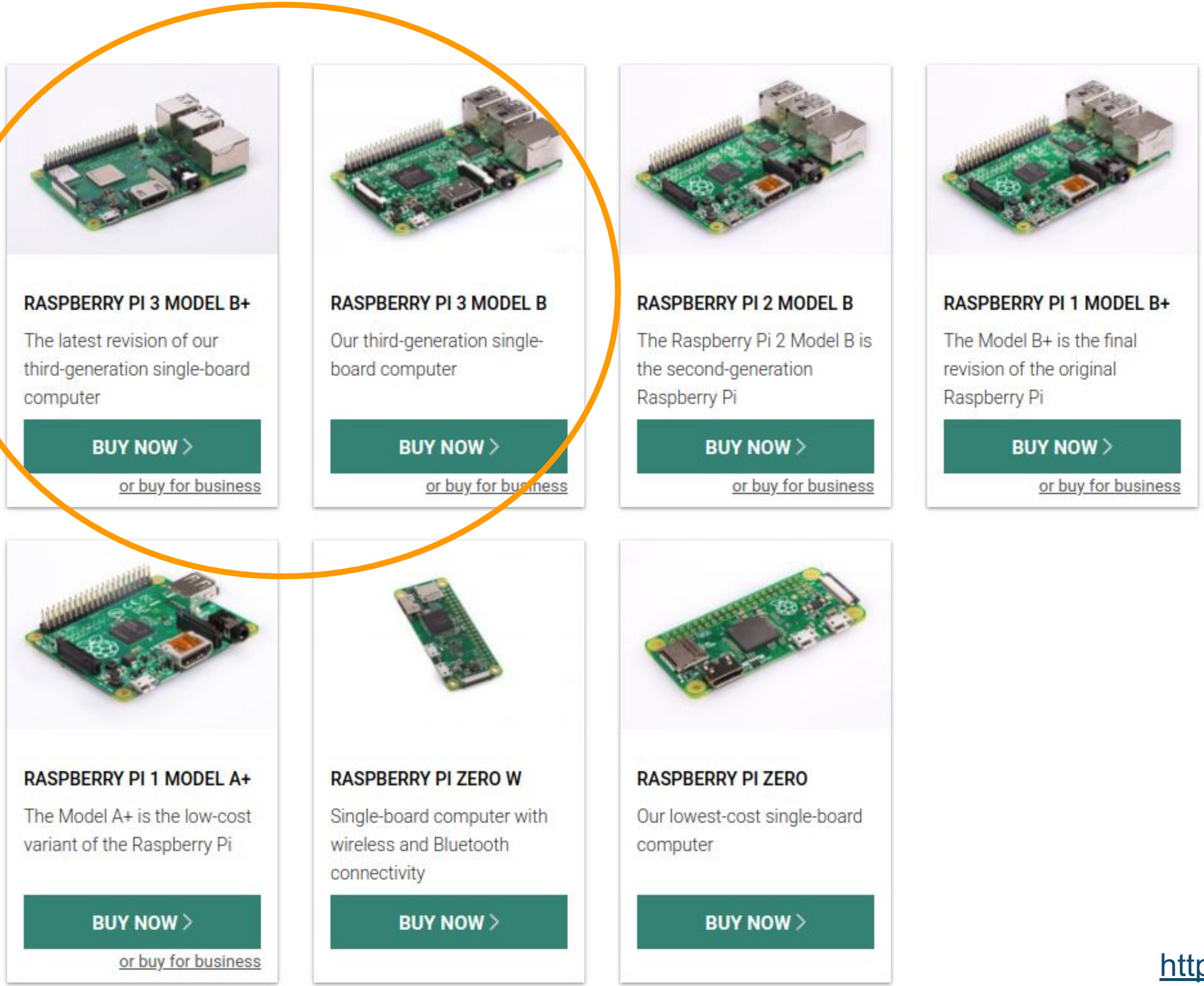
Web: http://www.inoueatsushi.net/

Raspberry Pi

- Open source
- Small and lean
- Low cost
- Versatile
- Similar CPU as Android and iPhone
- Easy to use





RASPBERRY PI 3 MODEL B+

The latest revision of our third-generation single-board computer

BUY NOW >

or buy for business

RASPBERRY PI 3 MODEL B

Our third-generation single-board computer

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RASPBERRY PI 2 MODEL B

The Raspberry Pi 2 Model B is the second-generation Raspberry Pi

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RASPBERRY PI 1 MODEL B+

The Model B+ is the final revision of the original Raspberry Pi

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RASPBERRY PI 1 MODEL A+

The Model A+ is the low-cost variant of the Raspberry Pi

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RASPBERRY PI ZERO W

Single-board computer with wireless and Bluetooth connectivity

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RASPBERRY PI ZERO

Our lowest-cost single-board computer

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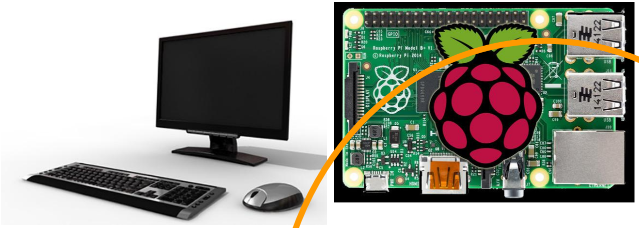
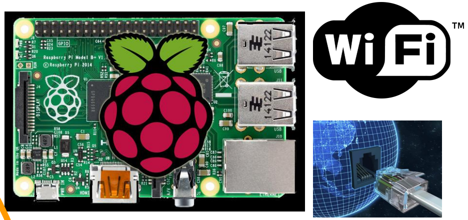
https://www.raspberrypi.org/products/

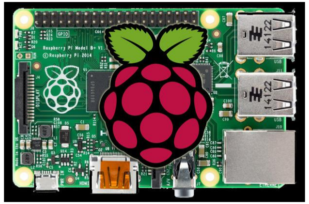
Raspberry Pi (LINUX) Networking & IoT @ iπLab



LINUX Workstation



Router, Hotspot



Database, WordPress, etc.

Clients (web, apps, etc.)

Sensor stations

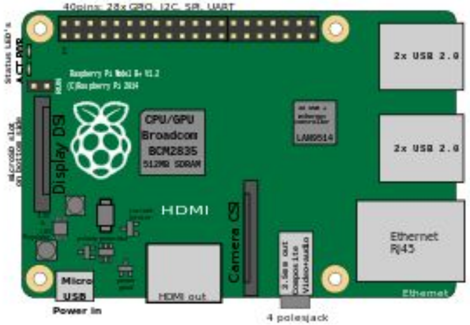
Networking

Servers (database, etc.)

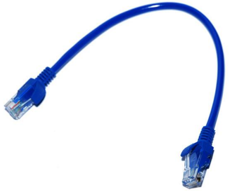
IoT stations

Sidenote: PiLab Setting for DIY -- a variation of headless Pi

Ras Pi System Disk
On micro SD card


40pins: 28x GPIO, I2C, SPI, UART
Status LED's ACT PWR
Raspberry Pi Model B+ V1.2
(C)Raspberry Pi 2014
CPU/GPU Broadcom BCM2835 512MB SDRAM
2x USB 2.0
2x USB 2.0
LAN9514
Display DSI
microSD slot on bottom side
HDMI
Camera CSI
Ethernet RJ45
Micro USB Power in
HDMI out
3.5mm out Composite Video+audio
4 polesjack
Ethernet

ICS connection via Ethernet



USB Ether adapter works
when no Ether ports.

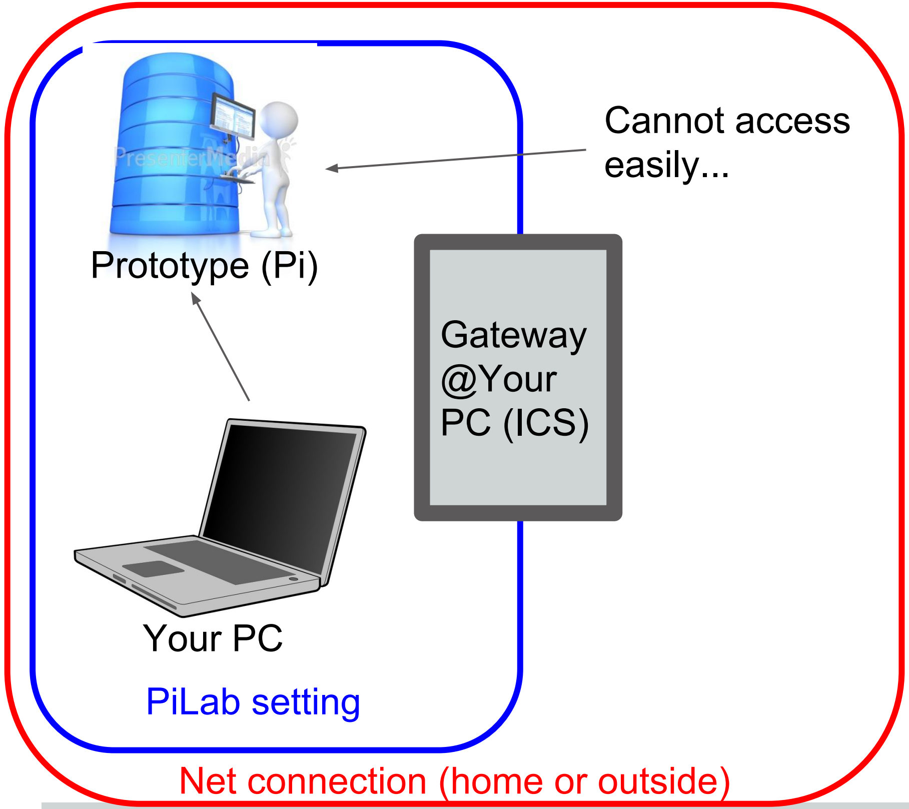
BYOL or cart laptop

Power from the laptop USB

Convenient to have
USB card reader &
USB memory stick

CLI: ssh on laptop + sshd on Pi
GUI: X server or RDP client on laptop + sshd and/or xrdp on Pi

Sidenote: Prototyping individually with high mobility



Prototype (Pi)

Cannot access easily...

Gateway @Your PC (ICS)

Your PC

PiLab setting

Net connection (home or outside)

[1] Download Raspbian OS image

Please start downloading the OS image for Raspberry Pi. It takes 1-30min (faster or slower depending on speed).

Raspbian Stretch With Desktop (with GUI)

ZIP -- 1.7GB (to be downloaded)

Unzip to extract .img file -- a few GB (to be extracted from the downloaded ZIP)

Note for PIXEL: unzipping a file >4GB has issues with an old unzipper. File Explore unfortunately cannot handle this. Use 7ZIP for Windows 7.

SD card imaging (vs file copying)

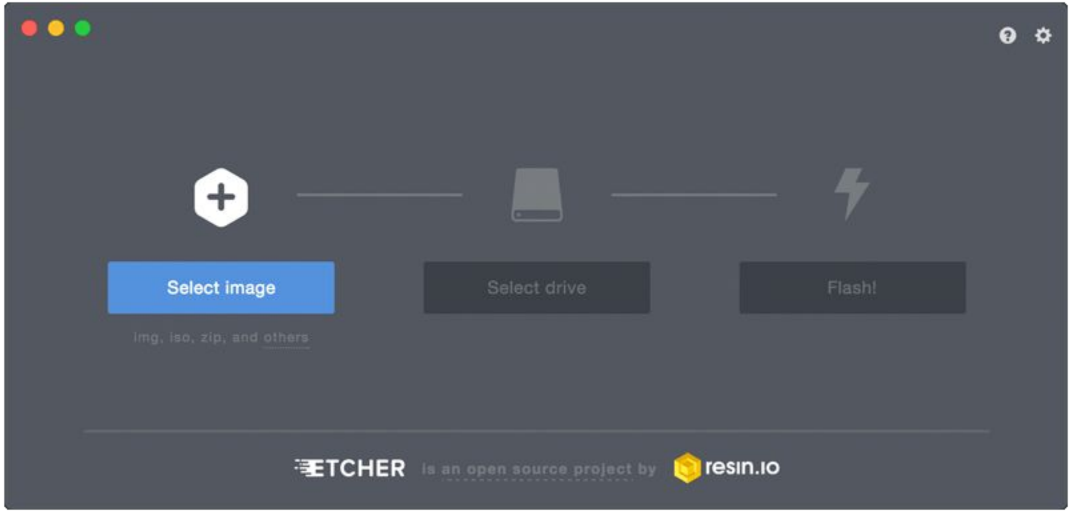
Imaging -- duplication of the entire drive/disk.

Sudo privilege is required.

Password needs to be entered in many cases.

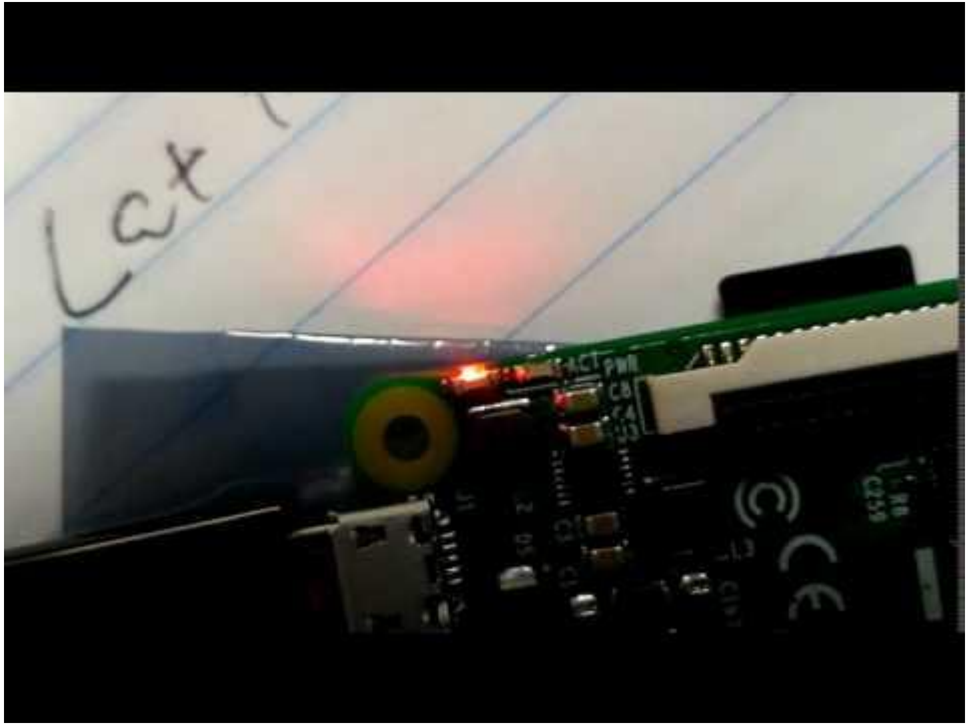
[2] SD card imaging: Etcher

Simply double click to execute Etcher (unzip is necessary for LINUX). NO INSTALLATION PROCESS.


Select image
img, iso, zip, and others
Select drive
Flash!
ETCHER is an open source project by resin.io

[5] Booting Raspberry Pi

- Remember: NO POWER switch on Pi.
  Plugging in and out the micro USB power cable.
- Standard procedure
  1. Insert the micro SD card
  2. Plug in the Ether cable to the laptop and the Pi.
  3. Plug in the micro USB power cable (to power on)
  4. Observe the red LED (power indicator)
     This should be steady.
  5. Observe the green LED (disk access indicator).
     This should be actively blinking.


Lat
ACT
PWR
C8
C4
U3

Raspbian OS Housekeeping

- Housekeeping <u>after installation</u>
  - ’**`raspi-config`**’ (clock, keyboard, overclocking, fs exp, etc.)
  - Update the OS
    - `sudo apt-get update`
    - `sudo apt-get upgrade -y`
    - `sudo apt-get autoremove -y`
    - `sudo apt-get clean`
  - Full upgrade (inplace of upgrade) -- takes longer
    - `sudo apt-get dist-upgrade -y`

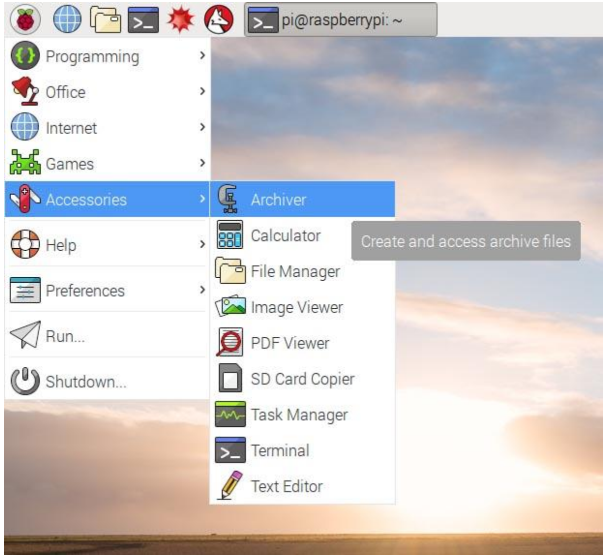
Update after the first installation may take very long -- over 1 hour easily.

Shutdown

- In Bash, SSH

```
sudo shutdown -h now
```

- On desktop, In RDP
  Go to the menu->Shutdown
  (Shutdown)



Reboot

- In Bash, SSH

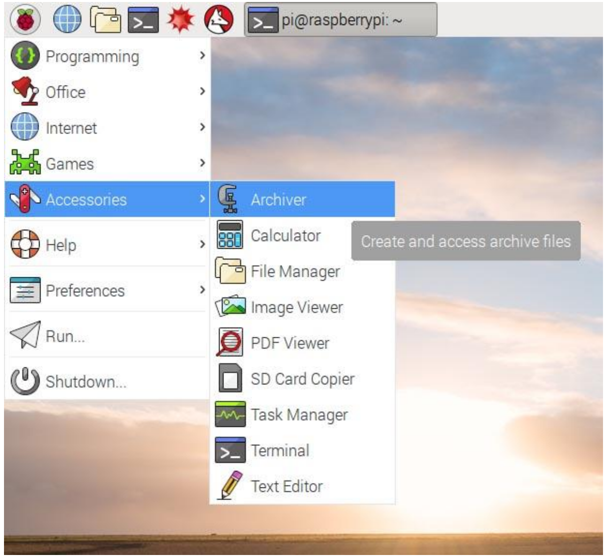
```
sudo shutdown -r now
```

OR

```
sudo reboot
```

- On desktop, In RDP

  Go to the menu->Shutdown (Reboot)



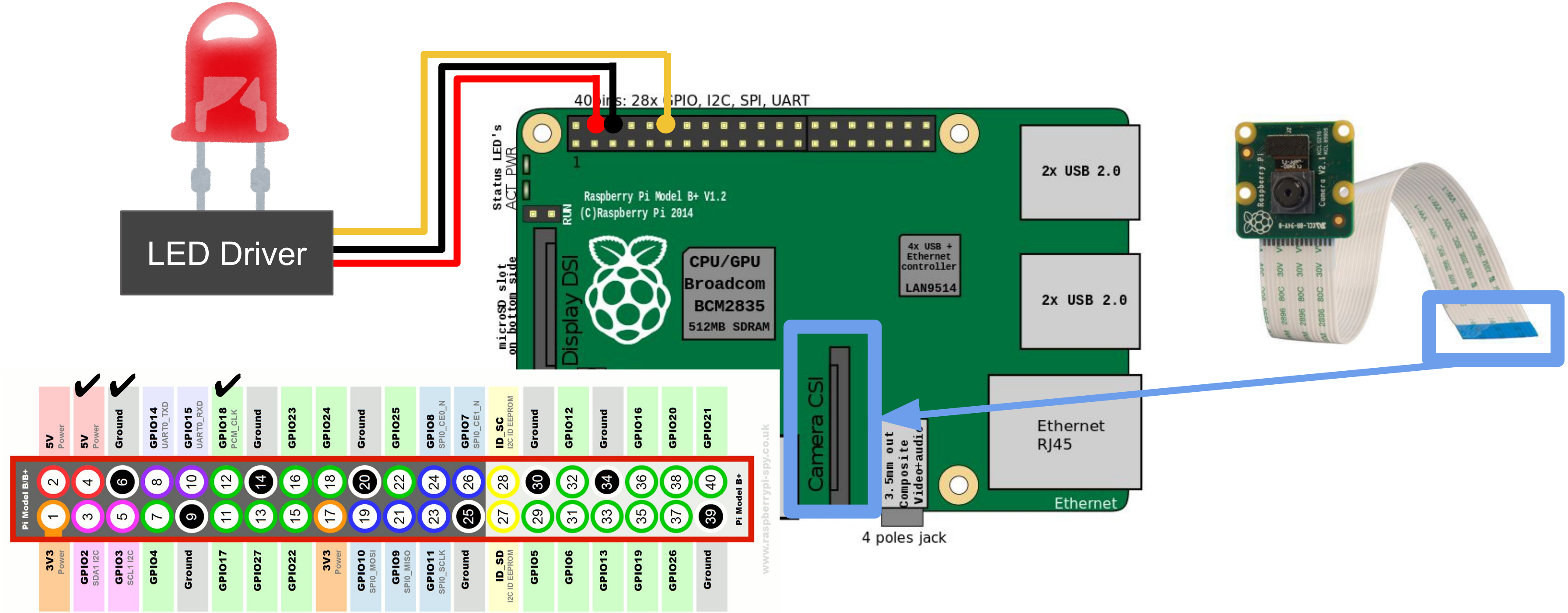
Raspbian is ready! Enjoy Pi!!

Follow task specific instructions from this point and on.

Image Processing

How to install & configure OpenCV on Raspberry Pi 3 Model B

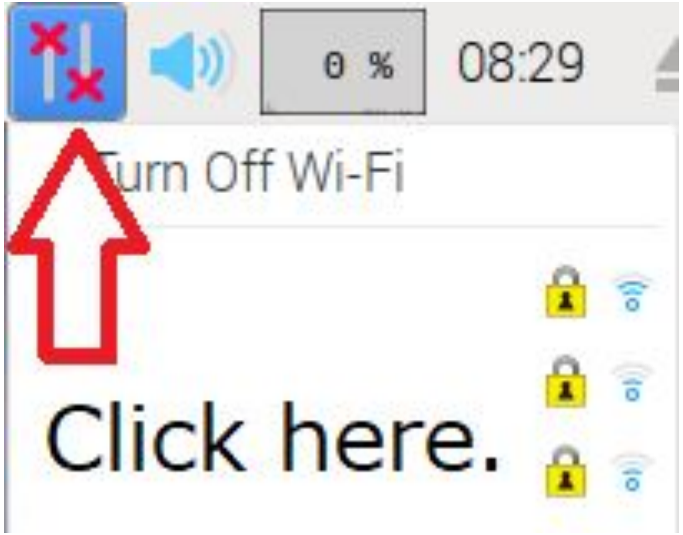
Connect Devices


LED Driver
40 pins: 28x GPIO, I2C, SPI, UART
1
Status LED's
ACT PWR
RUN
Raspberry Pi Model B+ V1.2
(C)Raspberry Pi 2014
microSD slot on bottom side
Display DSI
CPU/GPU Broadcom BCM2835 512MB SDRAM
4x USB + Ethernet controller LAN9514
2x USB 2.0
2x USB 2.0
Ethernet RJ45
Ethernet
Camera CSI
3.5mm out Composite Video+audio
4 poles jack
Pi Model B/B+
Pi Model B+
www.raspberrypi-spy.co.uk

	Pin	Name	Pin	Name	
	1	3V3 Power	2	5V Power	
	3	GPIO2 SDA1 I2C	4	5V Power	✓
	5	GPIO3 SCL1 I2C	6	Ground	✓
	7	GPIO4	8	GPIO14 UART0_TXD	
	9	Ground	10	GPIO15 UART0_RXD	
	11	GPIO17	12	GPIO18 PCM_CLK	✓
	13	GPIO27	14	Ground	
	15	GPIO22	16	GPIO23	
	17	3V3 Power	18	GPIO24	
	19	GPIO10 SPI0_MOSI	20	Ground	
	21	GPIO9 SPI0_MISO	22	GPIO25	
	23	GPIO11 SPI0_SCLK	24	GPIO8 SPI0_CE0_N	
	25	Ground	26	GPIO7 SPI0_CE1_N	
	27	ID_SD I2C ID EEPROM	28	ID_SC I2C ID EEPROM	
	29	GPIO5	30	Ground	
	31	GPIO6	32	GPIO12	
	33	GPIO13	34	Ground	
	35	GPIO19	36	GPIO16	
	37	GPIO26	38	GPIO20	
	39	Ground	40	GPIO21	

Establish WiFi Connection

- Select the SSID of Kitakyuhsu International Conference Center and input password.



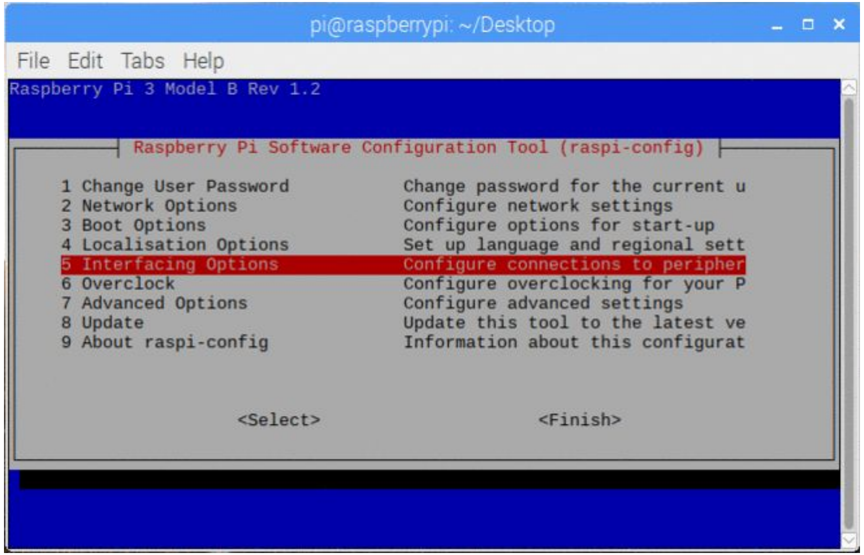
Raspberry Pi Configuration 1/2

❖ Open Raspberry Pi Configuration Window with this command.

```
$ sudo raspi-config
```

Raspberry Pi Configuration 2/2

- Raspi Camera should be enabled.



```
Raspberry Pi 3 Model B Rev 1.2

           Raspberry Pi Software Configuration Tool (raspi-config)

    1 Change User Password            Change password for the current u
    2 Network Options                 Configure network settings
    3 Boot Options                    Configure options for start-up
    4 Localisation Options            Set up language and regional sett
    5 Interfacing Options             Configure connections to peripher
    6 Overclock                       Configure overclocking for your P
    7 Advanced Options                Configure advanced settings
    8 Update                          Update this tool to the latest ve
    9 About raspi-config              Information about this configurat

                    <Select>                     <Finish>
```

- After Rebooting, pls check WiFi connection

Install Packages to Raspberry Pi

- OpenCV (Image Processing Library)
- Raspberry Pi GPIO Library

```
$ sudo apt-get update
$ sudo apt-get upgrade
$ sudo apt-get install libopencv-dev
$ sudo apt-get install python-opencv
$ sudo apt-get install python-rpi.gpio
```

Clone our project from GitHub

- https://github.com/shu-ramen/VeinVisualizationPi.git

```
$ cd [somewhere to put project files]
$ git clone
https://github.com/shu-ramen/VeinVisualizationPi.git
$ cd VeinVisualizationPi
```

Run our Vein Visualization System

- Run our project with these commands.

```
$ cd VeinVisualizationPi
$ python VeinVisualizer.py
```

Demonstration

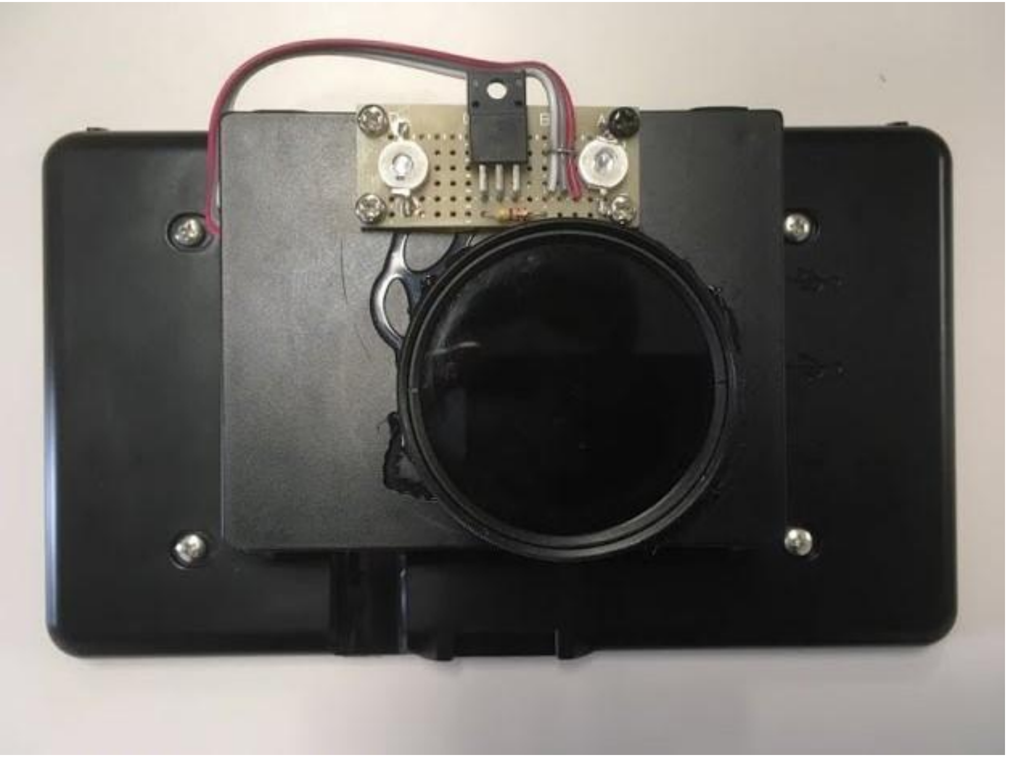


Image Processing Programming 1/7

Python Program

```
from picamera.array import PiRGBArray
from picamera import PiCamera
from datetime import datetime
import RPi.GPIO as gpio
import numpy as np
import time
import math
import cv2
import sys
import os
```

Comments

# PiCamera Control = Image Obtaining

# GPIO COntrol = LED Driver

# OpenCV = Image Processing

Image Processing Programming 2/7

Python Program

```
# PWM
self.pwmPort = pwmPort
self.pwmFrequency = pwmFrequency
self.pwm = 0

# camera
self.frameWidth = frameWidth
self.frameHeight = frameHeight
self.framerate = framerate
self.camera = 0
self.rawCapture = 0
```

Comments

```

# GPIO Port = 12
# f = 1kHz




# 320 * 240 pixels

# 16 FPS
```

Image Processing Programming 3/7

Python Program

```
for frame in self.camera.capture_continuous(self.rawCapture,
                                            format="bgr",
                                            use_video_port=True):
...
    img_original = frame.array
```

Comments

# Image Capturing. ⇒ Very Very Easy!!

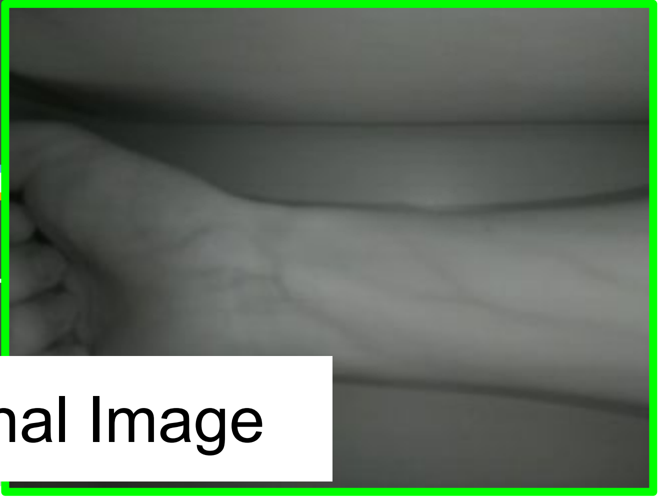
Image Processing Programming 3/7

Python Program

```
for frame in self.camera.capture_continuous(self.rawCapture,
                                            format="bgr",
                                            use_video_port=True):
...
    img_original = frame.array
```

Comments

# Image Capturing. ⇒ Very Very Easy!!



Original Image

Image Processing Programming 4/7

Python Program

```
# create contrast image
def __contrast(self, img):
    gray = cv2.cvtColor
    (img,cv2.COLOR_BGR2GRAY)

    resultImg = np.array
    ( [ self.lut[value] for value in gray.flat],
      dtype=np.uint8 )

    resultImg = resultImg.reshape(gray.shape)
    return resultImg
```

Comments

# Color Conversion
(BGR to Gray)

# Contrast Adjustment
With Sigmoid Function

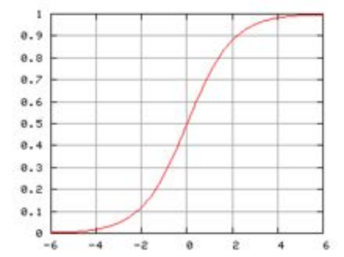


Image Processing Programming 4/7

Python Program

```
# create contrast image
def __contrast(self, img):
    gray = cv2.cvtColor
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    resultImg = np.array
    ( [ self.lut[value] for value in gray.flat],
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    resultImg = resultImg.reshape(gray.shape)
    return resultImg
```
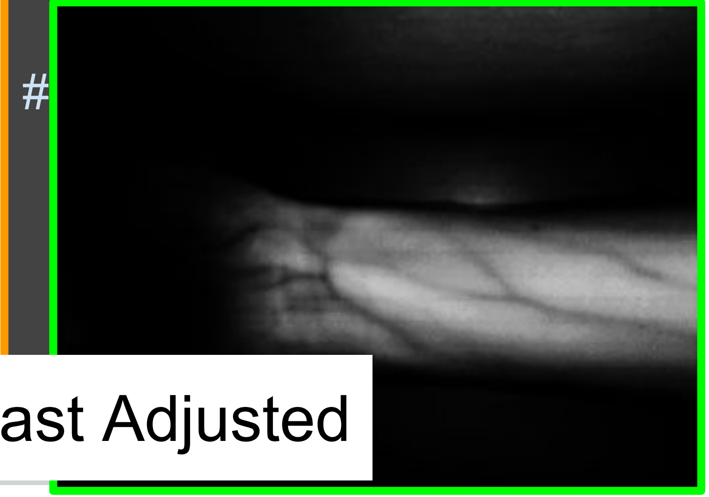

Comments

# Color Conversion
(BGR to Gray)

#



Contrast Adjusted

Image Processing Programming 5/7

Python Program

```
 # get hand mask
def __getHandMaskAndOutline(self, contrast):
    ret, thresh = cv2.threshold(contrast, 0, 255, cv2.THRESH_BINARY +
                                    cv2.THRESH_OTSU)
    contours, hierarchy = cv2.findContours(thresh, cv2.RETR_TREE,
                                                 cv2.CHAIN_APPROX_SIMPLE)

    # Get maximum size convex
    maxIdx = -1
    maxLen = -1
    for i in range(len(contours)):
        if (maxLen < len(contours[i])):
            maxIdx = i
            maxLen = len(contours[i])

    # Create Mask
    mask = np.zeros(contrast.shape, dtype=np.uint8)
    mask.fill(0)
    outline = -1
    if maxIdx > 0:
        outline = [ contours[maxIdx] ]
        cv2.fillPoly(mask, outline, (255))

    return mask, outline
```

Comments

# Binarization

# Get Contours of White Area

# Get Maximum Contour ⇒ Hand Area

# Create Mask of Hand Area

Image Processing Programming 5/7

Python Program

```
    # get hand mask
    def __getHandMaskAndOutline(self, contrast):
        ret, thresh = cv2.threshold(contrast, 0, 255, cv2.THRESH_BINARY +
                                                        cv2.THRESH_OTSU)
        contours, hierarchy = cv2.findContours(thresh, cv2.RETR_TREE,
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        mask = np.zeros(contrast.shape, dtype=np.uint8)
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        outline = -1
        if maxIdx > 0:
            outline = [ contours[maxIdx] ]
            cv2.fillPoly(mask, outline, (255))

        return mask, outline
```

Comments

# Binarization

Get Contours of W te
Area

Get Maximur C
⇒ Hand Ar

# Create Mask of H
Area

Hand Detection!!

Image Processing Programming 6/7

Python Program

```
def __getVeinMask(self, contrast):
    veinMask = cv2.Canny(contrast,
                 self.lut_b_val-40, self.lut_b_val+5)
    kernel = np.ones((3, 3), np.uint8)
    veinMask = cv2.dilate(veinMask, kernel)
    return veinMask
```

Comments

```
# Edge Detection

# Pixel Dilation
```

Image Processing Programming 6/7

Python Program

```
def __getVeinMask(self, contrast):
    veinMask = cv2.Canny(contrast,
                   self.lut_b_val-40, self.lut_b_val+5)
    kernel = np.ones((3, 3), np.uint8)
    veinMask = cv2.dilate(veinMask, kernel)
    return veinMask
```

Comments

# Edge Detection

# Pixel Dilation

Edge Detection!!

Image Processing Programming 7/7

Python Program

```
def __getVein(self, handMask, outline, veinMask,
                                        original):
    if outline == -1:
        return original

    red = np.zeros(original.shape, np.uint8)
    red[:] = (0, 0, 255)
...
    vein = cv2.bitwise_and(red, red, mask=handMask)
    vein = cv2.bitwise_and(vein, vein, mask=veinMask)
    vein = cv2.bitwise_or(original, vein)

    cv2.drawContours(vein, outline, 0, (0, 255, 255))

    return vein
```

Comments

# If Hand Area was not detected.

# Overwrap Hand Area Mask and Vein Area Mask
⇒ Vein Emphasize

Image Processing Programming 7/7

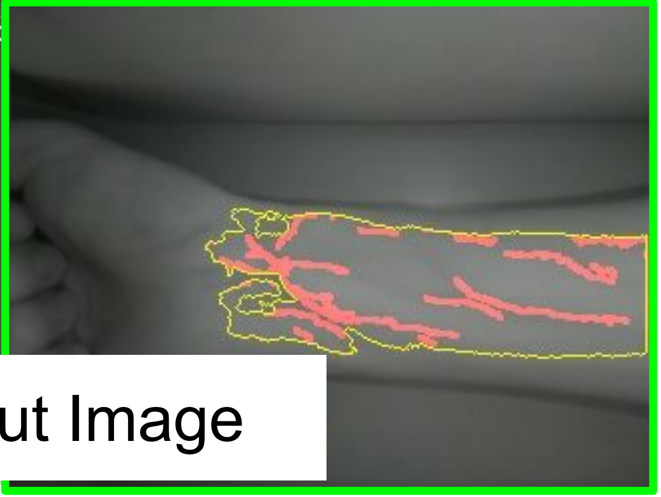
Python Program

```
def __getVein(self, handMask, outline, veinMask,
                                                  original):
    if outline == -1:
        return original

    red = np.zeros(original.shape, np.uint8)
    red[:] = (0, 0, 255)
...
    vein = cv2.bitwise_and(red, red, mask=handMask)
    vein = cv2.bitwise_and(vein, vein, mask=veinMask)
    vein = cv2.bitwise_or(original, vein)

    cv2.drawContours(vein, outline, 0, (0, 255, 255))

    return vein
```

Comments

# If Hand Area was not detected.

#



Output Image

Vein Visualization

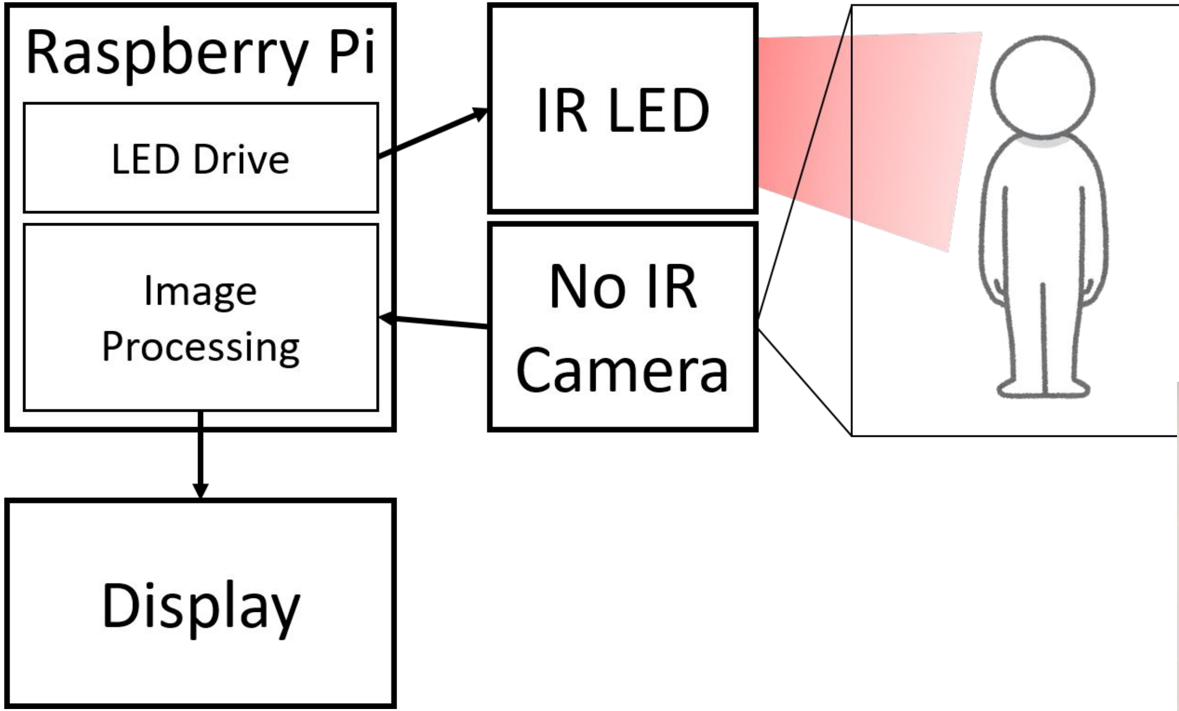
I’ll talk about...

1. About Vein Visualization
2. About Hardware
3. Developing IR Flood lighting Unit
4. Developing Camera Unit

I’ll talk about...

1. About Vein Visualization
2. About Hardware
3. Developing IR Flood lighting Unit
4. Developing Camera Unit

Raspberry Pi + NoIR Camera + LED



Raspberry Pi

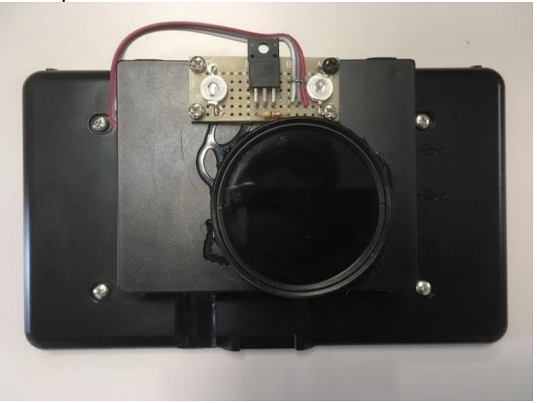
LED Drive

Image Processing

IR LED

No IR Camera

Display



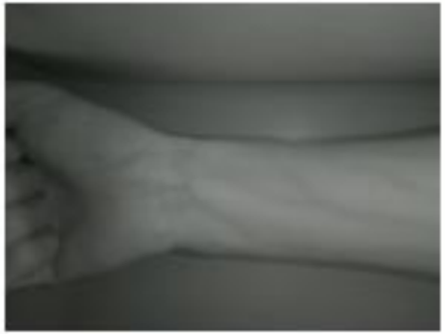


Fig. 6. Original photo from RasPi NoIR Camera.

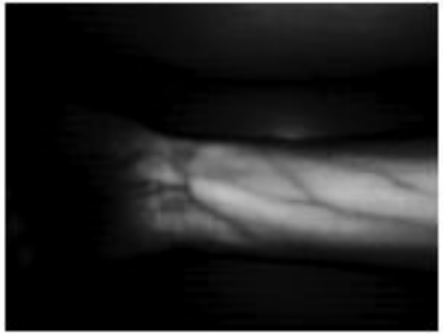


Fig. 7. Image after contrast adjustment.

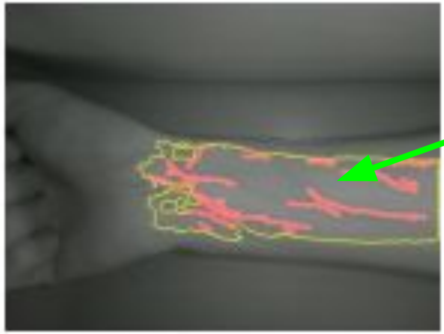


Fig. 8. Image after emphasizing.

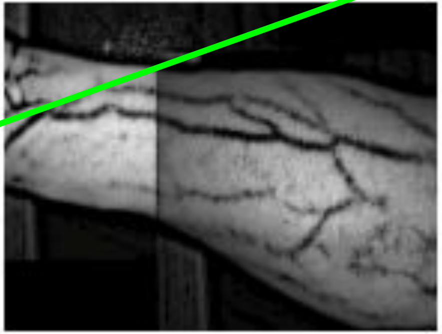


Fig. 9. Vein Visualized Image [6].

Image Processing
Using OpenCV on Raspberry Pi

OpenCV

https://opencv.org/

About Venipuncture

Venipuncture is medical practice.

Performed high frequency and high invasiveness.

Ex. Blood sampling , Injection of medicine

Therefore, importance of practical training is high.

Every year, caused some accidents.

Ready Made Products

Vein Viewer

Projection shape of Vein
On Human skin.

Reported increase performance for venipuncture
On the

http://www.noba.com/what-is-a-veinviewer/

Ready Made Products

- 装置使用による作業時間短縮効果は実証されている[*]
  - 小児の静脈穿刺は苦痛な時間をどれだけ短縮するかがキモ
  - 針の刺し直しは少ないほうが良い(事故のリスクも減る)

http://www.noba.com/what-is-a-veinviewer/

Vision

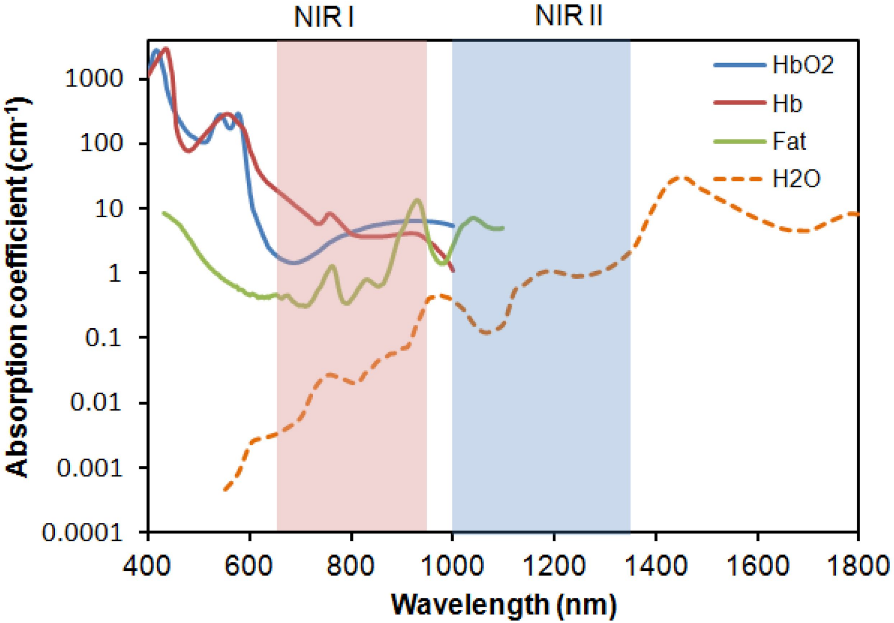
簡単で安く作れるデバイスを作ってみよう

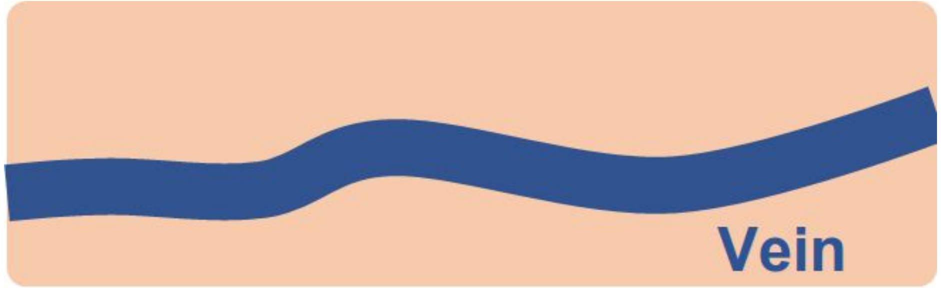
I’ll talk about...

1. About Vein Visualization
2. About Hardware
3. Developing IR Flood lighting Unit
4. Developing Camera Unit

How to Visualize the Vein

The Hb and HbO2 have good coefficient to NIR Ray





How to Visualize the Vein

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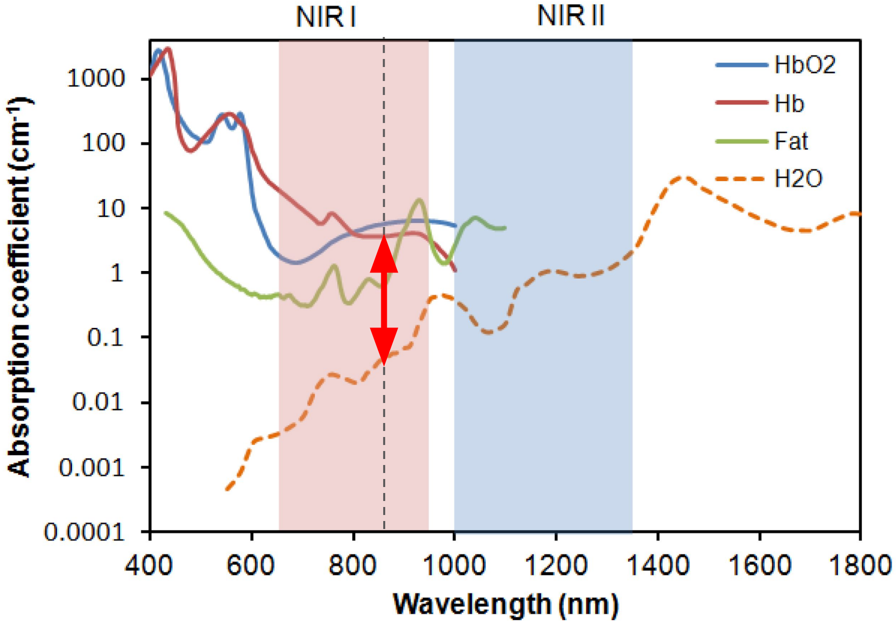

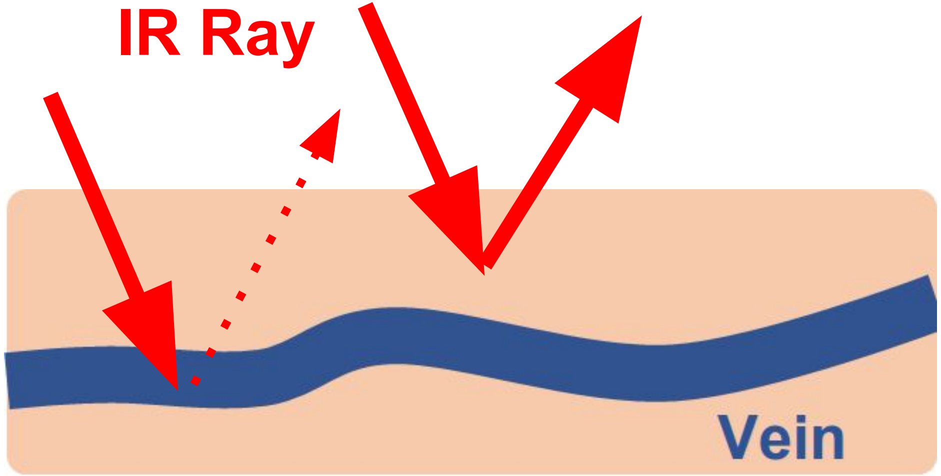

How to Visualize the Vein

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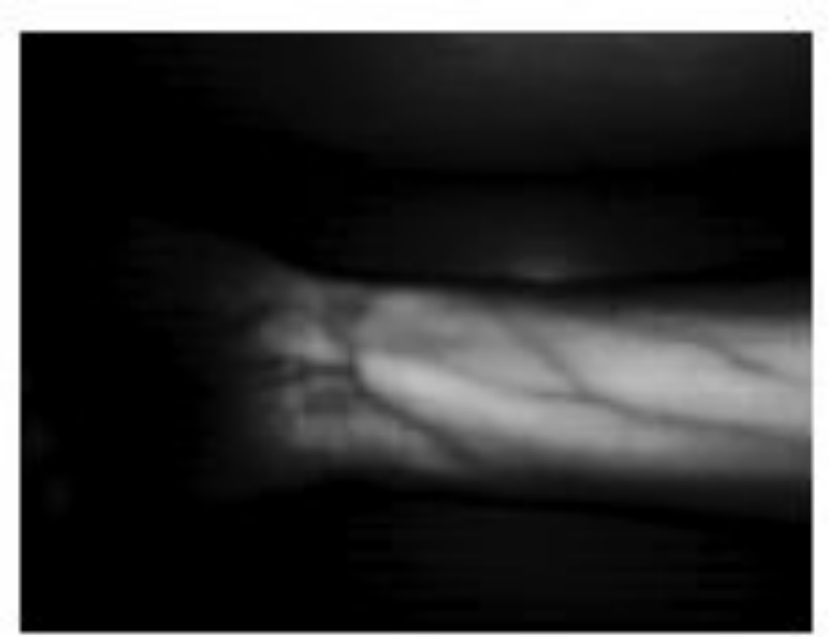
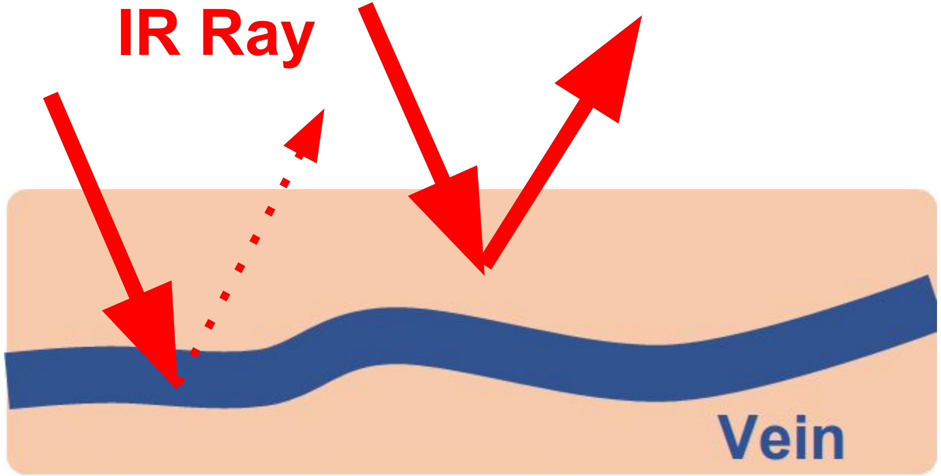
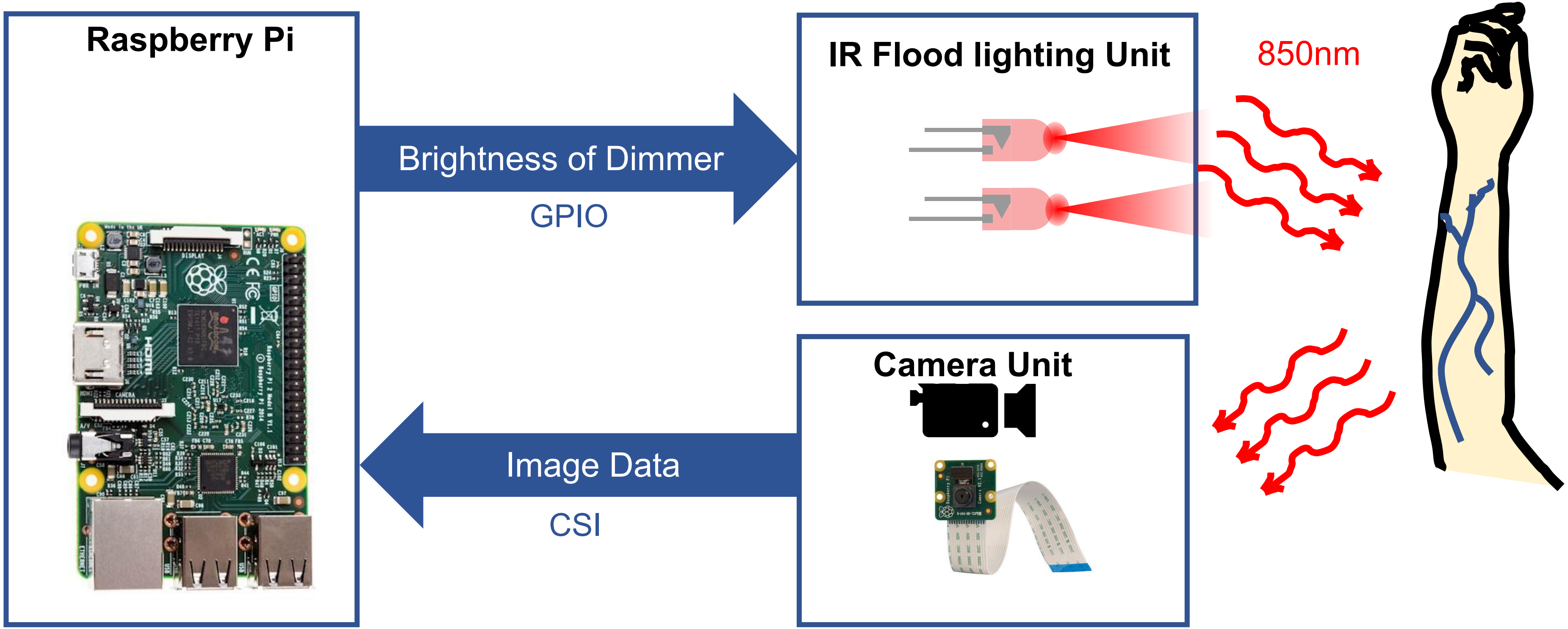




System Diagram



Raspberry Pi

Brightness of Dimmer

GPIO

IR Flood lighting Unit

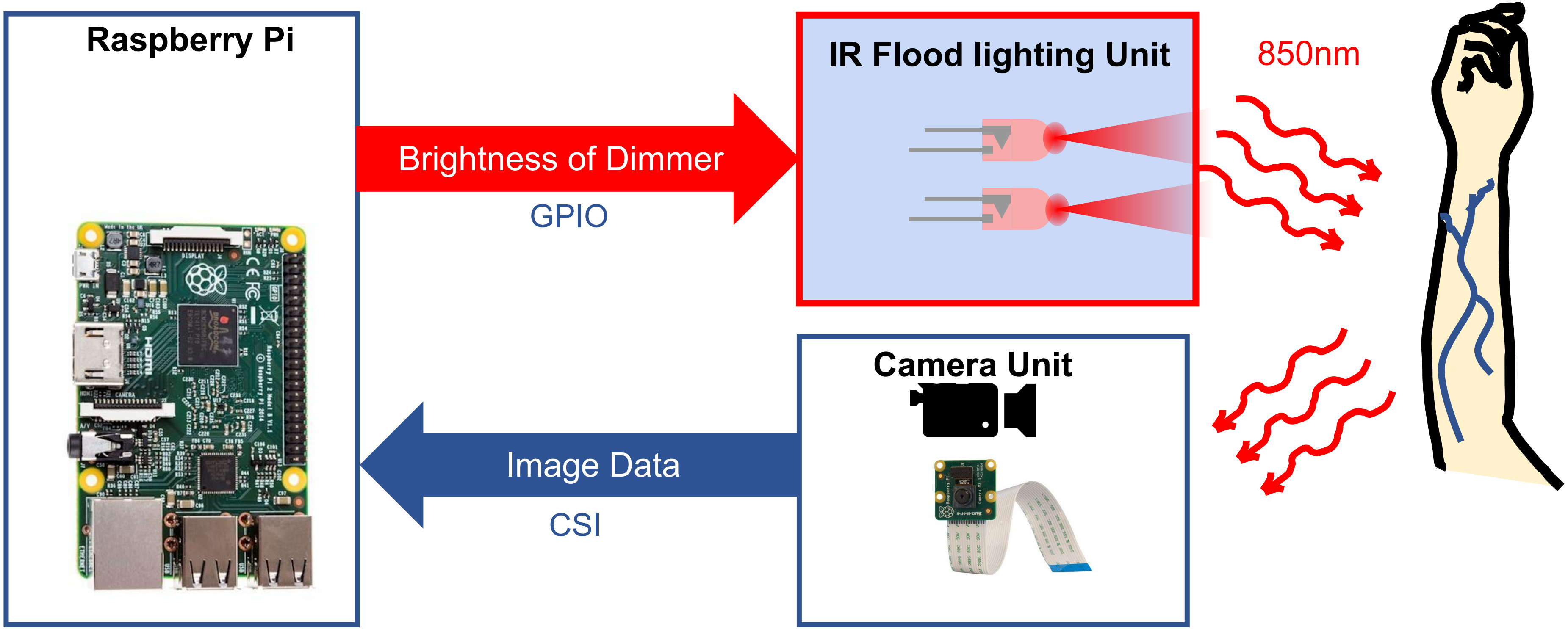
850nm

Camera Unit

Image Data

CSI

System Diagram



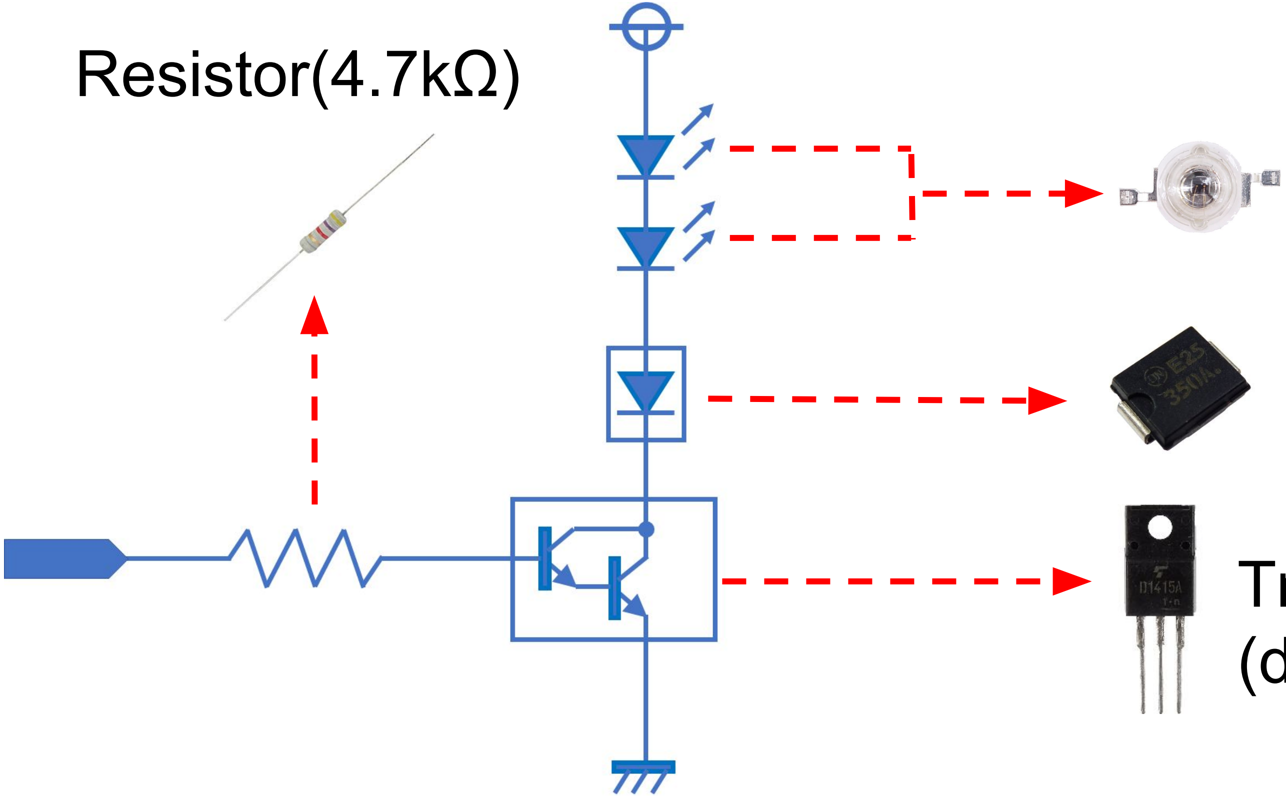
IR Flood light Unit

Function:

Flood lighting：irradiate IR Ray.

Control：Adjusting brightness of IR Ray.

Circuit Diagram (Flooding Light Unit)



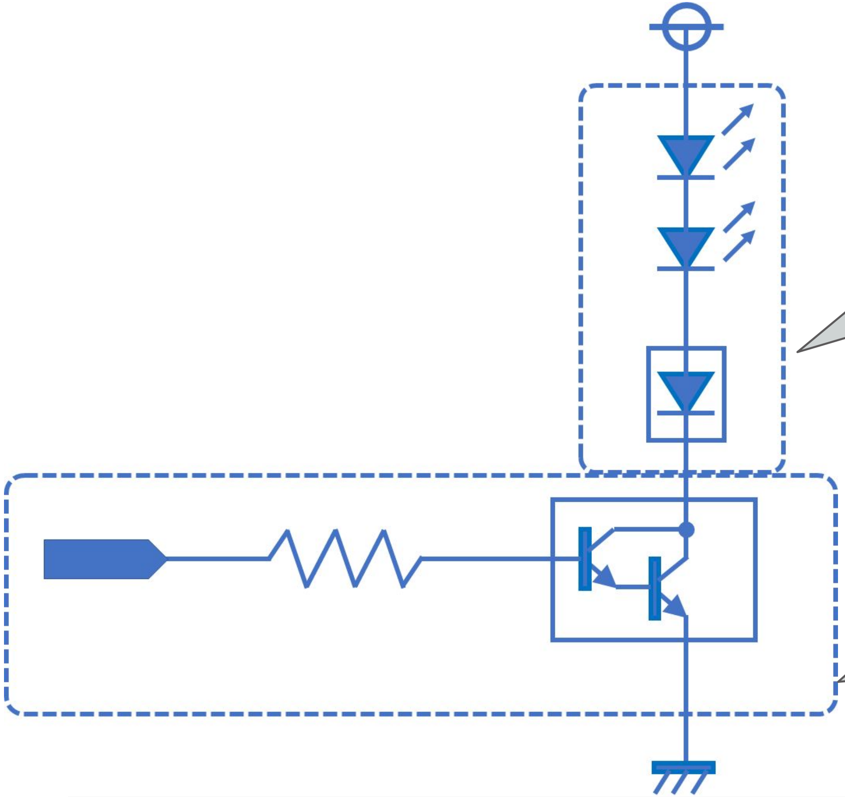
Resistor(4.7kΩ)

IR LED(850nm) x2

Current Regulator (350mA)

Transistor (darlington pair)

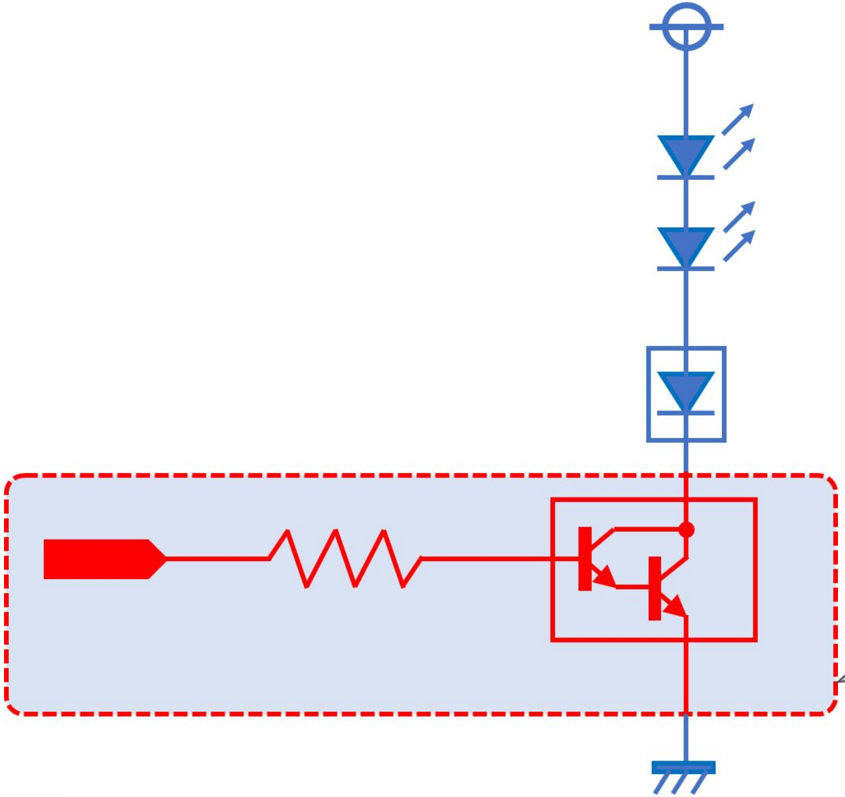
Circuit Diagram (Flooding Light Unit)



Lighting Circuit:
Lighting LED
Current Regulator

LED Drive Circuit:
Switching

Block 1 -LED Drive Circuit



LED Drive Circuit:

Switching

GPIO Pin Current is not enough for LED drive

Therefore Using Transistor.

- Maximum LED Drive Current is **700mA**
- However, GPIO Pin’s current limit is **50mA**

In this Case, Employing Switching Circuit

- Transistor

Base Resistor’s value

V_{in}=3.3[V],

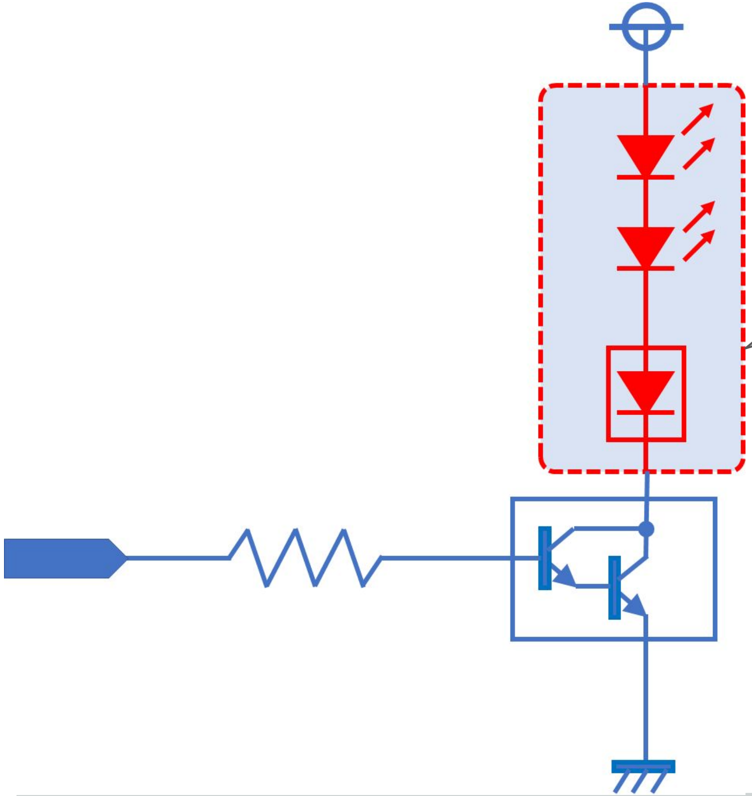
h_{fe}=1000 ,

Maximum Current for Drive LED=700 [mA]

R= $\frac{V_{in}}{i_c/f_{fe}} = \frac{3.3}{0.7/1000} = 4714.28571429$

R=4.7kΩ

Block 2-LED Circuit:



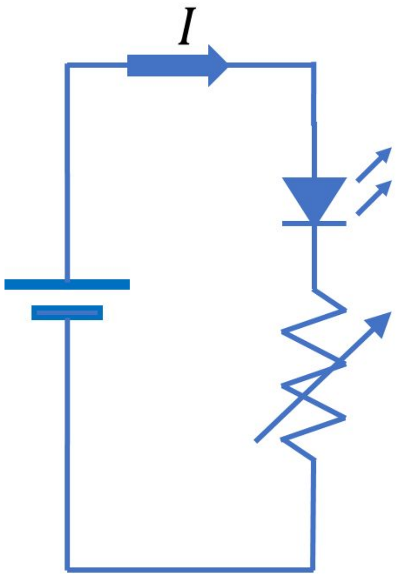
Lighting Circuit:

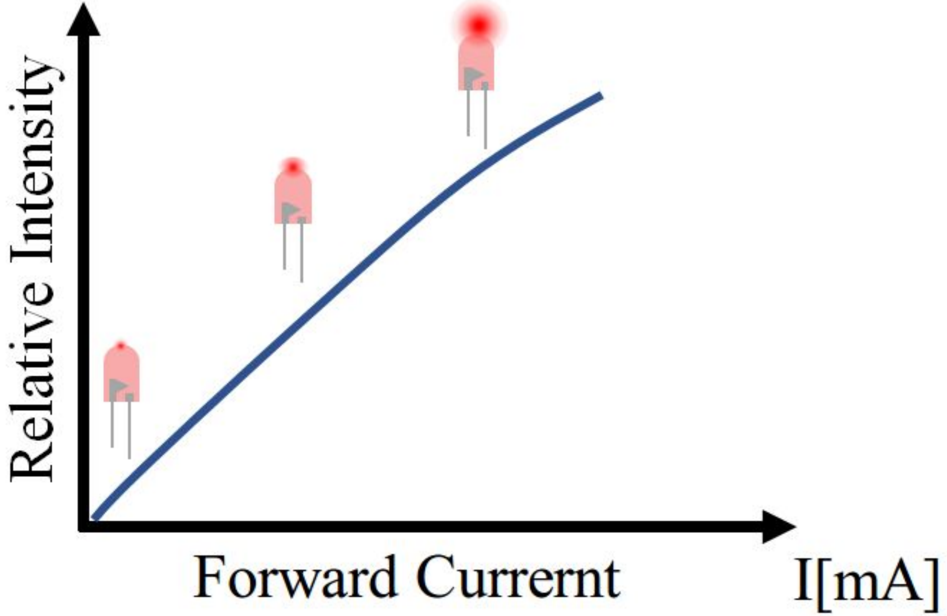
Lighting LED

Current Regulator

LED’s Brightness is decided by Current Value

The brightness of the light of an LED is proportional to an electric current.





Heat of LED Cause Changing Current Value

When the almost semiconductor devices has heat,
The current value increase.

Hi-Power LEDs self heating caused changing current value (= brightness).

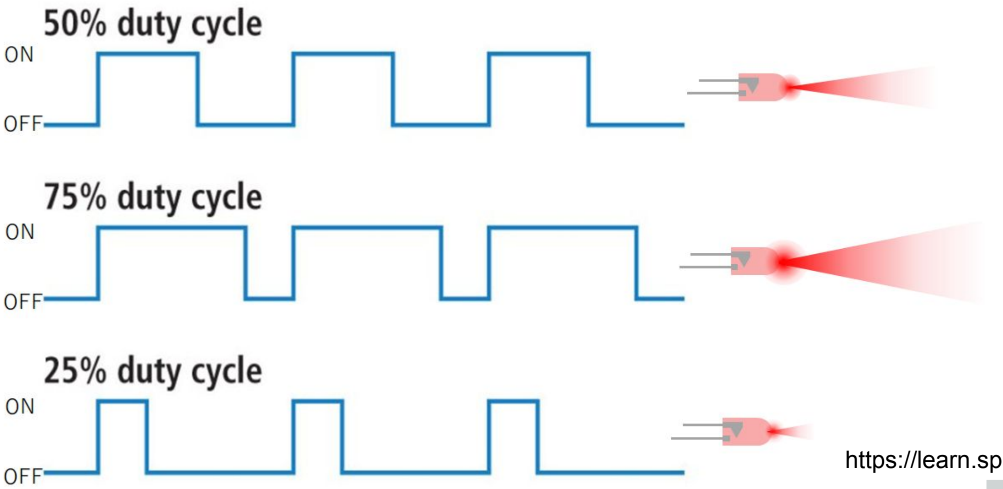
Therefore, We insert current regulator (350mA) to lightning circuit to get constant current Value.

How to Adjusting Brightness

GPIO Pin outputs are only HIGH(3.3V) or LOW(0V).

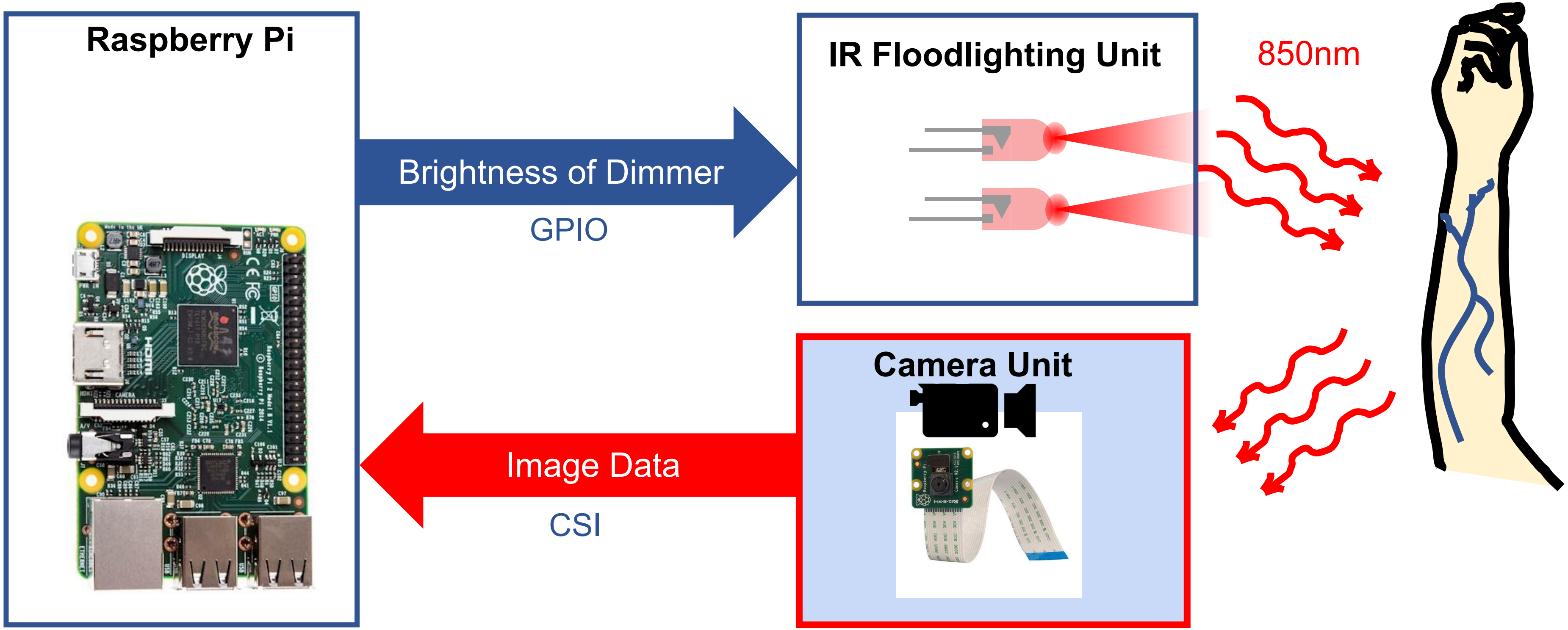
PWM(Pulse Width Modulation):

High frequency switching for control power.



https://learn.sparkfun.com/tutorials/pulse-width-modulation

System Diagram



Raspberry Pi

Brightness of Dimmer

GPIO

IR Floodlighting Unit

850nm

Camera Unit

Image Data

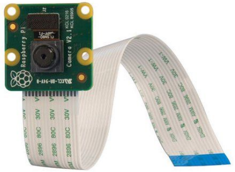
CSI

Camera Unit

Function

Camera:

Get pixel Information by Image sensor

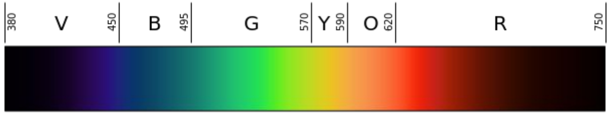


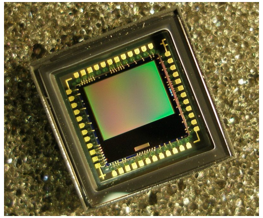
Filtor :

Cut Visible light and , get only IR Ray.

Almost Camera can’t take IR Ray

CMOS Image sensor can convert invisible Ray(IR , UV) to electrical signal too.



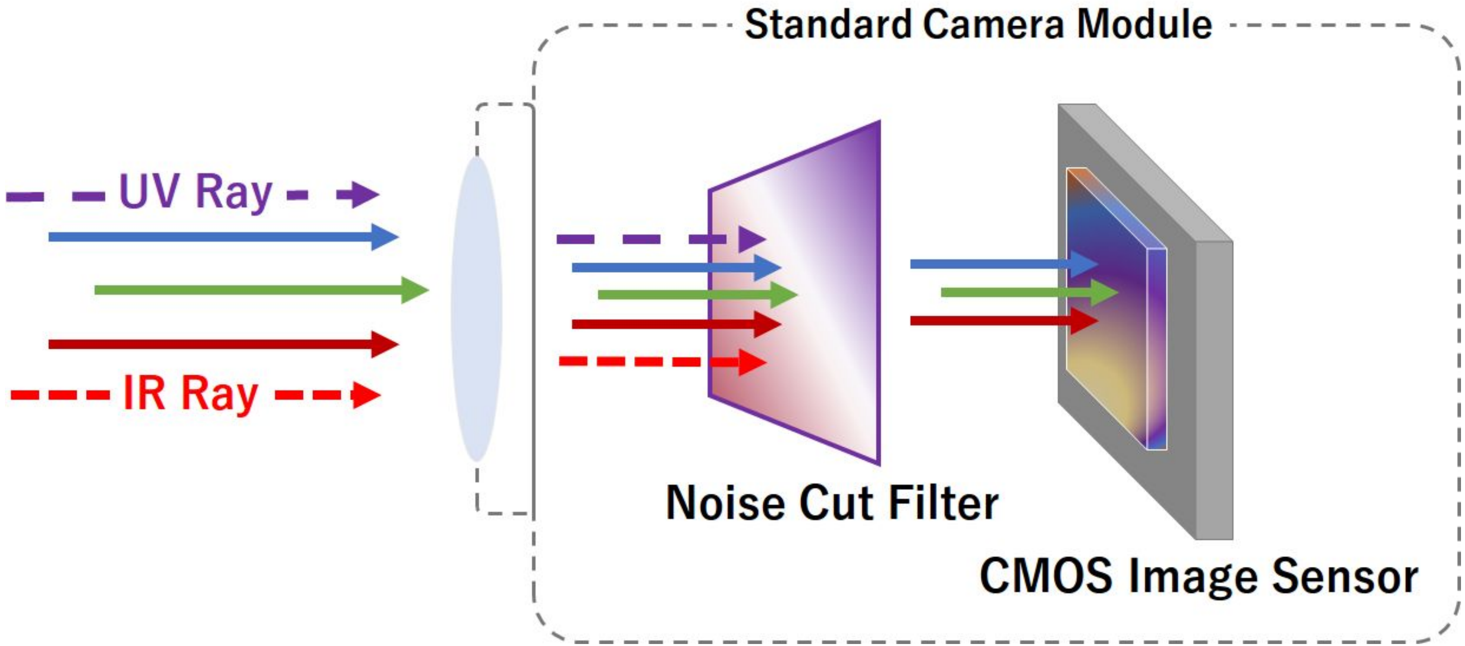


However, Invisible color informations on a Picture is noise for human.

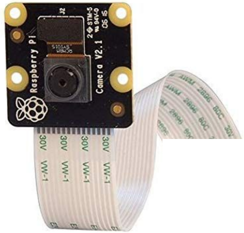
Almost digital camera include Noise Cut Filter.

Standard Camera Module

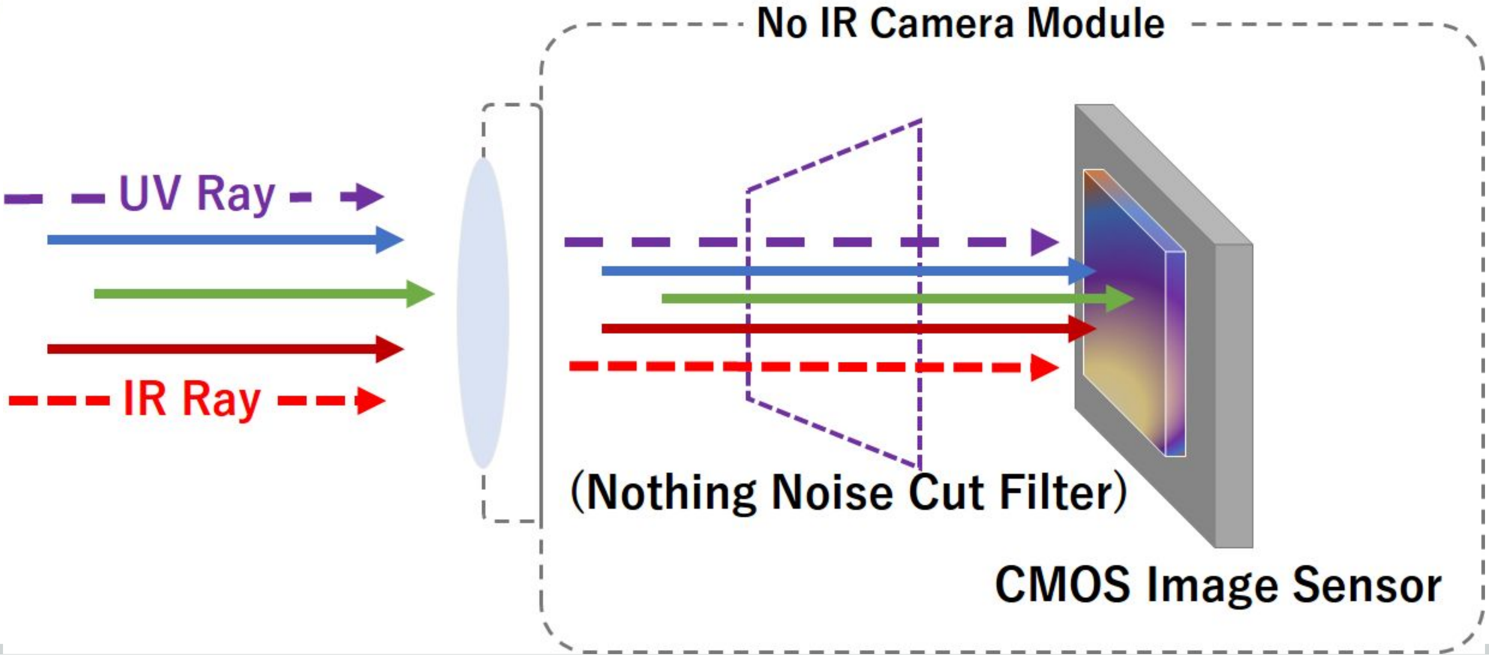
Almost digital camera include Noise Cut Filter.



We want to IR Ray information

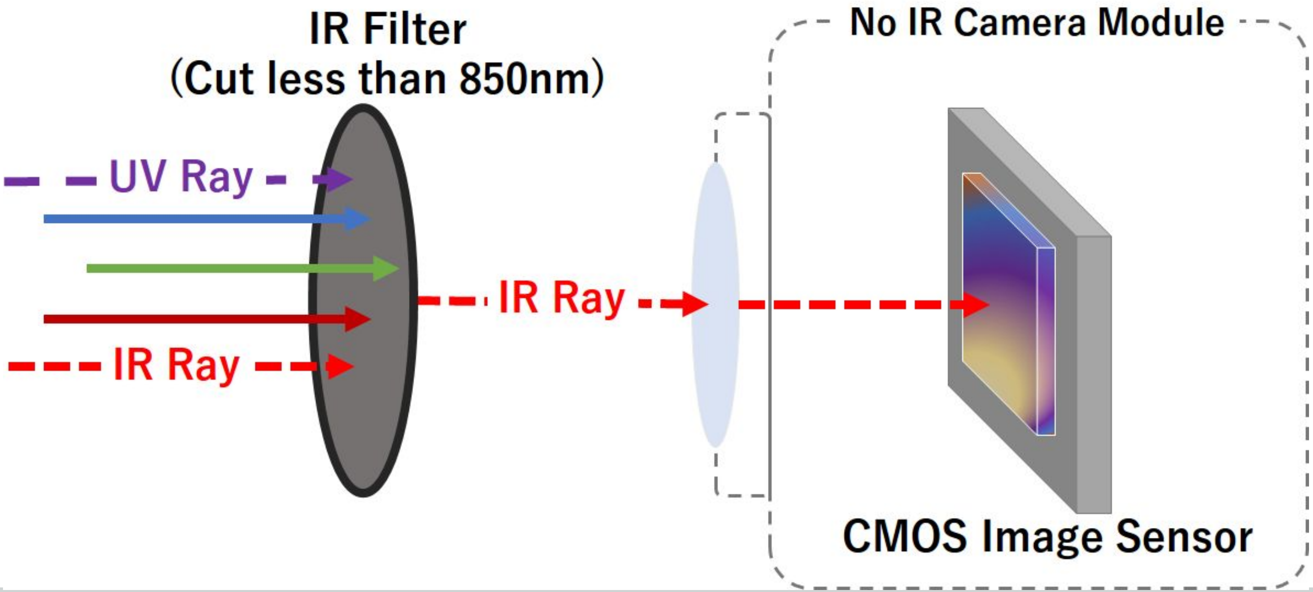


In No IR Camera, nothing Noise Cut Filter.



We only need IR light information!

The IR Filter cut less than specific wavelength rays.



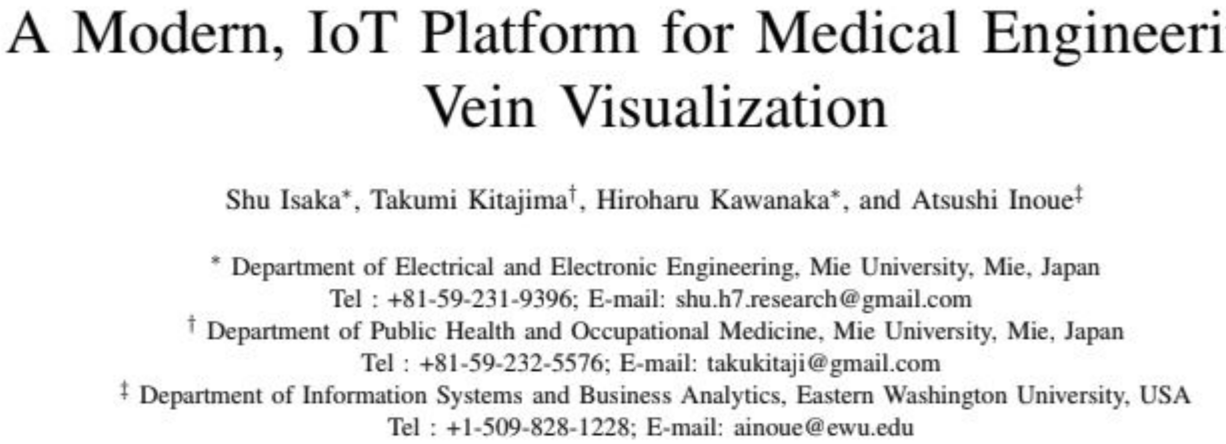
Enjoy!

Question?
Demonstration

Contact Atsushi Inoue (Business Card: https://goo.gl/Ltho3I, Web: http://www.inoueatsushi.net/)

This tutorial is based on the R&D to be presented at ICIEV 2018.

13:20-14:50 on Wednesday, June 27 @Room 22
Regular session (7-B): IoT, Control and Automation III
Paper 282 -- the last presentation.



A Modern, IoT Platform for Medical Engineering: Vein Visualization

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You are welcome to join us to discuss further.