5. PI camera

National Chiao Tung University

Outline

- 嵌入式應用: 網路攝影機
  - 控制Raspberry Pi Camera
  - 建立網路串流
    - 使用 RTSP + H.264
    - 使用 HTTP + MJPG
    - 使用 RTMP

https://cdn.sparkfun.com/datasheets/Dev/RaspberryPi/ov5647_full.pdf

PI Camera Spec.

- Sensor: OmniVision OV5647 (5MP)
- 靜態拍照最高解析度:2592 x 1944 pixel
- Pixel Size:1.4 x 1.4 µm
- Lens: f=3.6 mm, f/2.9
- Angle of View:54 x 41 degrees
- Field of View:2.0 x 1.33 m at 2 m
- Fixed Focus:1m to infinity
- 動態攝影最高解析度:1080p@30 FPS with H.264/AVC

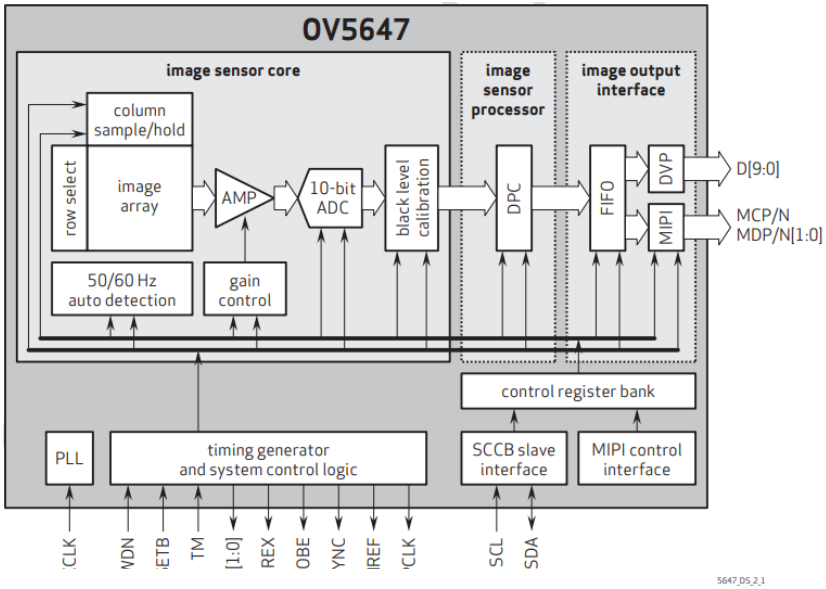
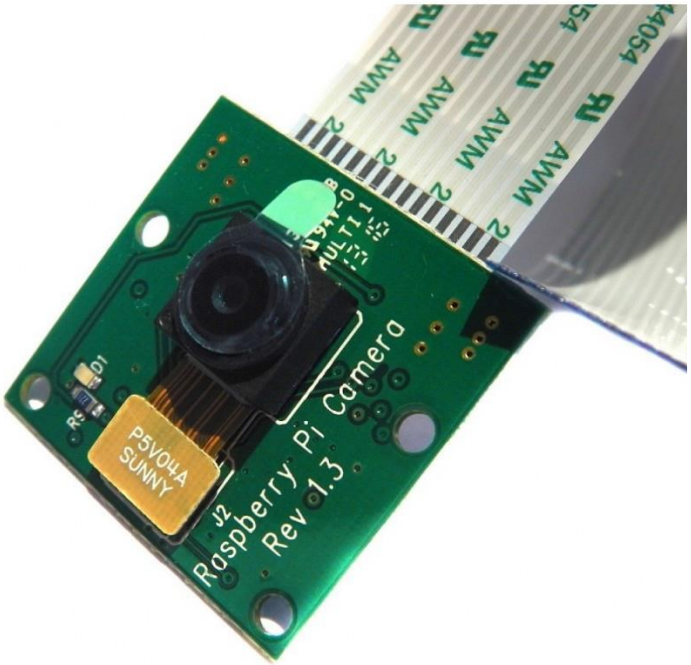


table 2-1 format and frame rate

format	resolution	frame rate	scaling method	pixel clock
5 Mpixel	2592x1944	15 fps	full resolution	80 MHz
1080p	1920x1080	30 fps	cropping	68 MHz
960p	1280x960	45 fps	cropping, subsampling/ binning	91.2 MHz
720p	1280x720	60 fps	cropping, subsampling/ binning	92 MHz
VGA	640x480	90 fps	cropping, subsampling/ binning	46.5 MHz
QVGA	320x240	120 fps	cropping, subsampling/ binning	32.5 MHz

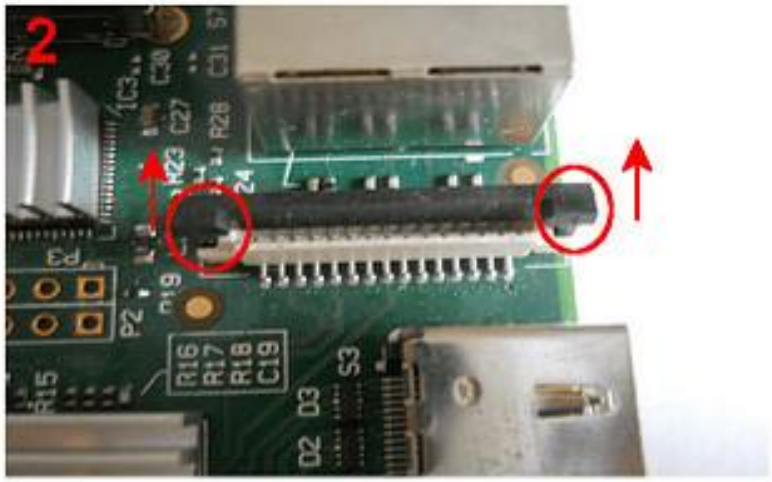
Install PI camera

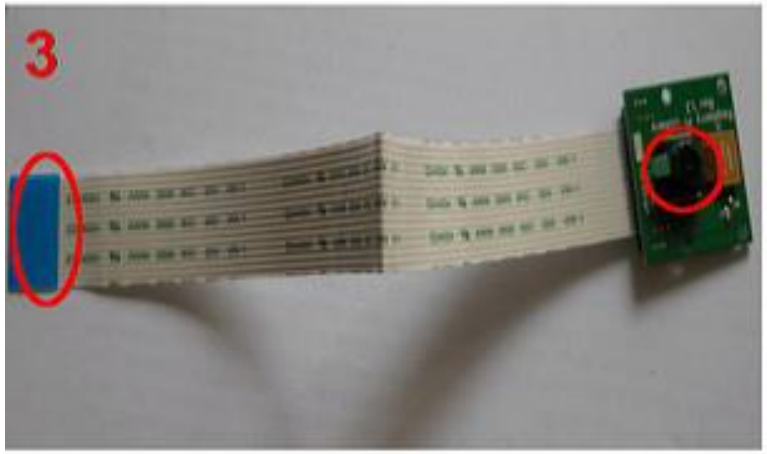
15-Pins, CSI interface

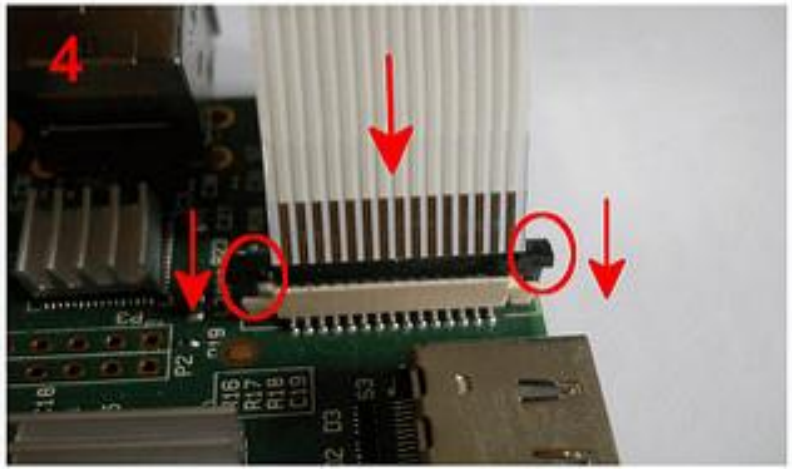


http://xmodulo.com/install-raspberry-pi-camera-board.html

Install PI camera

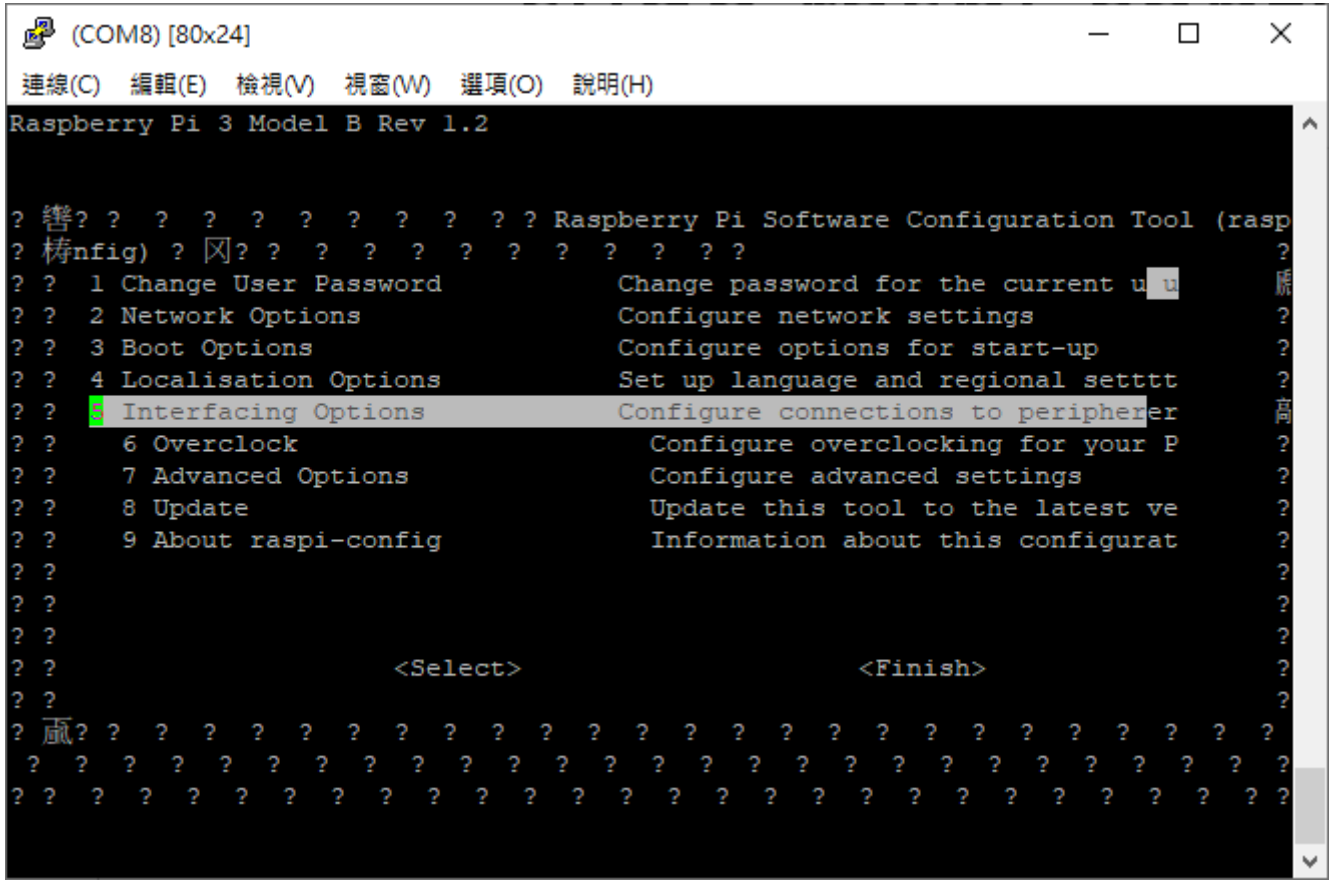






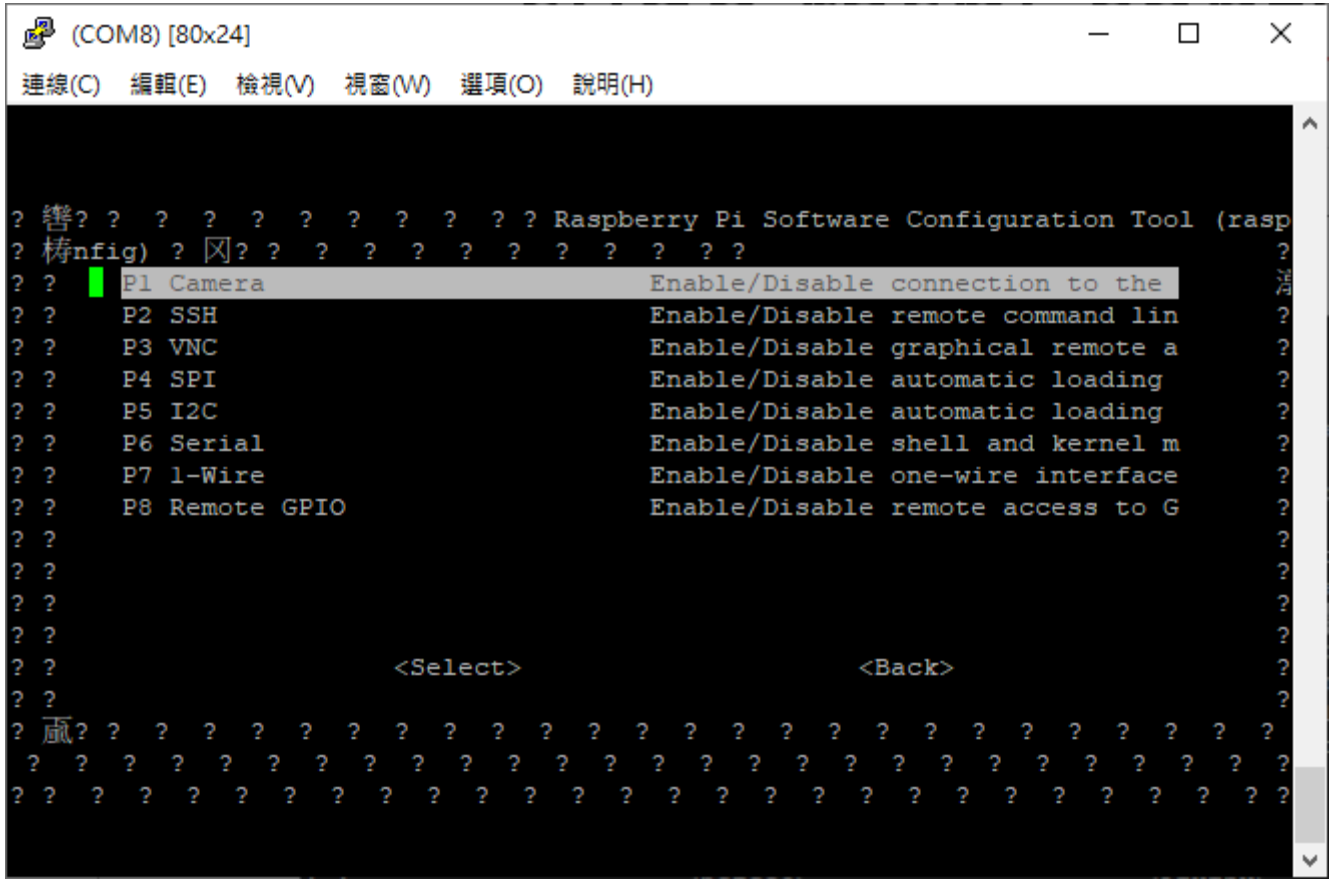
Raspbian configuration

- sudo raspi-config



Raspbian configuration

- sudo raspi-config -> P1 Camera



Raspbian configuration

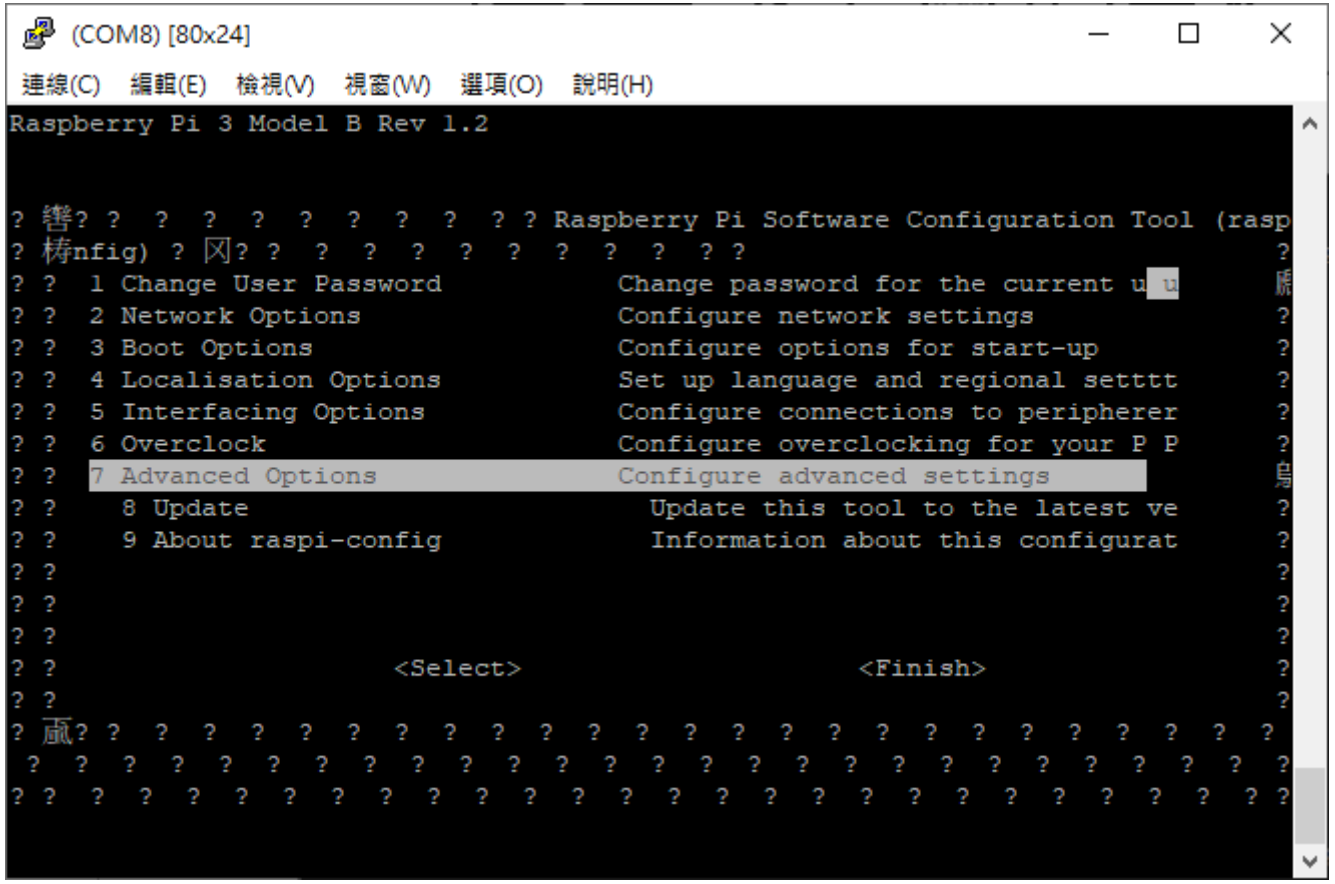
- sudo raspi-config -> P1 Camera -> Enable

Raspbian configuration

- sudo raspi-config -> P1 Camera -> Enable

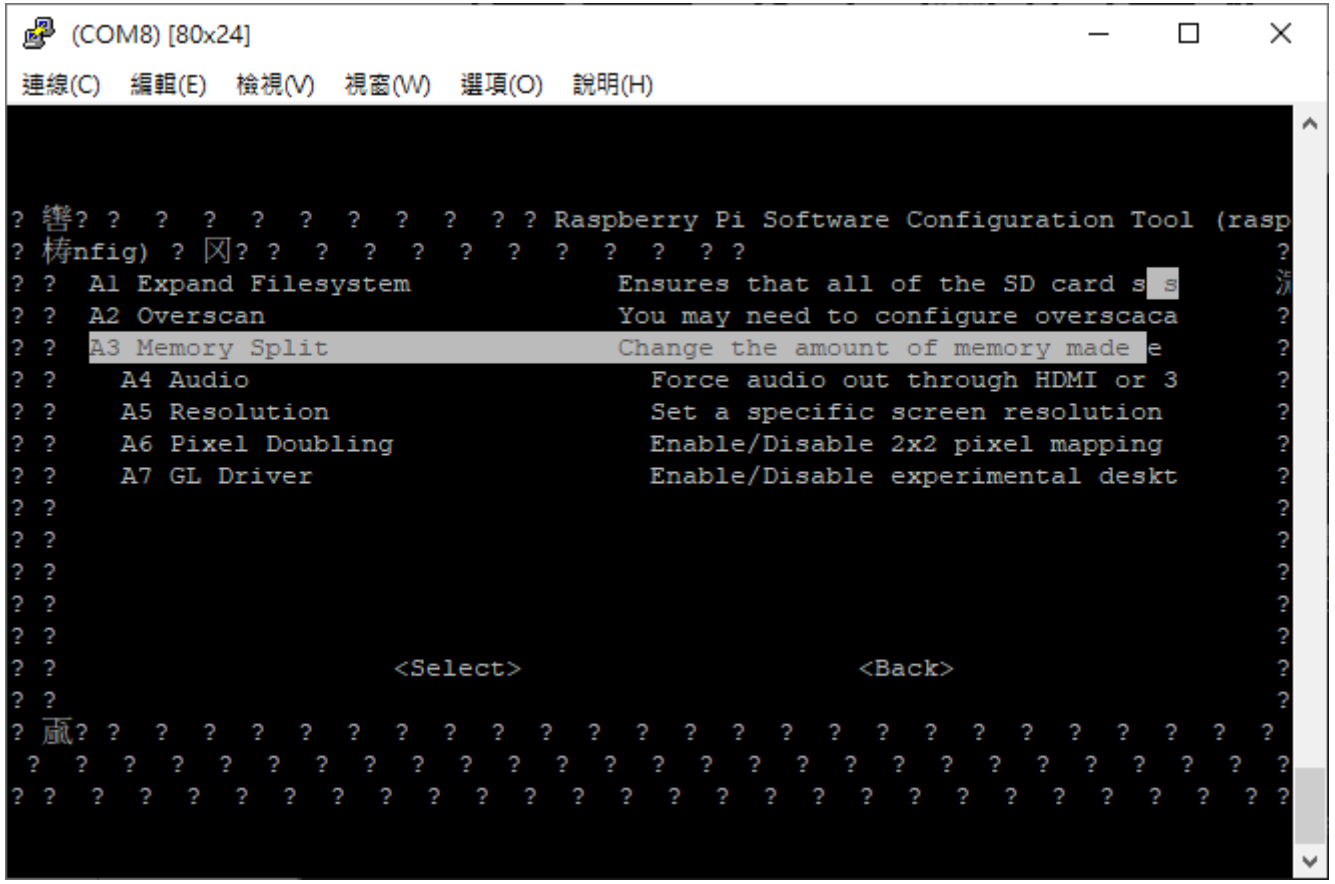
Raspbian configuration

- sudo raspi-config -> P1 Camera -> Enable



Raspbian configuration

- Optional



Raspbian configuration

- Optional

https://www.raspberrypi.org/documentation/raspbian/applications/camera.md

Camera commands

- Take a picture: raspistill
  - raspistill -n -t 3000 -o test.png -e png -w 640 -h 480
  - 3秒後拍照, 並編碼成png格式,長640x寬480, 無預覽
    - n: Do not display a preview window
    - t: timeout, Time before the camera takes picture and shuts down
    - o: output filename
    - e: Encoding to use for output file (jpg, bmp, gif, and png)
    - w: Set image width <size>
    - h: Set image height <size>

Camera commands

- Record a video: raspivid
  - Raspivid -n -t 5000 -w 640 -h 480 -o video.h264
    - 錄5秒的1080p30影片, 長640x寬480, 無預覽
    - t: Time (in ms) to capture for. Default = 5 sec.
    - o: output filename
    - w: Set image width <size>
    - h: Set image height <size>
- Official document
  - https://github.com/raspberrypi/documentation/blob/master/raspbian/applications/camera.md

Error message?

- Msg: Camera is not enabled in this build

(COM8) [80x24]

連線(C) 編輯(E) 檢視(V) 視窗(W) 選項(O) 說明(H)

```
pi@raspberrypi:~$ raspistill -n
mmal: mmal_vc_component_create: failed to create component 'vc.ril.camera' (1:EN
OMEM)
mmal: mmal_component_create_core: could not create component 'vc.ril.camera' (1)
mmal: Failed to create camera component
mmal: main: Failed to create camera component
mmal: Camera is not enabled in this build. Try running "sudo raspi-config" and e
nsure that "camera" has been enabled
```

- Sol: go to “sudo raspi-config”, then enable camera

https://www.modmypi.com/blog/how-to-replace-the-raspberry-pi-camera-cable

Error message?

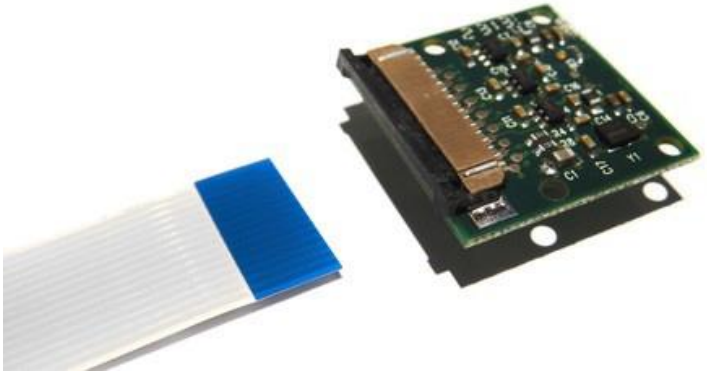
- Msg: Camera is not detected

(COM8) [80x24]

連線(C) 編輯(E) 檢視(V) 視窗(W) 選項(O) 說明(H)

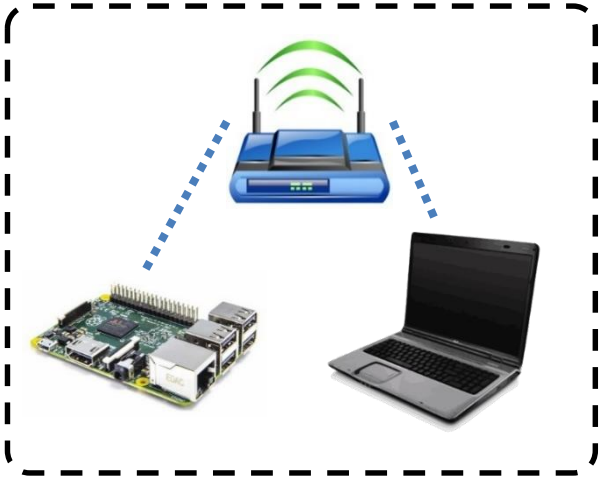
```
pi@raspberrypi:~$ raspistill -n
mmal: Cannot read camera info, keeping the defaults for OV5647
mmal: mmal_vc_component_create: failed to create component 'vc.ril.camera' (1:EN
OMEM)
mmal: mmal_component_create_core: could not create component 'vc.ril.camera' (1)
mmal: Failed to create camera component
mmal: main: Failed to create camera component
mmal: Camera is not detected. Please check carefully the camera module is instal
led correctly
```

- Sol:
  - 重新安裝camera,或是更換排線
  - 或是檢查camera module是否鬆脫

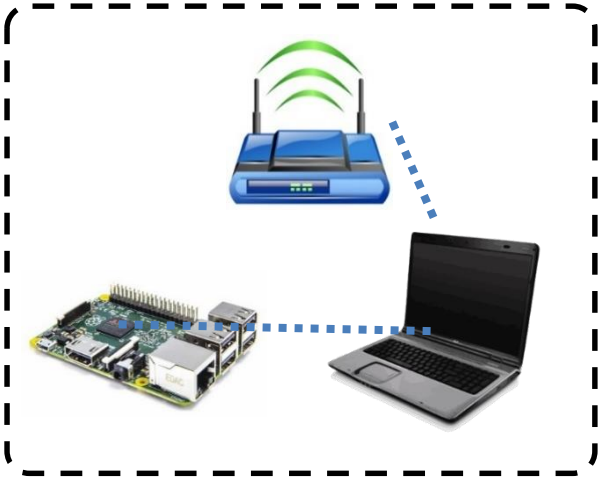


How to view image/video?

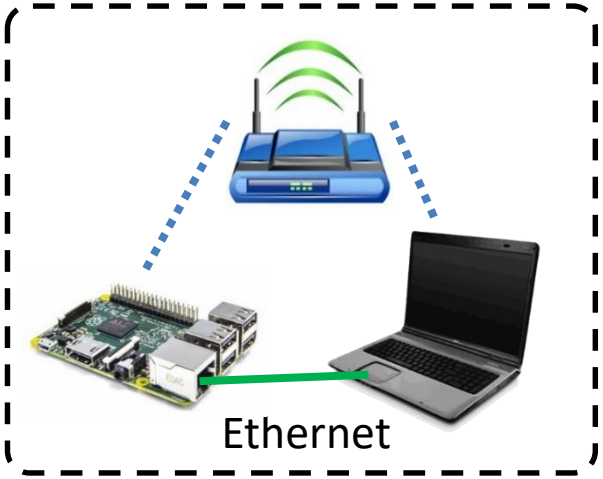
- Methods:
  1. python -m SimpleHTTPServer 8000
  2. winscp
  3. vnc
  4. HDMI



Wi-Fi AP



Wi-Fi hotspot



Wired + Wireless

Python code

- Sample code for taking a picture

```
import picamera
import time

camera = picamera.PiCamera()
time.sleep(2)    # Camera warm-up time
camera.capture('test.jpg')
```

9.1. PiCamera

class **picamera.PiCamera**(*camera_num=0, stereo_mode='none', stereo_decimate=False, resolution=None, framerate=None, sensor_mode=0, led_pin=None, clock_mode='reset', framerate_range=None*) [source]

capture(*output, format=None, use_video_port=False, resize=None, splitter_port=0, bayer=False, **options*) [source]

https://picamera.readthedocs.io/en/release-1.13/api_camera.html

Python code

- Sample code for record a video

start_recording(*output, format=None, resize=None, splitter_port=1, **options*) [source]

Start recording video from the camera, storing it in *output*.

```
import picamera

camera = picamera.PiCamera()
camera.start_recording('video.h264')
camera.wait_recording(3)
camera.stop_recording()
```

wait_recording(*timeout=0, splitter_port=1*) [source]

Wait on the video encoder for timeout seconds.

stop_recording(*splitter_port=1*) [source]

Stop recording video from the camera.

https://picamera.readthedocs.io/en/release-1.13/api_camera.html

https://picamera.readthedocs.io/en/release-1.13/api_camera.html

Python code

- Sample code for taking many pictures

```
import time
import picamera
with picamera.PiCamera() as camera:
    camera.start_preview()
    try:
        for i, filename in enumerate(camera.capture_continuous('image{counter:02d}.jpg')):
            print(filename)
            time.sleep(1)
            if i == 59:
                break
    finally:
        camera.stop_preview()
```

File name

Discussion

- Read the online document. If we want to set the output file name as data and time, how do we set filename in the code?
  - Ex: image20190403_1720.jpg

`capture_continuous`(*output, format=None, use_video_port=False, resize=None, splitter_port=0, burst=False, bayer=False, **options*) [source]

Capture images continuously from the camera as an infinite iterator.

This method returns an infinite iterator of images captured continuously from the camera. If *output* is a string, each captured image is stored in a file named after *output* after substitution of two values with the `format()` method. Those two values are:

- `{counter}` - a simple incrementor that starts at 1 and increases by 1 for each image taken
- `{timestamp}` - a `datetime` instance

  - Original: camera.capture_continuous(**'image{counter:02d}.jpg'**)):
  - New: ??????????????

Hint: https://docs.python.org/2/library/datetime.html

Discussion

- Read the online document. If we want to set the output file name as data and time, how do we set filename in the code?

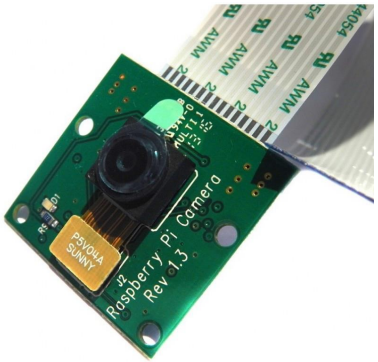
%w	Weekday as a decimal number, where 0 is Sunday and 6 is Saturday.
%d	Day of the month as a zero-padded decimal number.
%b	Month as locale's abbreviated name.
%B	Month as locale's full name.
%m	Month as a zero-padded decimal number.
%y	Year without century as a zero-padded decimal number.
%Y	Year with century as a decimal number.
%H	Hour (24-hour clock) as a zero-padded decimal number.
%I	Hour (12-hour clock) as a zero-padded decimal number.

Hint: timestamp

Quiz 1

- Automatically sunrise timelapse pictures
  - Execute the code, then take a series pictures at a specific time.
  - You might need “schedule” module.

AM 08:00, start capturing…



001.jpg

002.jpg

.

.

.

.

010.jpg

https://schedule.readthedocs.io/en/stable/

Python schedule

- Usage: pip install schedule

```
import schedule
import time

def job():
    print("I'm working...")

schedule.every(10).minutes.do(job)
schedule.every().hour.do(job)
schedule.every().day.at("10:30").do(job)
schedule.every().monday.do(job)
schedule.every().wednesday.at("13:15").do(job)
schedule.every().minute.at(":17").do(job)

while True:
    schedule.run_pending()
    time.sleep(1)
```

at(*time_str*) [source]

Specify a particular time that the job should be run at.

Parameters: **time_str** – A string in one of the following formats: *HH:MM:SS*, *HH:MM*,`:MM`, *:SS*. The format must make sense given how often the job is repeating; for example, a job that repeats every minute should not be given a string in the form *HH:MM:SS*. The difference between *:MM* and *:SS* is inferred from the selected time-unit (e.g. *every().hour.at(':30')* vs. *every().minute.at(':30')*).

Returns: The invoked job instance

https://picamera.readthedocs.io/en/release-1.10/recipes1.html
https://docs.python.org/2/library/time.html
https://docs.python.org/2/library/datetime.html

Quiz 2

- Take a picture with UNIX timestamp. (Ex: 1554282107)
  - Hint: read the online document and understand the definition of parameters

```
import picamera
import time

with picamera.PiCamera() as camera:
    camera.resolution = (640, 480)
    camera.framerate = 24
    camera.start_preview()
    camera.annotate_text = 'Hello world!'
    time.sleep(2)
    # Take a picture including the annotation
    camera.capture('foo.jpg')
```

Put message on picture

https://www.unixtimestamp.com/

What is UNIX timestamp?

The unix time stamp is a way to track time as a running total of seconds. This count starts at the Unix Epoch on January 1st, 1970 at UTC. Therefore, the unix time stamp is merely the number of seconds between a particular date and the Unix Epoch. It should also be pointed out (thanks to the comments from visitors to this site) that this point in time technically does not change no matter where you are located on the globe. This is very useful to computer systems for tracking and sorting dated information in dynamic and distributed applications both online and client side.

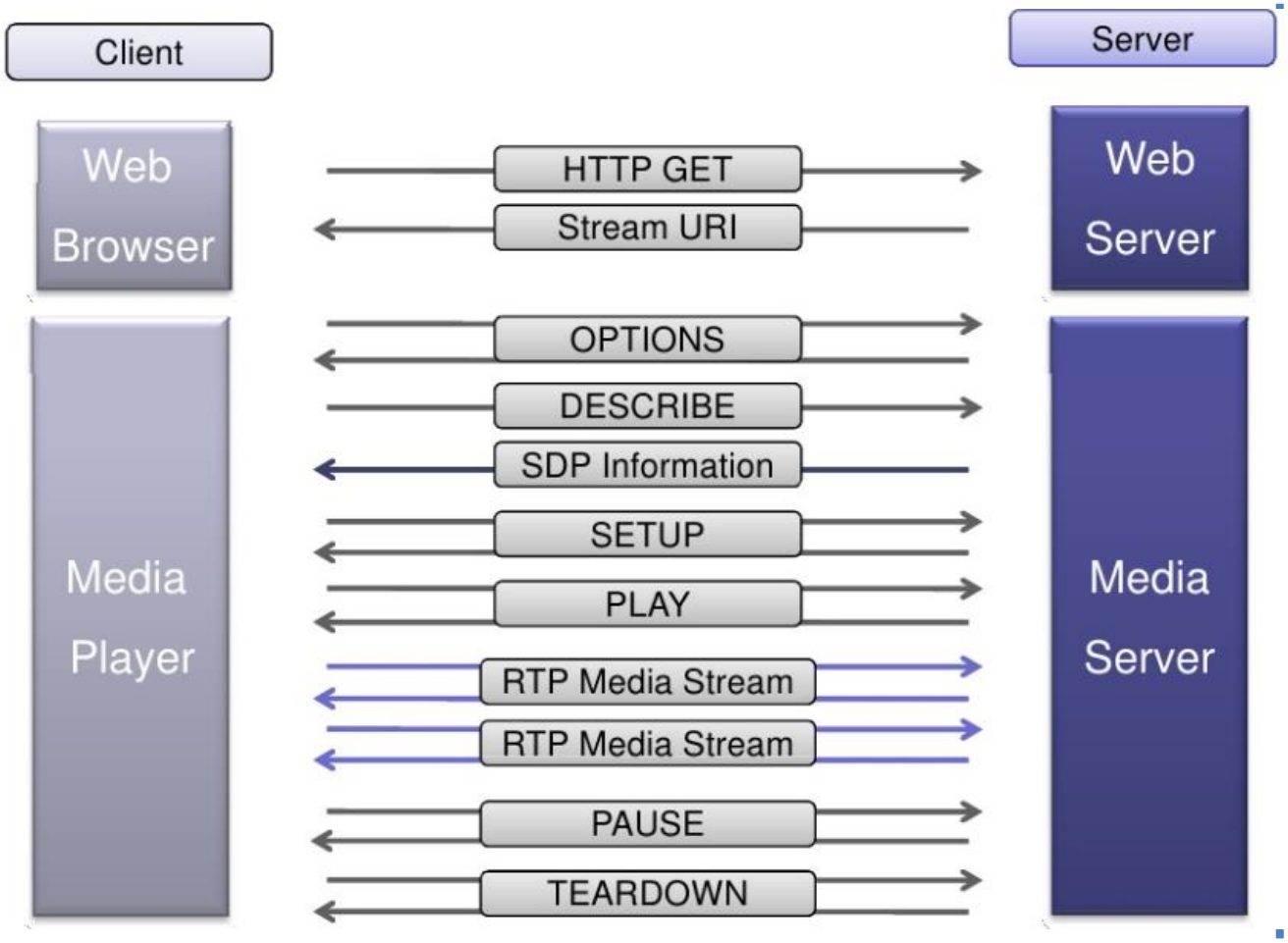
IP cam

- Video Streaming
  - 使用 RTSP + H.264
  - 使用 HTTP + MJPG
  - 使用 RTMP

https://www.slideshare.net/DSPIP/rtsp-analysis-wireshark
https://tools.ietf.org/html/rfc2326

1. RTSP

The Real Time Streaming Protocol, or RTSP, is an application-level protocol for control over the delivery of data with real-time properties. RTSP provides an extensible framework to enable controlled, on-demand delivery of real-time data, such as audio and video. Sources of data can include both live data feeds and stored clips. This protocol is intended to control multiple data delivery sessions, provide a means for choosing delivery channels such as UDP, multicast UDP and TCP, and provide a means for choosing delivery mechanisms based upon RTP (RFC 1889).



1. RTSP on Raspberry PI

- Execute the command

raspivid -o - -t 0 -hf -w 320 -h 240 -fps 15 | cvlc -vvv stream:///dev/stdin --sout '#rtp{sdp=rtsp://:8554}' :demux=h264

(COM8) [80x24]

連線(C) 編輯(E) 檢視(V) 視窗(W) 選項(O) 說明(H)

```
o=- 16162396461258043171 16162396461258043171 IN IP4 raspberrypi
s=Unnamed
i=N/A
c=IN IP4 0.0.0.0
t=0 0
a=tool:vlc 3.0.6
a=recvonly
a=type:broadcast
a=charset:UTF-8
m=video 0 RTP/AVP 96
b=RR:0
a=rtpmap:96 H264/90000
a=fmtp:96 packetization-mode=1;profile-level-id=640028;sprop-parameter-sets=J2QA
KKwrQKD9APEiag==,KO4BDyw=;

[75400520] main input debug: Buffering 66%
[75400520] main input debug: Buffering 73%
[75400520] main input debug: Buffering 80%
[75400520] main input debug: Buffering 86%
[75400520] main input debug: Buffering 93%
[75400520] main input debug: Buffering 100%
[75400520] main input debug: Stream buffering done (320 ms in 335 ms)
[75400520] main input debug: Decoder wait done in 0 ms
```

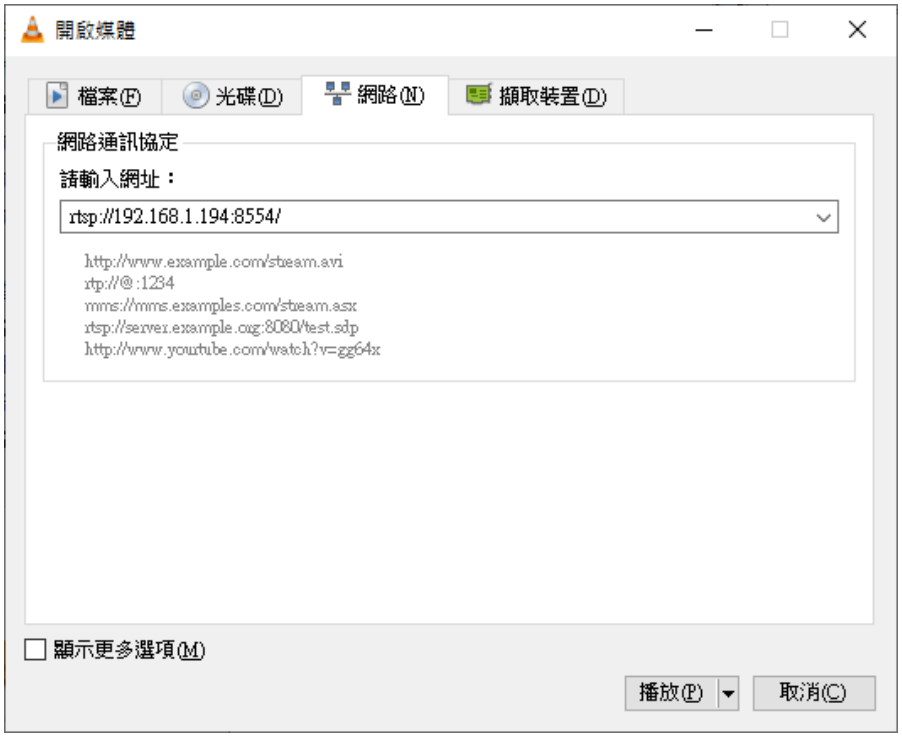
https://wiki.videolan.org/Documentation:Streaming_HowTo/Command_Line_Examples/
https://wiki.videolan.org/VLC_command-line_help/
https://helpmanual.io/help/cvlc/

1. RTSP on Raspberry PI

- cvlc -vvv stream:///dev/stdin --sout '#rtp{sdp=rtsp://:8554}' :demux=h264
  - stream: Stream MRL syntax: [[access][/demux]://]URL[#[title][:chapter][-title][:chapter]]] [:option=value ...]
  - /dev/stdin: Standard input. The source of input data for command line programs. Here, the input is from raspivid.
  - sout: stream output
  - rtp: A Transport Protocol for Real-Time Applications
  - sdp: RTSP Session Descriptions
  - rtsp: an application-level protocol
  - demux: handle the different formats

1. RTSP on Raspberry PI

- Use VLC to watch video



https://en.wikipedia.org/wiki/Real-Time_Messaging_Protocol
https://www.adobe.com/content/dam/acom/en/devnet/rtmp/pdf/rtmp_specification_1.0.pdf

2. RTMP

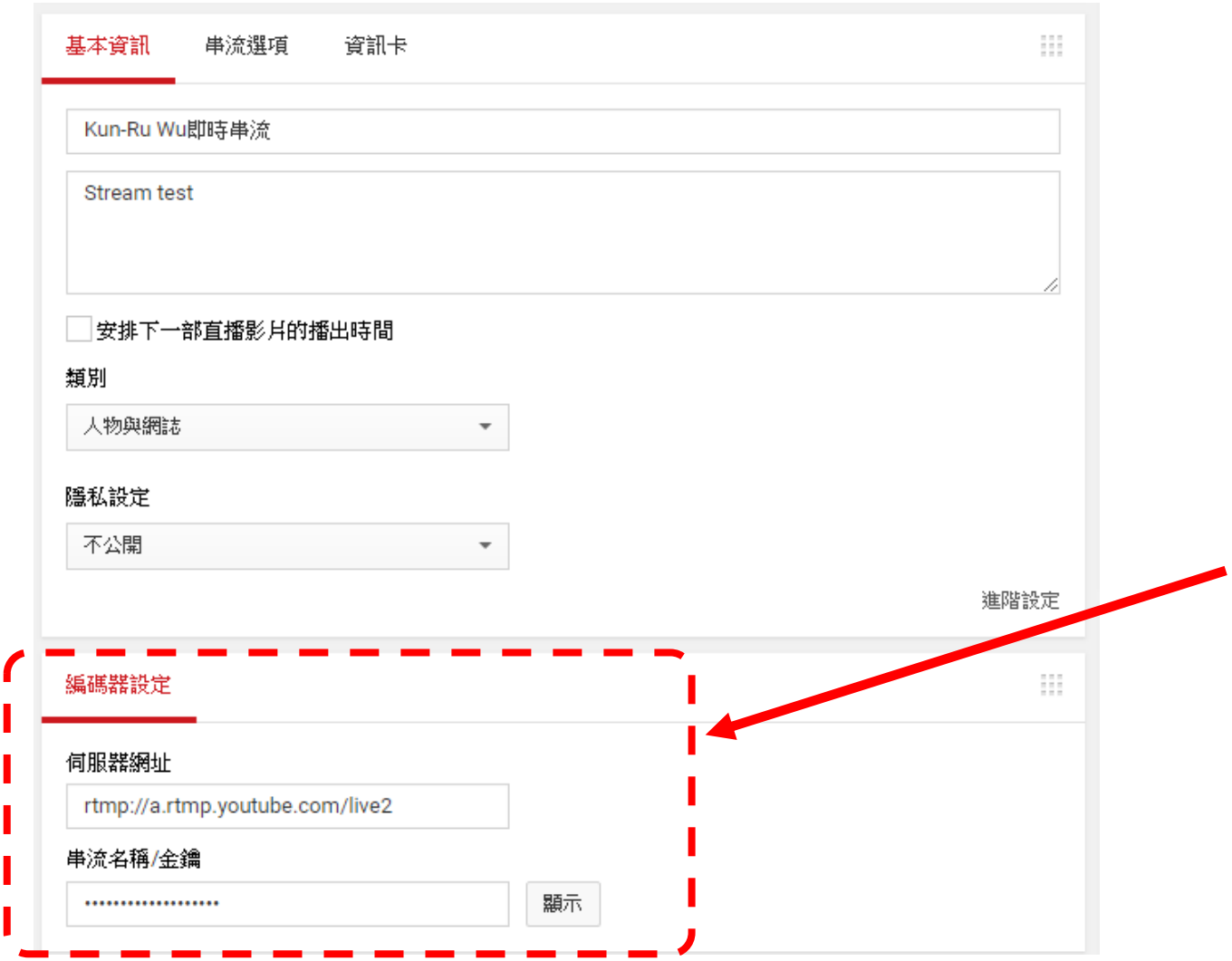
5.2.5. Handshake Diagram

```
+-------------+                           +-------------+
|    Client   |       TCP/IP Network      |    Server   |
+-------------+             |             +-------------+
      |                     |                     |
Uninitialized               |               Uninitialized
      |          C0         |                     |
      |-------------------->|          C0         |
      |                     |-------------------->|
      |          C1         |                     |
      |-------------------->|          S0         |
      |                     |<--------------------|
      |                     |          S1         |
 Version sent               |<--------------------|
      |          S0         |                     |
      |<--------------------|                     |
      |          S1         |                     |
      |<--------------------|                 Version sent
      |                     |          C1         |
      |                     |-------------------->|
      |          C2         |                     |
      |-------------------->|          S2         |
      |                     |<--------------------|
   Ack sent                 |                  Ack Sent
      |          S2         |                     |
      |<--------------------|                     |
      |                     |          C2         |
      |                     |-------------------->|
 Handshake Done             |               Handshake Done
      |                     |                     |
```

Pictorial Representation of Handshake

2. RTMP to Youtube

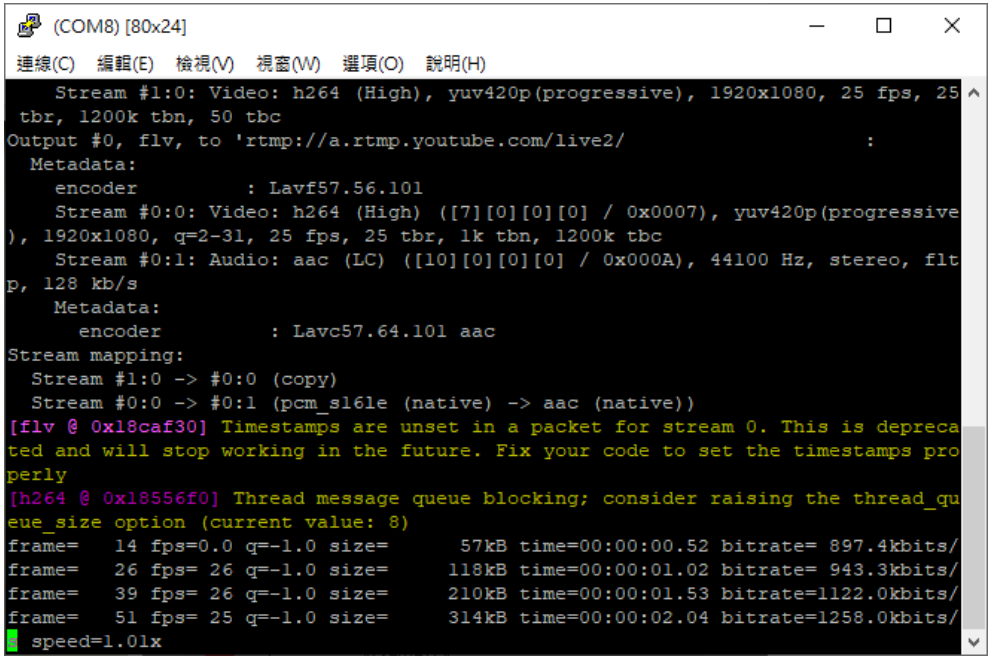
https://www.youtube.com/live_dashboard



2. RTMP on PI

- Execute command:

raspivid -o - -t 0 -vf -hf -fps 10 -b 500000 | ffmpeg -re -ar 44100 -ac 2 -acodec pcm_s16le -f s16le -ac 2 -i /dev/zero -f h264 -i - -vcodec copy -acodec aac -ab 128k -g 50 -strict experimental -f flv rtmp://a.rtmp.youtube.com/live2/**keyxxxx**

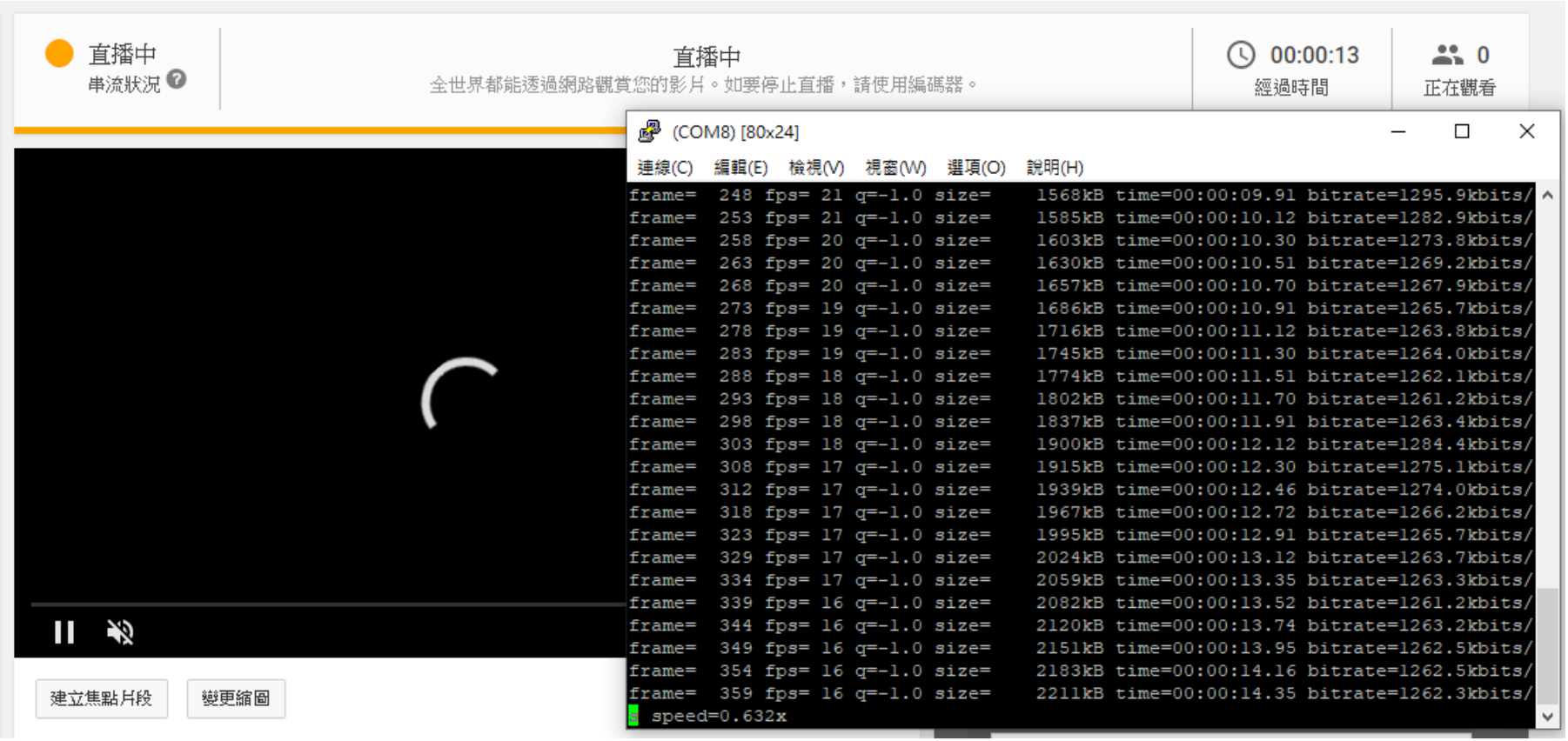


2. RTMP on PI

- ffmpeg -re -ar 44100 -ac 2 -acodec pcm_s16le -f s16le -ac 2 -i /dev/zero -f h264 -i - -vcodec copy -acodec aac -ab 128k -g 50 -strict experimental -f flv rtmp://a.rtmp.youtube.com/live2/keyxxxx
  - re: Read input at native frame rate.
  - ar: Set the audio sampling frequency.
  - ac: audio channels.
  - acodec: Set the audio codec.
  - f: Force input or output file format. (S16LE: 16-bit signed PCM audio)
  - vcodec: set the video codec. Use “copy” to indicate that the stream is not to be re-encoded.

2. RTMP on PI

- Start streaming…



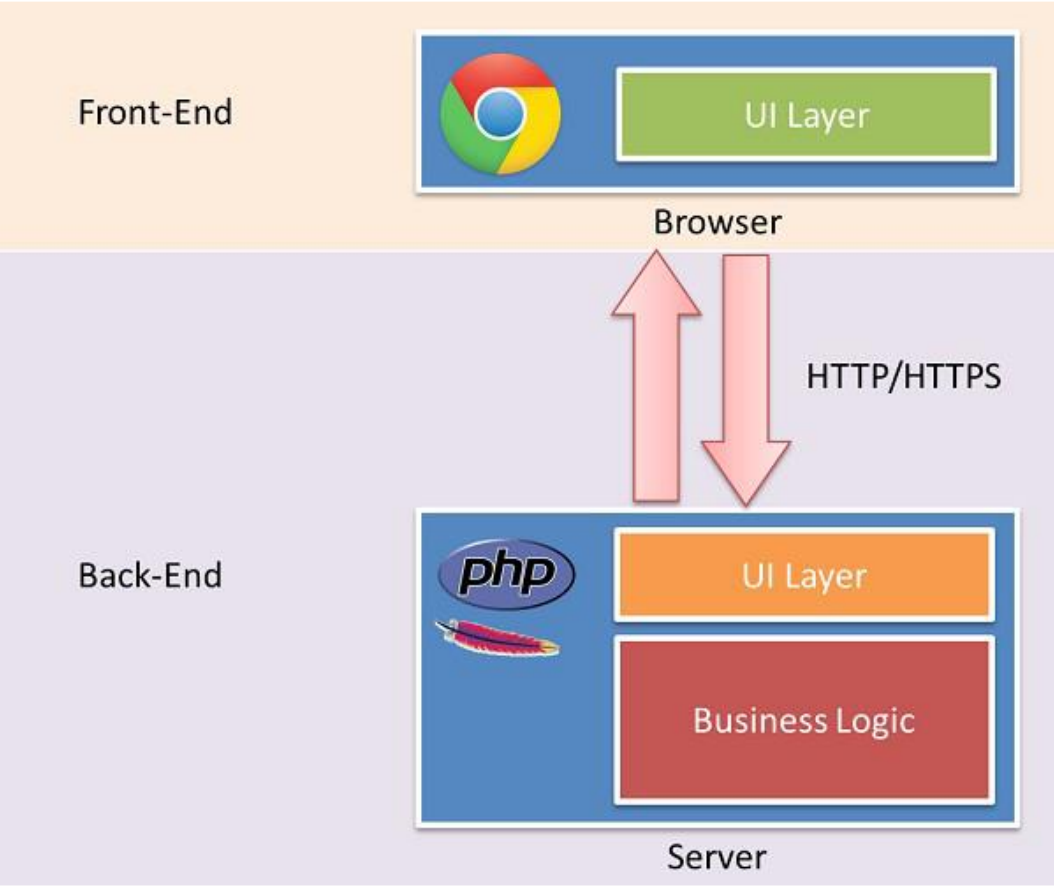
2. RTMP on PI

- Watch video

https://www.nczonline.net/blog/2013/10/07/node-js-and-the-new-web-front-end/
https://docs.microsoft.com/zh-tw/visualstudio/python/learn-flask-visual-studio-step-01-project-solution

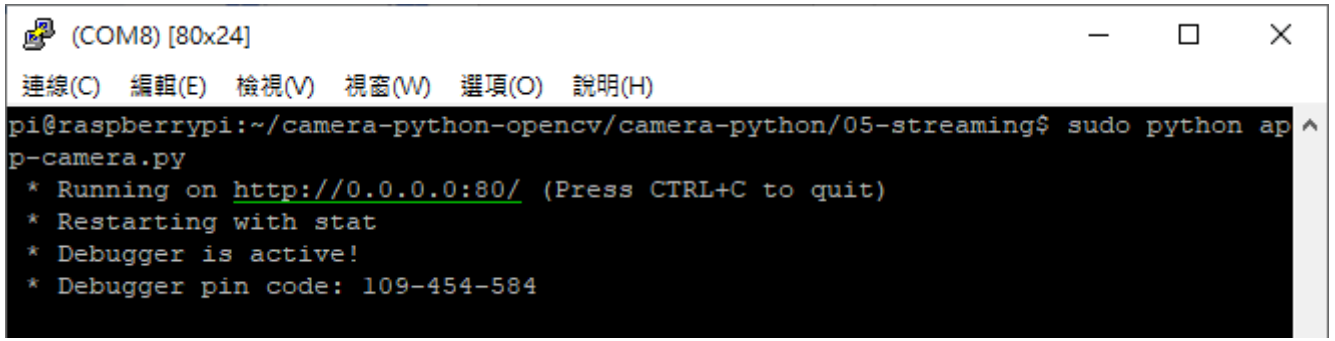
3. HTTP + MJPG

- MJPEG = Motion JPEG
  - 一種視訊壓縮格式
  - 每一個frame都使用JPEG編碼
  - 對運算能力與記憶體的需求較低
  - 許多網頁瀏覽器原生支援M-JPEG
- Flask 是一個輕量型的 Python Web 應用程式架構，可提供 URL 路由和頁面轉譯的基本要素。



3. HTTP + MJPG on PI

- Install tools:
  - sudo pip install request flask numpy
  - sudo modprobe bcm2835-v4l2
  - Download and unzip “5_mjpg_sample.zip” file
  - sudo python app-camera.py



http://flask.pocoo.org/docs/1.0/tutorial/layout/

3. MJPG on PI

- Sample code (app-camera.py)

```
from flask import Flask, render_template, Response
from camera_pi import Camera

app = Flask(__name__)

@app.route('/')
def index():
    return render_template('stream.html')

def gen(camera):
    while True:
        frame = camera.get_frame()
        yield (b'--frame\r\n'
               b'Content-Type: image/jpeg\r\n\r\n' + frame + b'\r\n\r\n')

@app.route('/video_feed')
def video_feed():
    return Response(gen(Camera()),
                    mimetype='multipart/x-mixed-replace; boundary=frame')

if __name__ == "__main__":
    app.run(host='0.0.0.0', port=80, debug=True)
```

```
<h1>Hello Stream</h1>
<img id="bg" src="{{ url_for('video_feed') }}">
```

https://docs.opencv.org/2.4/modules/highgui/doc/reading_and_writing_images_and_video.html

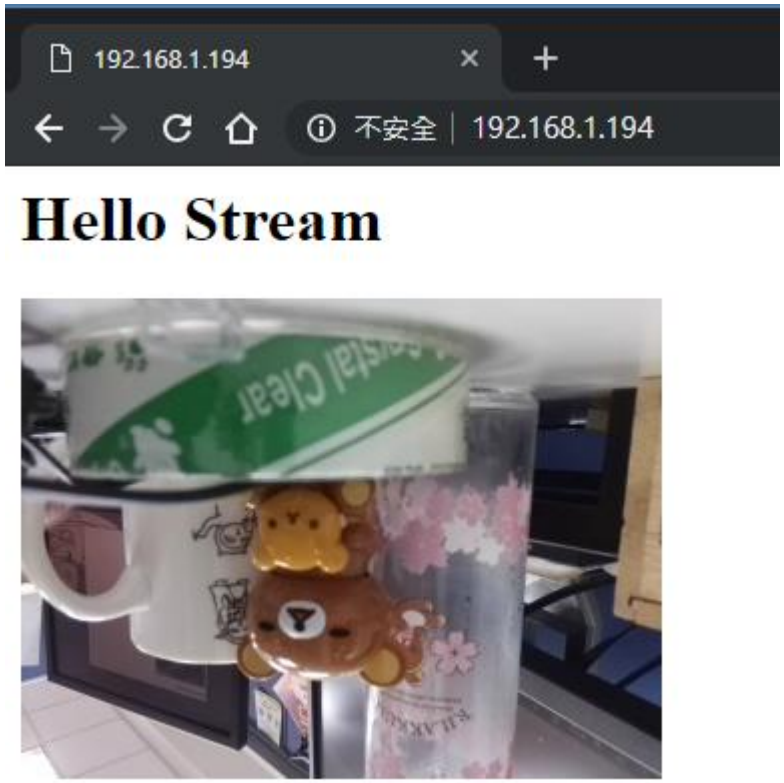
3. MJPG on PI

- camera_pi.py

```
import cv2

class Camera(object):
    def __init__(self):
        if cv2.__version__.startswith('2'):
            PROP_FRAME_WIDTH = cv2.cv.CV_CAP_PROP_FRAME_WIDTH
            PROP_FRAME_HEIGHT = cv2.cv.CV_CAP_PROP_FRAME_HEIGHT
        elif cv2.__version__.startswith('3'):
            PROP_FRAME_WIDTH = cv2.CAP_PROP_FRAME_WIDTH
            PROP_FRAME_HEIGHT = cv2.CAP_PROP_FRAME_HEIGHT

        self.video = cv2.VideoCapture(0)
        #self.video = cv2.VideoCapture(1)
        #self.video.set(PROP_FRAME_WIDTH, 640)
        #self.video.set(PROP_FRAME_HEIGHT, 480)
        self.video.set(PROP_FRAME_WIDTH, 320)
        self.video.set(PROP_FRAME_HEIGHT, 240)

    def __del__(self):
        self.video.release()

    def get_frame(self):
        success, image = self.video.read()
        ret, jpeg = cv2.imencode('.jpg', image)
        return jpeg.tostring()
```

3. MJPG on PI

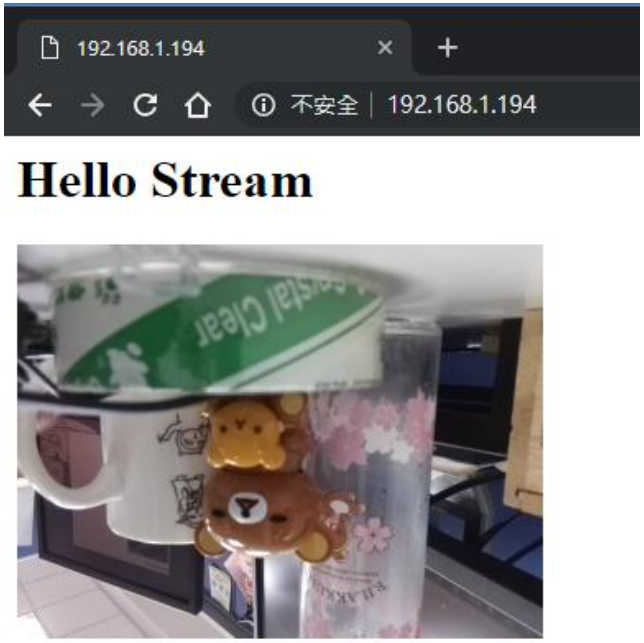
- Watch video



No stream? You might need: **sudo modprobe bcm2835-v4l2**

Discussion

- Try to use RTSP, RTMP and MJPG to stream your camera.
  - Put screenshot to show your result.



Summary

- Practice Lab (PI camera, RTSP, MJPG)
- Write down the answer for discussion
  - **Discussion:**
    - **1. Read the online document. How do we set filename in the code?**
    - **2. Show your RTSP and MJPG results**

- Write code for Quiz 1 - 2, then demonstrate it to TAs
  - **Quiz1: Timeslape**
  - **Quiz2: Camera overlay (put timestamp)**