Camera live streaming using H264 format

Use PiCamera to capture and make H264 video stream. Split video into H264 NAL units, and send over the internet via websocket. Decode H264 frames by Broadway.js.

#pi #stream #camera #h264 #python #picamera

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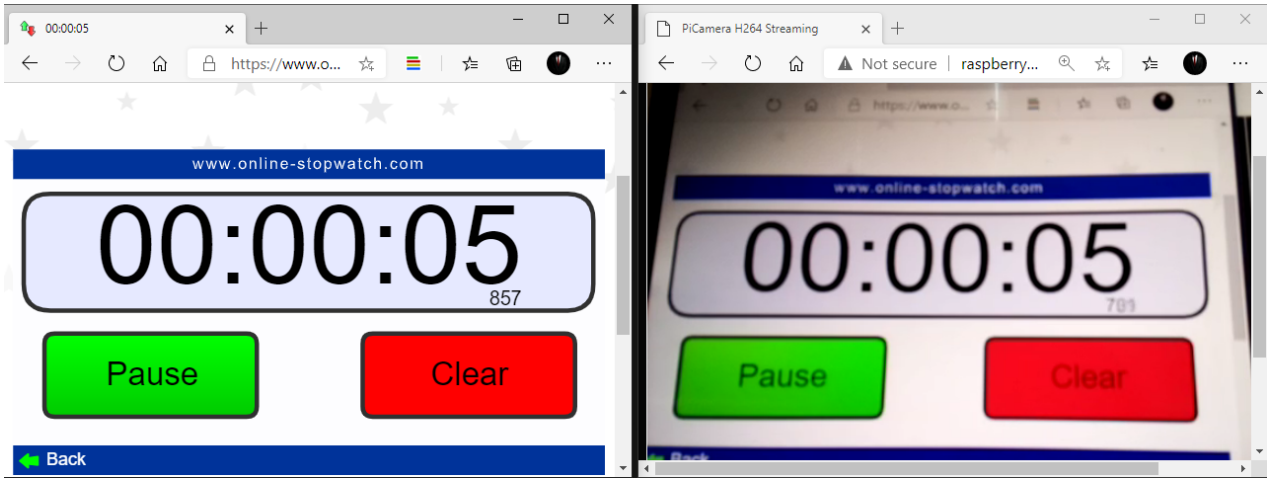

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Source code available at https://github.com/vuquangtrong/pi_streaming

An example of streaming real video (not frame by frame) is pistreaming which uses `mpeg1video` format. The video stream is sent to user's browser via a `websocket`, and is decoded by JSMPEG javascript library.

1. Broadway.js - H264 decoder

The h264-live-player is used for streaming an Android screen to a webpage. That player uses Broadway.js to decode the video stream. It also has a streaming server for Raspberry Pi using `raspivid`, `nodejs`, `websocket`, and `Broadway.js`.

The method used in that player is quite similar to MJPEG Streaming: video stream is split into NAL units (h264 frames), then transported using websocket, and finally decoded by the Broadway.js library.

Broadway.js provides `Player.js`, `Decoder.js`, `YUVCanvas.js`, and `avc.wasm`, with very simple usage: create a new Player object; then put the player's canvas to an element to display the video; and call decode function on the stream data.

```
var player = new Player({<options>});
playerElement = document.getElementById(playerId)
playerElement.appendChild(player.canvas)
player.decode(<h264 data>);
```

2. Create a webpage

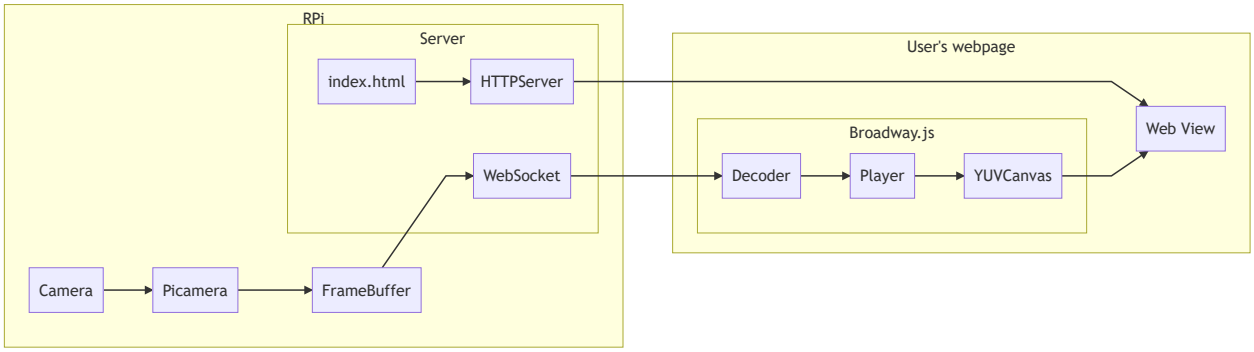
The webpage firstly loads necessary libraries and requests to open a websocket connection, then feeds Broadway decoder with a streaming data chunk by calling `player.decode()` method.

index.html

```
<!DOCTYPE html>
<html>

<head>
  <meta charset='utf-8'>
  <title>PiCamera H264 Streaming</title>
</head>

<body>
  <h1>PiCamera H264 Streaming</h1>
  <div id='viewer'></div>
  <script src='Decoder.js'></script>
  <script src='YUVCanvas.js'></script>
  <script src='Player.js'></script>
  <script>
    // player
    window.player = new Player({ useWorker: true, webgl: 'auto', size: { width:
848, height: 480 } })
    var playerElement = document.getElementById('viewer')
    playerElement.appendChild(window.player.canvas)
    // Websocket
    var wsUri = window.location.protocol.replace(/http/, 'ws') + '//' +
window.location.hostname + ':9000'
    var ws = new WebSocket(wsUri)
    ws.binaryType = 'arraybuffer'
    ws.onopen = function (e) {
      console.log('Client connected')
      ws.onmessage = function (msg) {
        // decode stream
        window.player.decode(new Uint8Array(msg.data));
      }
    }
    ws.onclose = function (e) {
      console.log('Client disconnected')
    }
  </script>
</body>

</html>
```

3. Create server

Here is the structure of streaming system:



3.1. Frame buffer

The `FrameBuffer` is implemented as an output of Picamera which store each H264 Network Abstraction Layer (NAL) unit from H264/AVC or HEVC video stream. There is a `Condition` object to synchronize between `FrameBuffer` and `WebSocketServer`.

For more detail of how to construct FrameBuffer class, refer to Streaming using MJPEG

```
import io
from threading import Condition

class FrameBuffer(object):
    def __init__(self):
        self.frame = None
        self.buffer = io.BytesIO()
        self.condition = Condition()

    def write(self, buf):
        if buf.startswith(b'\x00\x00\x00\x01'):
            with self.condition:
                self.buffer.seek(0)
                self.buffer.write(buf)
                self.buffer.truncate()
                self.frame = self.buffer.getvalue()
                self.condition.notify_all()
```

3.2. HTTP Server

The web interface server is served by `ThreadingHTTPServer` with `SimpleHTTPRequestHandler` to serve requested files (`index.html`, `*.js`, etc.).

```
from http.server import SimpleHTTPRequestHandler, ThreadingHTTPServer
from threading import Thread
```

```
httpd = ThreadingHTTPServer(('', 8000), SimpleHTTPRequestHandler)
httpd_thread = Thread(target=httpd.serve_forever)
```

3.3. Websocket Server

One of WebSocket packages for Python is ws4py which supports both Python 2 and Python 3 (while websockets requires Python ≥ 3.6.1).

From the package `ws4py`, use module `wsgiref` as a Web Server Gateway Interface to make a websocket server.

The function `make_server()` needs to know the port, and some classes to initialize a server, those can be built-in objects in `ws4py` such as `WebSocketWSGIRequestHandler`, `WebSocketWSGIApplication`, and base `WebSocket`.

Finally, a client manager should be created in the websocket server, to use broadcasting function later.

```
from wsgiref.simple_server import make_server
from threading import Thread

websocketd = make_server('', 9000, server_class=WSGIServer,
    handler_class=WebSocketWSGIRequestHandler,
    app=WebSocketWSGIApplication(handler_cls=WebSocket))
websocketd.initialize_websockets_manager()
websocketd_thread = Thread(target=websocketd.serve_forever)
```

3.4. Main thread

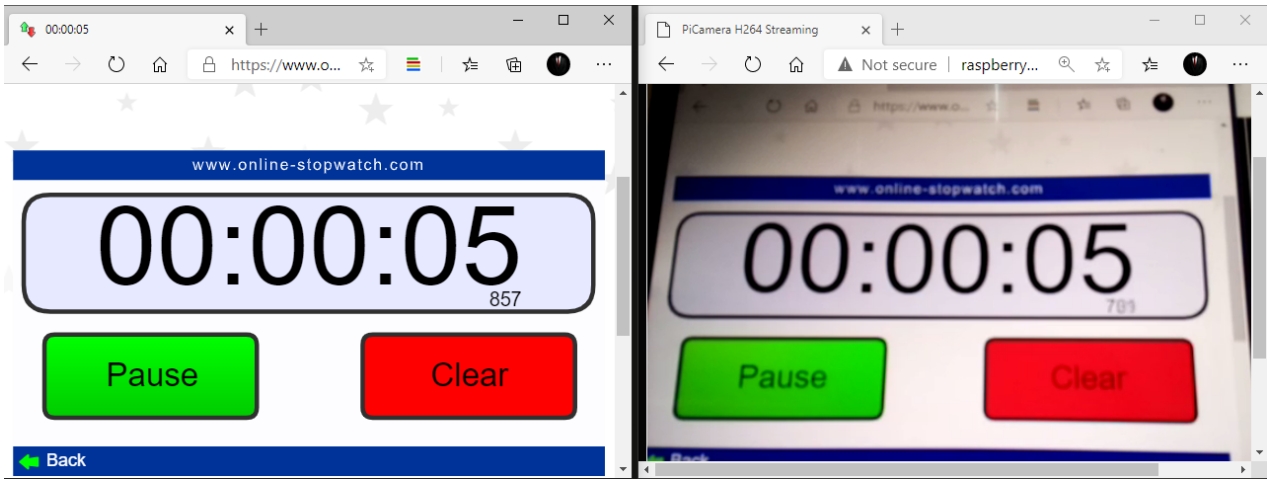
The main application will start PiCamera and write output video in `h264` encode. As noted in Broadway.js, it only supports H264 **Baseline** profile, therefore, set `profile="baseline"` when starting video record.

```
import picamera

with picamera.PiCamera(resolution='640x480', framerate=24) as camera:
    broadcasting = True
    frame_buffer = FrameBuffer()
    camera.start_recording(frame_buffer, format='h264', profile="baseline")
```

The main loop should broadcast H264 NAL units to all connected clients, after it starts threads for HTTP Server and WebSocket Server.

```
try:
    websocketd_thread.start()
    httpd_thread.start()
    while broadcasting:
```

```
        with frame_buffer.condition:
            frame_buffer.condition.wait()
            websocketd.manager.broadcast(frame_buffer.frame, binary=True)
```



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There may be some delay before the video shows up in user webpage because the Player has to wait for a Main Frame to be able to start decoding.

Some lines of code to handle exception are also needed, for full source code, please download by clicking the below button:

Download stream_picamera_h264