Utilising Raspberry Pi as a cheap and easy do it yourself streaming device for astronomy

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Abstract. Recent developments in personal computing platforms have been revolutionary. With the advent of the Raspberry Pi series and the Arduino series, sub USD 100 computing platforms have changed the playing field altogether. It used to be that you would need a PC or an FPGA platform costing thousands of USD to create a dedicated device for a dedicated task. Combining a PiCam with the Raspberry Pi allows for smaller budgets to be able to stream live images to the internet and to the public in general. This paper traces our path in designing and adapting the PiCam to a common sized eyepiece and telescope in preparation for the TSE in Indonesia this past March.

1. Introduction
Astronomy education and outreach programs in this information era can benefit a lot from the advances in technology. One of the technologies that currently flourishes is live video streaming which has become a common thing for people who have access to Internet. Many people and organisations has already use this technology to broadcast astronomy related events.

To be able to capture astronomy event and broadcast it lives, the basic setup usually comprise of telescope, specifically design camera for telescope and computer or laptop. This setup is relatively expensive and not easy to acquire in Indonesia, especially for the camera.

A few months prior the 2016 Total Solar Eclipse (TSE), we had made plans to broadcast the event to the public around the observation area using a big screen and if possible to the Internet simultaneously. We were trying to build a cheaper and simpler setup for the live streaming event with hope it can be replicated easily so other people can also reap the benefits.

2. Astrophotography method using digital camera
There are three basic methods to capture an image from a telescope using a camera[1]:

(i) Prime Focus[2]: the camera is connected directly to the telescope, with no lens on the camera, and no eyepiece in the telescope so the telescope takes the place of the camera lens.

(ii) Eyepiece projection[3]: an eyepiece is used in the telescope but no lens is used on the camera. The eyepiece projects the image directly onto the camera sensor. This produces more magnification compared to prime focus.

(iii) Afocal[4]: the camera with the lens on it focused on infinity attached to the telescope with an eyepiece also focused at infinity. It’s the best method for any camera with non-removable lens.

For eyepiece projection and afocal method, we have to calculate the distance between the eyepiece and the camera sensor or lens to get the focused image.
3. Hardware design
We decided to use a Raspberry pi mini computer and pi camera module (PiCam) as the computer and camera sensor for the streaming hardware because it is cheap, simple, and relatively easy to be bought on online or offline electronic store. It’s also open to be modified and customised to meet other requirement outside the video streaming purposes.

3.1. Raspberry Pi
The Raspberry Pi is a series of credit card-sized single-board computers developed in the United Kingdom by the Raspberry Pi Foundation with the intent to promote the teaching of basic computer science in schools and developing countries[5].

The Raspberry Pi 2 model B used in this paper has a Broadcom BCM2836 900 MHz 32-bit quad-core ARM Cortex-A7, 1GB onboard memory shared with Broadcom VideoCore IV @ 250 MHz 3D GPU with 1080p30 H.264/MPEG-4 AVC high-profile video decoder and encoder. It is powerful enough to be used as a video streaming device and it cost about USD 40 (IDR 550,000)

3.2. Pi Camera module (PiCam)
We are using the Raspberry pi camera module (PiCam) version 1.3 which can be connected directly to the Raspberry Pi board via CSI connector using a ribbon cable provided on the package. The camera module features a 5MP Omnivision 5647 CMOS sensor with 1.4 μm X 1.4 μm pixel size and fix focused lens able to deliver a 2592x1944 pixels resolution still image, or 1080p HD video recording at 30fps[6]. The PiCam module is cost about USD 30 (IDR 350,000)

3.3. Telescope attachment and accessories
To attach the Raspberry pi and PiCam to the telescope, we made an attachment out of PVC pipe. We used a $\frac{3}{4}$-inch pipe for the prime focus attachment and 1$\frac{1}{2}$-inch pipe for the eyepiece projection and afocal, and other additional part from an acrylic sheet.

![Figure 1. Prime focus adapter](image1)

![Figure 2. Eyepiece projection and Afocal adapter](image2)

Other hardware we used was a USB Wifi dongle for network connection, a USB power 5V 2A adapter to run the system, and 3.5 inch LCD screen for raspberry pi to make the focusing easier. The total cost for the system is a little less than USD 100 and we can save more if we didn’t use the LCD screen (cost about USD 17).

4. Software
Installing Rasbian Linux on Raspberry Pi is quite easy. After the installation is finished, run the post installation step and enable the camera feature in order to be able to use the PiCam.

Next we need to install ffmpeg software and get the YouTube stream URL before we can start to stream the video from PiCam. Testing the system can be done by running below command on the terminal[7]:

```bash
ffmpeg -v info -f alsa -i /dev/raspberrypi -f h264 - | ffmpeg -i - -c:v libx264 -preset veryfast -c:a aac -f flv -
```
We should be able to see the video preview on the screen and on YouTube at the same time. Although the video on YouTube will have a few second delays depending on the internet speed.

All the detailed installation and setup process is available on the Internet and can be followed easily by any person with basic computer or technical skill.

5. Testing the system
We used a Celestron Travel Scope 70 400mm f/5.71 and Vixen Optics VMC110L 1035mm f/9.4 Maksutov-Cassegrain for the telescope. But for the 2016 TSE we used the Vixen telescope as it has a motorised mounting.

We tested the system on the moon as it relatively has the same apparent angular size as the sun. It’s easier to find on the telescope and also safer for the camera sensor and our eyes in case we forget to attach the solar filter.

A recommended internet connection speed for a video broadcast is about 300kbps[8] (2G connection[9]). We used Telkomsel 3G connection on WIFI modem for the live streaming test as Telkomsel have the widest network coverage and 3G speed for a good video quality.

(i) For the prime focus method, we will need to remove the pi camera lens without damaging it by carefully removing the adhesive and rotating the lens counter clockwise. The sensor size on the PiCam is small so the FOV will be narrow. Using the FOV calculator from [http://astronomy.tools](http://astronomy.tools) we saw that the resulting image of the moon will be cropped. Running the test command from before we saw a conforming result as the FOV calculator.

(ii) We used a 40mm eyepiece for the eyepiece projection and afocal method as the other eyepiece that we have has a narrow FOV. We couldn’t get a focus image when we tested the eyepiece projection method due to problem on the adapter.

(iii) We were able to get a good quality and focused image of the sun using the afocal method. The FOV is also suitable for monitoring the solar eclipse.

6. Testing the system on 2016 TSE
During 2016 TSE, as part of the langitselatan program, we setup an outreach and educational event at SMKN 1 Maba, North Maluku. We used a 21” LCD TV screen for public viewing.
The sky during the event was cloudy and the sun was covered by clouds. A few minutes after the first contact it was raining so we had to stop everything, cover all the equipment, and move it to a dry and safer place. After the rain has stopped, the sky was still cloudy and we decided to cancel the public viewing and streaming for fear it would be rain again.

7. Result and conclusions
Outreach and education programs in astronomy can benefit from current technological advances such as live video streaming to spread the knowledge and message to all people without any physical boundaries.

The basic setup for providing a live video streaming event doesn’t have to be expensive and can be achieved by utilising a sub USD 100 computing platforms such as Raspberry pi equipped with pi camera module.

Based on our test the image quality attained by the setup is good enough to be used for public viewing and with a little bit of adjustment and configuration, the system can be comparable with other dedicated astronomical camera system with the advantage of a simpler and more affordable setup.

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