Efficient and Flexible Live Streaming from Telescope

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Abstract — **One of the aspects of educational use of an astronomical observatory is organizing live streaming sessions. In order to succeed it is necessary to choose the right methodology of organizing such events, which would allow balancing between the image quality, bandwidth limitations and number of desired visitors in the best way.**

Index Terms — **Live, streaming, single board computer, camera, motion jpeg**

I. INTRODUCTION

Organizing live streaming from telescope is a hard task because there must be always considered 2 constraints. First one is the type of the object to be streamed. Celestial objects, even big ones such as Sun and Moon, are captivating only for theirs small features – spots on the Sun, craters on the Moon or bands on the Jupiter. In order to distinguish fine details of these features, the image quality must be very high (high resolution and low compression rate). The second one constraint is network bandwidth. Bandwidth imposes restriction on how many visitors can attend a live streaming session. In order to overcome in an efficient and reliable manner these 2 constraints, a methodology was elaborated. It proved to be low-cost, high-performance and flexible solution. Multiple trial runs and one public session were successfully conducted.

II. IMAGE CAPTURING

First step for achieving a live streaming from a telescope is capturing the image through it. This can be done with the help of different kinds of cameras – astronomical, webcam, IP, DSLR, etc. First one type which was tested is astronomical one. Several models were tested and all of them proved to be unusable specifically for Sun image capturing – too high sensitivity, even with the use of ND-filters. One webcam, with a custom box for fitting into telescope, was also tested, but shows the same signs as astronomical cameras – too high sensitivity and too small range of exposure setting. A high-end security IP camera, after adapting it to fit the telescope, was tested too. It has proved to be a viable solution, the achieved image quality is very high, but so is the bandwidth requirement – around 16 Mbps at the resolution of 2048x1536@7.5fps. DSLR also proved to be a viable solution if used in photo mode and with corresponding post-processing. But because of the post-processing step, requirements to the controlling PC are pretty high. Nevertheless, this solution is one of the accepted for the Sun and Moon because it meets both main constraints and has a large field of view.

Last camera which was tested is Raspberry Pi Camera. In order to use it is necessary to have one of the Raspberry Pi Single Board Computer (model B+ was chosen for having the Ethernet module on-board, which introduce much lower latency than Wi-Fi) and a corresponding adapter for telescope (as in case with webcam and IP camera it was produced using 3D printer). It is a low-cost solution, but with a wide range of possibilities because Raspberry Pi SBC is Linux-powered, which gives freedom in choosing and implementing the necessary software part. Raspberry Pi Camera has a resolution of 5 Mpixels, is handled by GPU (leaving CPU free for other tasks), a very wide range of exposure setting and full control of all other aspects of the capturing. As in case with DSLR, Pi Camera is best used in photo mode. In this way is achieved full control over number of frames per second, giving the possibility to shape the bitrate of the output stream. Raspberry Pi Camera proved to be able to capture Sun, Moon and Jupiter with great success, completely overcoming main constraints.

III. IMAGE PROCESSING AND TRANSPORTATION

Live streaming session can be both useful not only from educational point of view, but from scientific too. Cameras can capture in RAW format, but it is inconvenient for streaming because of large size and it is not fitted for human eye perception. In order to preserve the possibility to capture RAW images and to present visitors with easy-perceivable images, pre-processing is necessary. After RAW image is captured, a new image is generated from it with desired processing (e.g. debayering, hue manipulation, contrast enhancement, etc.). Resulting image is then served to visitor, and the RAW one is saved for more rigorous and in-depth processing by scientists.

Current architecture is using PUSH principle – PC which is controlling the camera is sending images to the PC which works as a web-server. The later is doing the processing part and serves the resulting image to the desired web page. Transportation of the RAW image from PC to the web server is a process which is very sensitive to the latency of the used transport protocol. Testing showed that FTP and SFTP are very high-latency transport protocols and could not be used for the

chosen purpose. Network File System, NFS, showed much better results with very low latency, thanks to the direct Linux kernel handling.
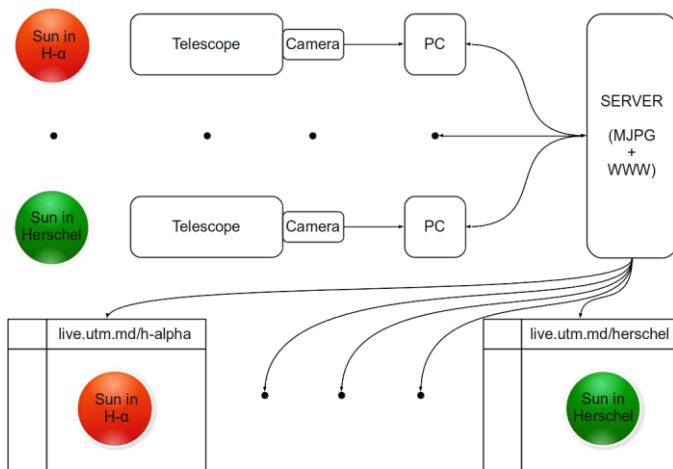

Fig. 1. Overall architecture of the live streaming system.

IV. IMAGE SERVING

Easiest way of getting the new images which are captured by the telescope to a viewer is to transform them into a video stream. For this purpose is used MJPG-streamer. This piece of software is able to constantly monitor new images in a folder and push them into a video stream. And even more – it makes the stream accessible by HTTP and has very low resource consumption. This gives the ability to embed it into any webpage.

MJPG-streamer, as well as the main web server, is installed on the server. This has the advantage that in case of Denial-of-Service attack on the server, PC which is controlling the camera won't be affected in any way and will continue its work. Also, in case of traffic congestion visitors are still able to watch the stream, but with a reduced rate of frames per second. For redundancy and fallback purposes the pictures from PC can be easily sent to several web servers at the same time, allowing to stream on several web sites (which can be even hosted by different providers in different countries). Another solution for redundancy and failback is usage of the peer-to-peer technology (e.g. AceStream). It allows to reduce drastically bandwidth requirements and connection of unlimited number of viewers (more viewers – more stable streaming). Last one solution for backup streaming is using one of the existing well-known on-line services e.g. Ustream and YouTube. For high-quality on Ustream is necessary to pay, on YouTube it is free but the video bitrate is not enough for preserving fine details. And there are also other problems – Ustream can stream only from traditional camera sources for free, for HTTP re-transmission is necessary to install shareware Windows software; YouTube allow as input only traditional cameras and desktop sharing. Altogether, this services can be used, but without flexibility and easiness (especially if using free services).

Fig. 2. View of the live.utm.md on the 20th of March 2015. This website was created for streaming captured images from 3 telescopes prepared for observing solar eclipse.

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