Realisation and validation of

stand alone stratum 1 time server

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Besançon
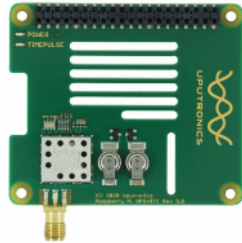
Realisation of the server: hardware part

- Raspberry Pi board
- 8 to 16 GB micro SD card
- Power supply 5V 2A
- GPS extension board
- GSP antenna

- The Uputronics GPS expansion board [2] is available from Kubii [3].
- A case to hold the Raspberry board and the GPS board [4].
- The power supply is a rechargeable battery pack so it can be used in the fields.
- A crossed RJ45 cable to connect the Raspberry Pi directly to the Windows-based acquisition computer
- A keyboard, a mouse and an HDMI screen.

Realisation of the server: software part

The Raspberry Pi OS

Downloading and installing the OS on the SD card is done with Raspberry Pi Imager [5].

The ntp server

For installation of a stand alone time server see Appendix A.

Stand Alone Mode

The NTP requires an internet connection to operate by fetching a time reference from a dedicated server on the internet. From this reference the local NTP corrects the variations of the Raspberry system clock.

The "Stand Alone" mode allows the server to operate without an internet connection. This mode is particularly useful for a mobile observation station.

The time server used for for this study was built in 2016 on a Raspberry Pi 2 base and the Raspian Jessie OS, following the instructions described at that time on the HAB site (now Uputronics).

The SEXTA

Hardware part

The SEXTA allows the verification of the time stamp of the images of a video.
This is **the reference device** currently used for this purpose.
SEXTA was described by Dave Gault and Tony Barry at ESOP 2019 in Paris [7].

Software part

The recorded video images are read by the **SEXTAreader** software.
The first step is to obtain a calibration image that allows us to identify the position of the LEDs ("Map").
In the second step, decoding allows us to obtain the **time stamps of the beginning and end of** the exposure of the images.
These timestamps can then be compared to the timestamp made by the video software.
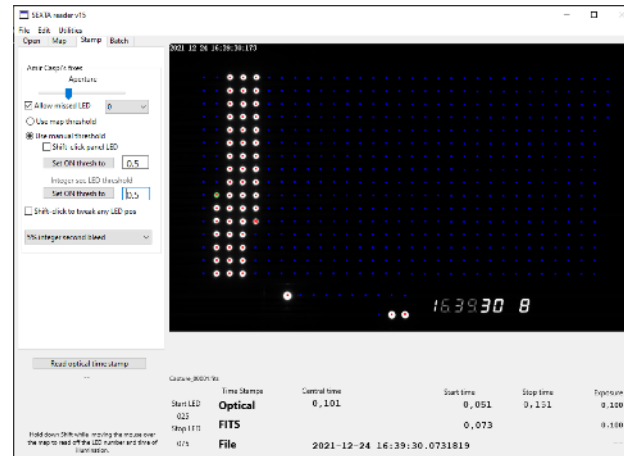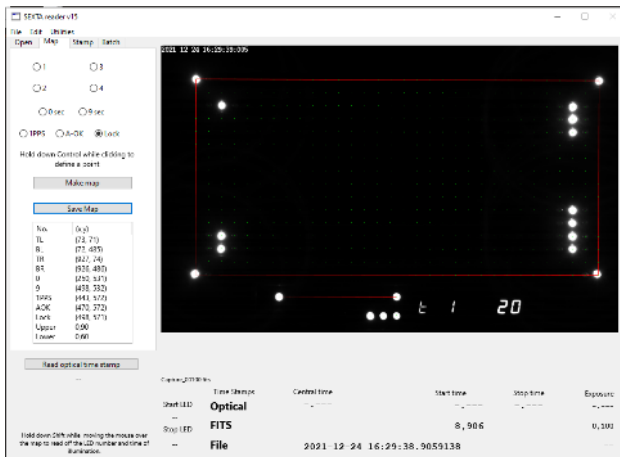
Recording of the videos: equipment used

- An Asus N750J laptop

  i7 processor at 2.4 GHz, 16 GB RAM, SSD disk, Windows 10 Home.
  the computer passes the "TSC invariant" test with OccuCheckTime by H. Pavlov [8].

- One crossed RJ45 cable

- The time server described above.

  The server is connected directly to the computer via the crossed RJ45 cable and regulates the computer's Windows system clock.

- A USB3 cable to connect the computer to the camera

Two cameras were tested:

- ZWO ASI 174MM
- QHY174M-GPS

Recording videos: software used

- **Sharcap**

  version 4.0.8395.0 for all video recordings [9].

- **SEXTAreader**

  Version 1.7 for the exploitation of videos.
  This latest version fixes some problems encountered with the previous versions 1.5 and 1.6 [10].

- **NTP Meinberg**

  Meinberg provides a free "full NTP" under Windows as an easy-to-install executable package [11].
  The reliability of this software has been tested by H. Pavlov and D. Gault [12].

- **NTP Server Monitor**

  The NTP Time Server Monitor software from Meinberg allows you to configure NTP in Windows and monitor its operation [13].

- **NTP Plotter**

  This software allows to obtain graphs of NTP operation over a whole day from the loopstats file [14].

  Note:
  More information about ntp can be found on David Taylor's website [15].

Measurement protocol

- All the equipment is powered up **30 minutes to 1 hour** before use

  allow the GPS to obtain its 3D FIX and the time server to regulate the Windows system clock.

- With the Meinberg NTP Monitor software check that the offset is less than 1 millisecond.

- Record of a first video in FITS format to make the " Map ".

- Then record a serie of four 600 frames videos in FITS format for each set of selected parameters.

- The videos are processed with SEXTAreader.

Results ZWO ASI 174MM camera

Example 1
Capture area = 1936x1216, binning = 2, exposure = 100 ms, Turbo USB = 80, gain = 10; average of the values on the last line.

DO(n)-SS(n)	3σ	SE(n)-SS(n)	3σ	SS(n+1)-SS(n)	3σ	SE(n+1)-SE(n)	3σ	DO(n+1)-DO(n)	3σ
22,003	1,853	99,947	0,967	100,097	1,727	100,097	1,727	100,096	0,510
22,017	1,842	99,933	1,078	100,097	1,620	100,097	1,582	100,095	0,635
22,047	1,836	99,957	0,873	100,097	1,617	100,097	1,617	100,095	0,544
22,037	1,808	99,947	0,967	100,097	1,543	100,097	1,619	100,096	0,598
22,026	**1,835**	**99,946**	**0,971**	**100,097**	**1,627**	**100,097**	**1,636**	**100,095**	**0,572**

DO :   SharpCap DATE-OBS ....../ System Clock:Est. Frame Start (Fits file header)
SS :   SEXTA Start Time
SE :   SEXTA End Time

SE(n)-SS(n) :   corresponds to the duration of SEXTA exposure
SS(n+1)-SS(n) :   regularity of SEXTA Start
SE(n+1)-SE(n) :   regularity of SEXTA End
DO(n+1)-DO(n) :   regularity of the SharpCap timestamp

DO(n)-SS(n):   time difference between the SharpCap frame start time stamp and the one measured by SEXTA.
DO(n)-SS(n):   Acquisition delay defined by D.Gault and H. Pavlov [12]

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Conclusion :

The parameter set corresponds to the one used for occultations.

The **acquisition delay** can be considered as **constant** and equal to **22.0 ms**.

The measurements are 99.7 % within the interval ± 1.9 ms.

Results ZWO ASI 174MM camera

Example 2

Capture area = 968x608, binning = 1, exposure = 100 ms, Turbo USB = 80, gain = 10; average of values in ms on the last line.

DO(n)-SS(n)	3σ	SE(n)-SS(n)	3σ	SS(n+1)-SS(n)	3σ	SE(n+1)-SE(n)	3σ	DO(n+1)-DO(n)	3σ
5,596	1,777	99,947	0,968	100,057	1,563	100,057	1,524	100,058	0,201
5,605	1,782	99,947	0,966	100,060	1,499	100,060	1,499	100,057	0,223
5,600	1,757	99,944	0,995	100,057	1,520	100,057	1,520	100,057	0,196
5,582	1,808	99,947	0,967	100,060	1,616	100,057	1,440	100,057	0,219
5,578	1,767	99,947	0,966	100,057	1,480	100,057	1,480	100,057	0,206
5,592	**1,778**	**99,946**	**0,972**	**100,058**	**1,536**	**100,057**	**1,493**	**100,058**	**0,209**

Conclusion :

The parameter set corresponds to the one used for occultations.

The **acquisition delay** can be considered as **constant** and equal to **5.6 ms**.

The measurements are 99.7 % within the interval ± 1.8 ms.

Summary of results for ZWO ASI 174MM camera

Influence on the acquisition delay

Parameter	Influence	± 3 σ
Exposure	NO	2,0
Gain	NO	1,9
Capture area	YES	1,8
Binning	YES	1,9
Turbo USB	YES	2,0
USB cable length	NO	1,9

Conclusion :

For the **same set of** parameters, the **acquisition delay** can be considered as **constant**.

The results of the measurements are 99.7 % in the interval ± 2 ms.

QHY174-GPS camera

Checking the camera calibration

KING	Bin.	Expo.	USB Traf.	Gain	Calibration Start DO(n)-SS(n)	3 σ	Calibration End DO2(n)-SE(n)	3 σ
960x600	1x1	40	0	30	0,137	1,81	-0,049	1,84
960x600	1x1	100	0	5	0,109	1,80	-0,018	1,78
960x600	1x1	400	0	0	0,176	1,86	-0,098	1,87
1920x1200	2x2	40	0	50	0,088	1,83	0,013	1,79
1920x1200	2x2	40	0	180	0,067	1,83	0,026	1,80
1920x1200	2x2	100	0	30	0,104	1,81	-0,002	1,80
1920x1200	2x2	100	0	110	0,118	1,80	-0,001	1,79
1920x1200	2x2	400	0	0	0,132	1,83	-0,050	1,79
			average		0,116	1,82	-0,022	1,81

DO SharpCap DATE-OBS GPS: **Start Exposure**
DO2 SharpCap DATE-OB2 GPS: **End Exposure**

To obtain an **accurate time stamp** the camera needs to be **calibrated** first (see Appendix B)**.**

Conclusion :
The DO - SS and DO2 - SE differences are virtually zero at the ± 2 ms accuracy of SEXTA.
The time stamps for the start and end of the image by the camera clock are identical to those of the SEXTA.
With the default calibration values proposed by SharpCap the camera is correctly calibrated.

QHY174-GPS camera

The question:

Can this camera be used to validate a time server instead of SEXTA?

KING	Bin.	Expo.	USB Traf.	Gain	DE(n)-DO2(n)	3 σ
1920x1200	2x2	40	0	50	22,680	2,04
1920x1200	2x2	40	0	180	22,288	1,92
1920x1200	2x2	100	0	30	22,507	1,85
1920x1200	2x2	100	0	110	22,433	1,79
1920x1200	2x2	400	0	0	22,380	1,87
			average		**22,458**	**1,89**

DE SharpCap DATE-END **System Clock: Frame Received**
DO2 SharpCap DATE-OB2 GPS: **End Exposure**

Conclusion :

DE - DO2 = Delay of acquisition of the QHY174-GPS camera.

For a given set of parameters this delay can be considered as **constant.**

The values obtained are 99.7% in the ± 1.9 ms range.

The camera can be used to validate a time server with an accuracy equivalent to SEXTA.

Conclusions

The results that we obtained show that **for the same set of recording parameters** in SharpCap :

- **the acquisition delay is constant**
- the values are **99.7% within ± 2 ms**.

**This last result shows that a time server built on a Raspberry Pi base in standalone mode
can be used for accurate time stamping of astronomical images, in particular occultations.**

This server is not connected to the Internet and does not suffer from the hazards of the Internet (e.g. delays with the remote server).

The measurements were performed at random times over a period of more than three months.
They therefore show a statistical validity of the reliability of the server.
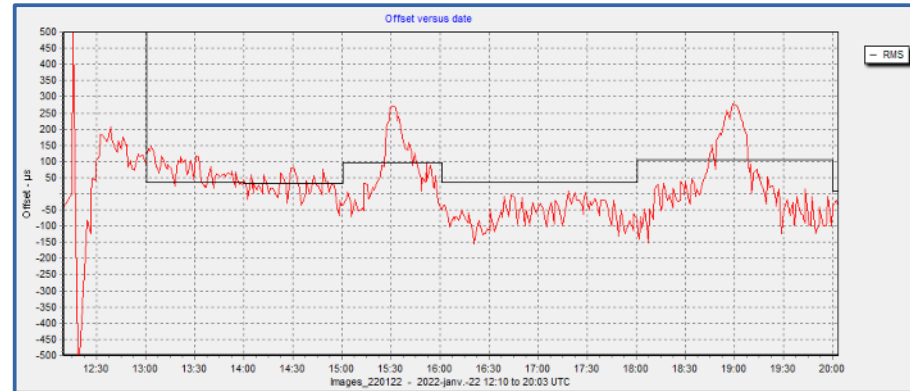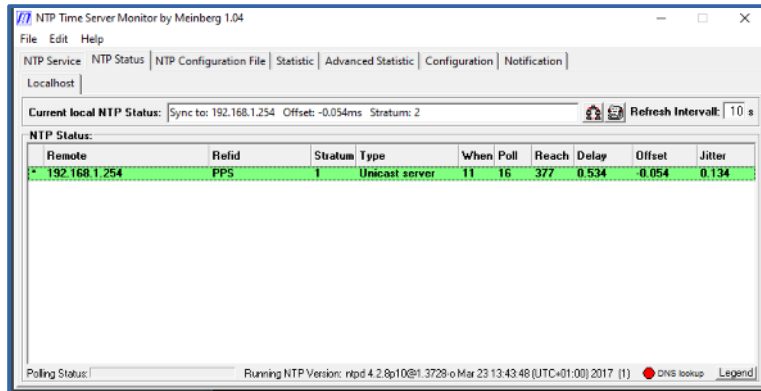
Thanks to

Thierry Midavaine and the Eclipse Club for the loan of the SEXTA and for its help.

Appendix A

Stand Alone Time Server

Since the realisation of the server, Anthony Stirk has removed the instructions for the "Stand Alone" functionality [6].

"I've also removed the off grid/standalone instructions as NTP isn't designed to work off grid using just the NMEA derived time and PPS to discipline it."
Updated: 25/05/16 Fixed for Pi3/May Raspbian. Removed Standalone mode (NTP isn't designed for this)

Even if the "NTP isn't designed for this", from experience this mode works perfectly.

The described NTP server works connected to the Internet but not stand alone.

More recent versions of NTP can be used. For example Chrony or NTPsec.

Chrony seems to be a better choice than NTP for synchronization.

Jean-Baptiste Marquette has made a time server version with **Chrony** that works perfectly [16].

By searching on the web with keywords such as "raspberry pi chrony time server" it is possible to easily find various standalone realisations.

Appendix B

Calibration of the QHY174-GPS camera

The protocol is described by QHY:
https://note.youdao.com/ynoteshare1/index.html?id=6e818b2c91ac61f1650fa9319f981074&type=note

This calibration is done in SharpCap with two parameters:

- Calibration End Pos Adjust
- Calibration Start Pos Adjust

The values of these calibration parameters depend on different factors (exposure time, USB Traffic, 8/16 bits, ROI).

Robin Glover the author of SharpCap has done some modeling of these factors.

Any change in the recording parameters automatically corrects the Calibration End Pos and Calibration Start Pos values.

The purpose of the measurements was therefore to verify the accuracy of this modeling.

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Executable ntp-4.2.8p15-v2-win32-setup.exe (4.29 MB) at time of writing.

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In the archive file: S05_11_poster_NTPstrate1_MarquetteLeCam.pdf