Cloud camera design from a raspberry pi.

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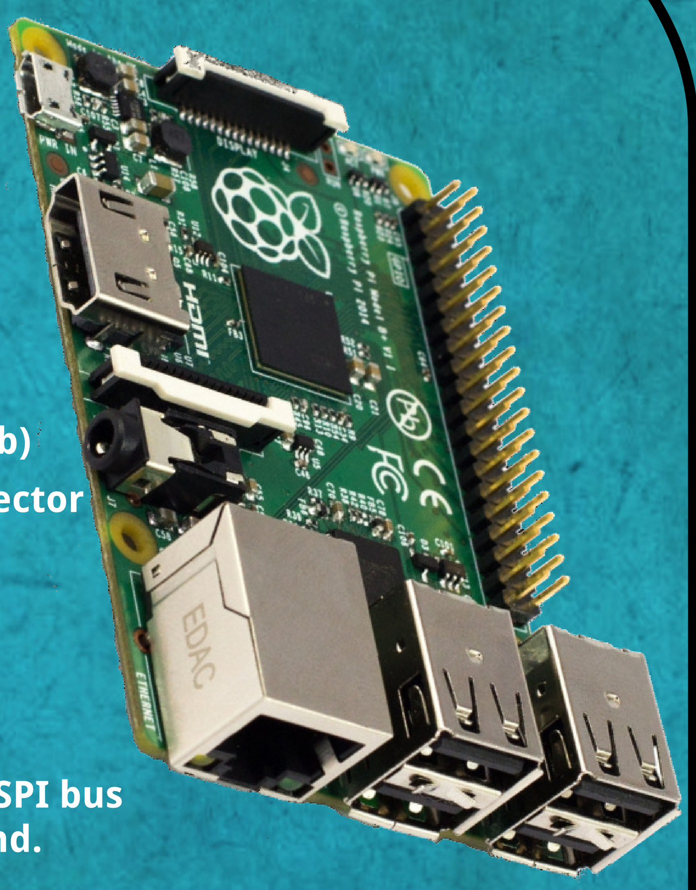
Abstract

The design and assembly of low cost all-sky camera for clouds detection is presented. The instrument comply with all the requirements currently established for this type of instrument. Under the conditions of Cuba it is impossible to acquire such a device which costs between $600 USD (only the camera) and $4000 USD (all system). Using a Raspberry Pi, its camera module with a CMOS (Complementary Metal-Oxide-Semiconductor) sensor, fish-eye lens and a unipolar stepper motor (recovered from a discontinued matrix printer) we have built a sky camera for less than $300 USD. The Raspberry Pi, using free software and hardware, will control and conduct the operation of the camera, the image capturing, the processing and the transmission of the latter results. Among the advantages provided for this device stand objectively determining the percentages of sky covered by clouds, the ability to archive images taken for potential future reprocessing, the classifications of clouds[1] according to the attenuation of solar radiation they produce, among others. All this advantages will be achieved with an instrument of very low cost, allowing access to this technology for both research networks and meteorological services in poor countries.

Hardware

Raspberry Pi B+ Specifications

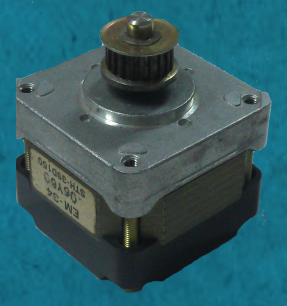


- **CPU:** 700 MHz single-core ARM1176JZF-S
- **GPU:** Broadcom VideoCore IV @ 250 MHz
- **Memory:** 512 MB (shared with GPU)
- **USB 2.0 ports:** 4 (via the on-board 5-port USB hub)
- **Video input:** 15-pin MIPI camera interface connector
- **Video output:** HDMI and composite video
- **On-board storage:** MicroSD slot
- **On-board network:** 10/100 Mbit/s Ethernet
- **Power:** 5V 600 mA (3.0 W)
- **GPIO:** 40 pins can also be used as UART, I²C bus, SPI bus with two chip selects, I²S audio +3.3 V, +5 V, ground.

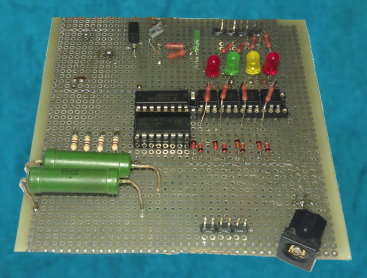
Raspberry Pi Camera Specifications

- **Still resolution:** 5 Megapixels
- **Video modes:** 1080p30, 720p60 and 640x480p60/90
- **Sensor:** OmniVision OV5647
- **Sensor resolution:** 2592 x 1944 pixels
- **Sensor image area:** 3.76 x 2.74 mm
- **Pixel size:** 1.4 µm x 1.4 µm
- **Optical size:** 1/4"
- **Full-frame SLR lens equivalent:** 35 mm
- **Densitivity:** 680 mV/lux-sec
- **Dark current:** 16 mV/sec @ 60 C
- **Focal length:** 3.60 mm +/- 0.01
- **Output formats:** 8-/10 bit raw RGB data

Stepper motor and driver



Unipolar stepper motor
(recovery from impact printer)
1.8 degree on single step
0.9 degree on half step

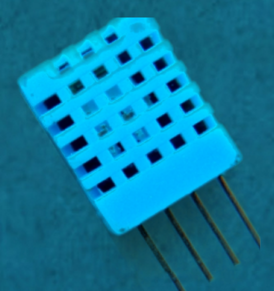


Driver for control stepper motor
(made by GOAC)
Using ULN2003 Darlington transistor arrays

A stepper motor is controlled by multiple electromagnetic coils able to work individually to provide a precise rotation of the motor divided into steps. There are several reasons to use stepper motors in robotic projects including here an accurate position, abilities to spin forward and backwards in discrete steps or in a continuous rotation, and the ability to be controlled with or without feedback.

Fish-eye lens

Humidity and temperature sensor

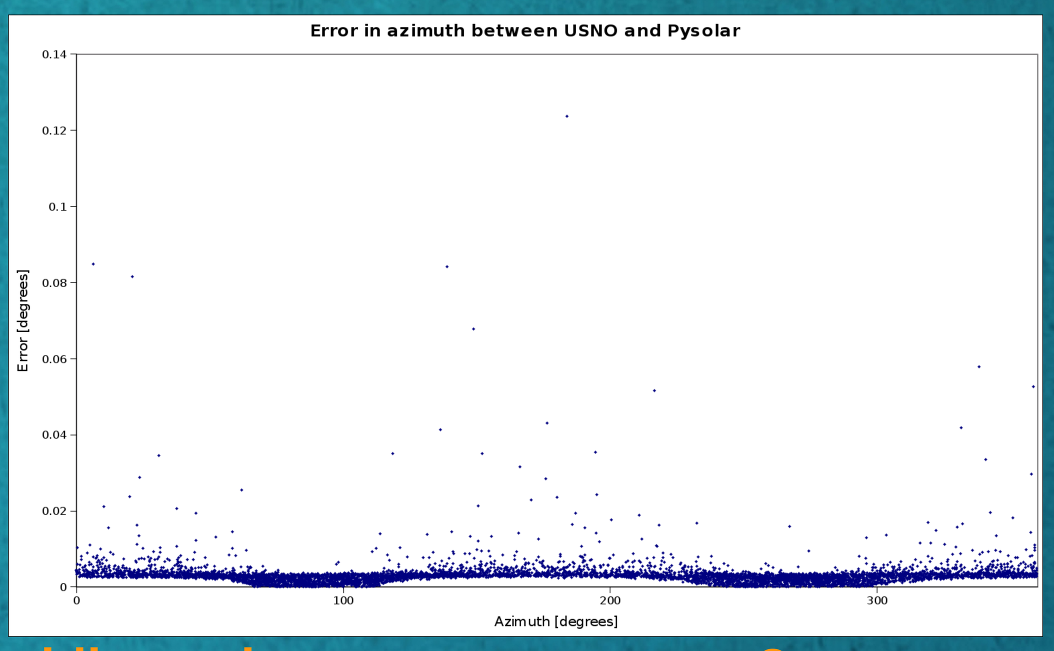


DTH11

Software

Why using a unipolar stepper motor?

The funtion of the stepper motor its to move a bar for shadowing the sun, because the direct incidence of the solar radiation damage the CMOS sensor. The azimuth for the bar is calculated using the library PySolar[2]. It has been validated against similar ephemeris code maintained by the United States Naval Observatory (USNO). In a random sampling of 6000 locations distributed across the northern hemisphere at random times in 2008, Pysolar matched the observatory's predictions very accurately. The azimuth estimations correlated much more closely than the altitude estimations, but both agreed with the naval observatory's to within less than 0.1 degrees on average.



Why humidity and temperature sensor?

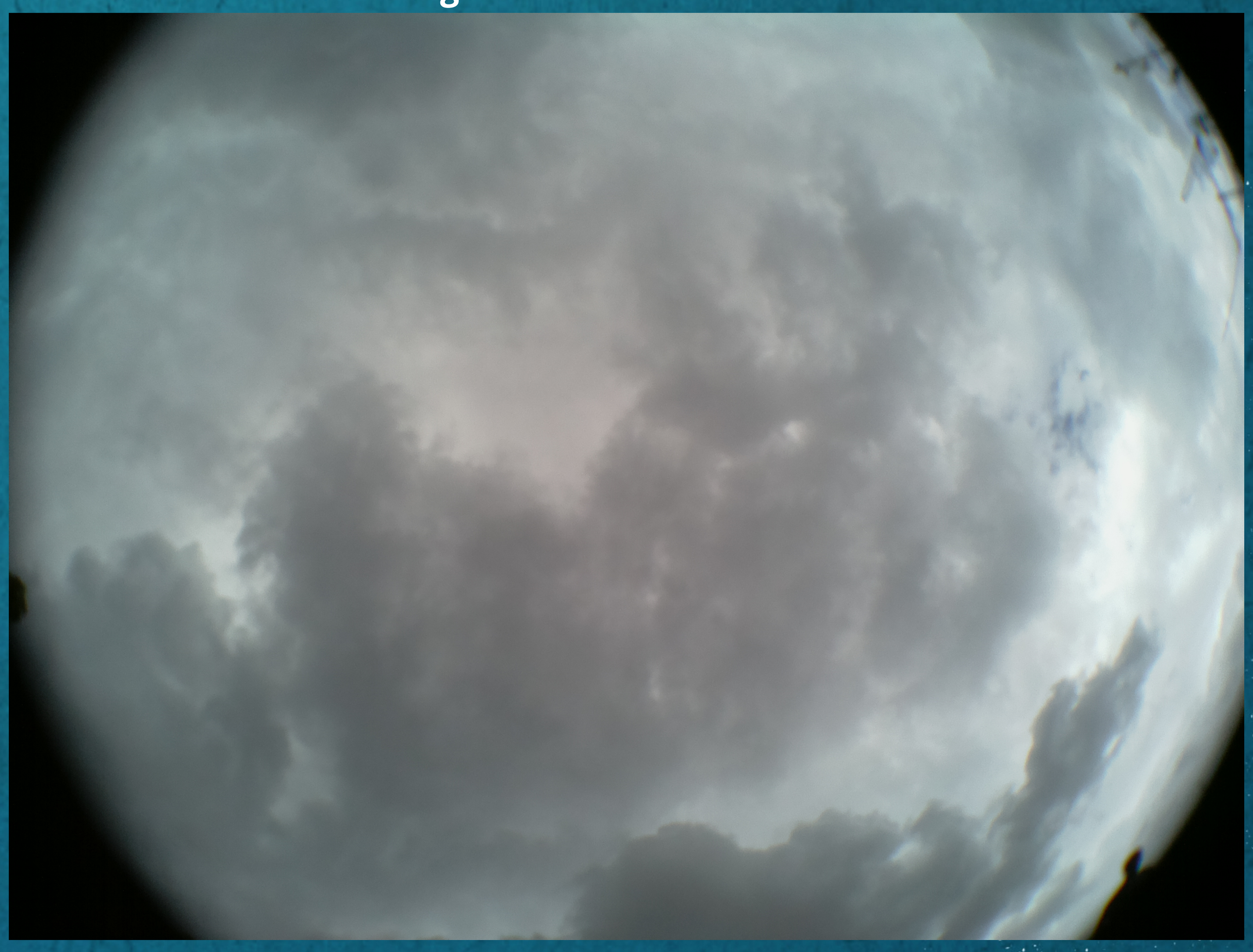
Because in the tropical region the high values of humidity and temperature affects (and could damage in extreme cases the hardware) it is necessary monitoring those variables. Monitoring those variables allow to send warning messages and in extreme cases to shutdown the hardware to protect it. This variables will be saved in the measurement's meta-data. On future hardware upgrades it will include devices to counter-balance the effects of temperature and humidity high values.

Expected operated regime

Current hardware setup: measurements, processing and output every 5 minutes, from sunrise to sunset, 365 days of the year.

First tests

Similar images than the one below will be taken in coincidence with the actinometric observation, for comparing with the observer cloud cover determination to test the algorithms for cloud cover detection.



The shadows in the image are: top right corner TV antenna, bottom right corner Eng. Nelson Diaz Spencer and the middle of the extreme left border a tree.

Conclusions

We have presented the preliminary results for building a cloud camera. It has been demonstrated the possibility of building such device using credit card-size single-board computer complying with the requirements for these instruments. The work in progress is dedicated to development and implementation of the software for controlling the operation of the cloud camera and the processing of its measurements. Upon completion of first version of the cloud camera several upgrades are envisaged: include devices for counter-balance temperature and humidity values; explore the capability of using the pixel RGB values for cloud type classification. The prototype under construction should became a cheap cloud camera that could be use for the meteorological services and research institution in poor countries.

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References

[1] Long, C.N., Sabburg, J. M., Calbó, J., Pagés, D., Retieving cloud characteristics from ground-based daytime color all-sky images. J. Atmosf. Oceanic Technol., 2006. 23: p. 633-652.

[2] I. Reda and A. Andreas, "Solar Position Algorithm for Solar Radiation Applications," National Renewable Energy Laboratory, NREL/TP-560-34302, revised November 2005.

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