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AN IOT SYSTEM FOR MONITORING ENVIRONMENTAL CONDITIONS AND ORIENTATION OF THE TELESCOPE

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Abstract

This paper describes the system based on Raspberry Pi with Sense HAT expansion board. This system is used for collecting the sensor data and sending to the cloud-based service. The environmental sensor data collected are temperature, humidity, and barometric pressure. The orientation sensor data collected are rotation angles around axes of the board, yaw, pitch, and roll. These data determine orientation and weather condition of the telescope. The Internet of Things concept is enclosed in ThingSpeak cloud platform for collecting and analyzing the data. This approach facilitates the remote maintenance of the telescope orientation and in situ weather conditions.

Keywords: cloud, Inertial Measurement Unit, Internet of Things, orientation, Raspberry Pi, Sense HAT, sensors, telescope, ThingSpeak.

INTRODUCTION

Internet of Things (IoT) concept has become vastly popular because of ability to send data to cloud-based services, and their remote analysis and visualization. Systems that intent to use IoT services have to include sensor devices and possibility to access the Internet via corresponding data transmission protocol. Due to the process of miniaturization of computer devices, it has become possible to integrate relatively great processing power with all the circuitries necessary into a board of the credit card size.

Raspberry Pi has become one of the most popular computer boards for IoT platforms. It has great possibilities for integration and expansion with large number of additional boards and software integrated into one of the operating systems that can be run on Raspberry Pi. Its third revision, Raspberry Pi 3 Model B, with integrated WiFi and Bluetooth module, along with Ethernet module, has great connecting possibilities and represents an excellent choice for an IoT system.

This paper represents continuation on our previous work on gathering Euler angles for representation of the telescope orientation [1]. We have tried a new approach with different hardware and software, and after all, with different system architecture. This system is at this point designed as a proof-of-concept, and its further development is planned and explained in this paper.

RASPBERRY PI AND SENSE HAT

The system for collecting data used is consisted of Raspberry Pi 3 Model B, and Sense HAT sensor board. Raspberry Pi 3 is small, but powerful single-board computer system that since its first appearance in 2012 has gained incredible popularity as teaching, but also scientific instrument. Its appearance is shown in Fig. 1 [2].

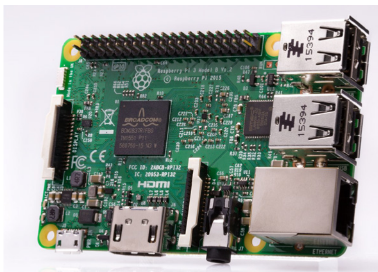

Fig. 1. *Raspberry Pi 3 Model B board*

The specifications of the Raspberry Pi 3 Model B computer system are as follows [2]:

- **SoC**: Broadcom BCM2837

– **CPU**: 4 x ARM Cortex-A53 @ 1.2GHz
– **GPU**: Broadcom VideoCore IV
– **RAM**: 1GB LPDDR2 @ 900MHz
– **Networking**: 10/100 Mbps Ethernet, 2.4GHz 802.11n wireless
– **Bluetooth**: Bluetooth 4.1 Classic, Bluetooth Low Energy
– **Storage**: microSD
– **GPIO**: 40-pin header
– **Ports**: HDMI, 3.5mm analogue audio-video jack, 4x USB 2.0, Ethernet, Camera Serial Interface (CSI), Display Serial Interface (DSI).

Raspberry Pi supports several operating systems, e.g. Raspbian, Ubuntu Mate, Windows 10 IoT Core, XBMC, etc. In our case, Raspberry Pi is powered by Raspbian, the official Debian Linux distribution, maintained by the Raspberry Pi foundation. It comes preloaded with Python and Wolfram Mathematica programming tools, among other software.

Sense HAT expansion board has been publicly available since its usage in Astro Pi mission on the International Space Station (ISS) in 2015. It represents multi-sensor board with LED matrix and joystick. Its appearance is shown in Fig. 2 [2].

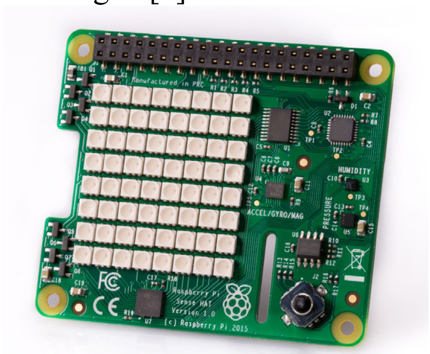

Fig. 2. *Sense HAT expansion board*

Sense HAT board specifications are as follows [2]:
– **Inertial measurement sensor**: ST LSM9DS1
– **Barometric pressure and temperature sensor**: ST LPS25H
– **Relative humidity and temperature sensor**: ST HTS221
– **PCB-mounted 5-button miniature joystick**: Alps SKRHABE010
– **Standard Pi Camera Module**
– **Pi NoIR Camera Module**
– **8x8 RGB LED matrix with ~60fps refresh rate and 15-bit color resolution**: Cree CLU6AFKW/CLX6AFKB
– **Microcontroller unit for driving the LED matrix and scanning for joystick input**: Atmel ATTINY88.

Its inertial measurement unit represents a 9DOF (Nine Degrees of Freedom) sensor which consists of three-axes accelerometer, gyroscope, and magnetometer. It can output each sensor values in all three axes, as well as their combination of Euler orientation angles, yaw, pitch, and roll. The orientation of axes is shown in Fig. 3 [3].

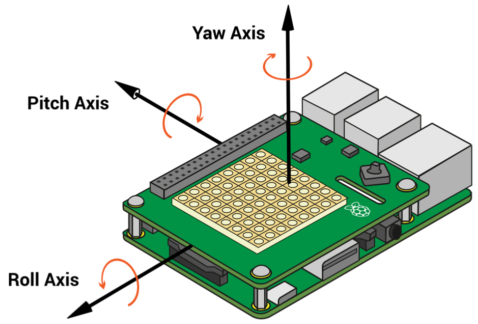

Fig. 3. *Orientation of axes on Sense HAT*

The programming of the Sense HAT board has been greatly facilitated with Python `sense_hat` API [4]. It consists of methods for LED matrix manipulation, environmental sensors readings, IMU sensor readings, and joystick events handling.

THINGSPEAK IOT CLOUD PLATFORM

ThingSpeak represents a Mathworks IoT platform with MATLAB analytics [5]. It's easy to use IoT solution for collecting, analyzing, and acting upon data received. It provides the following possibilities [5]:
– Collect data in private channels
– Share data with public channels
– RESTful and MQTT APIs for creating, sharing, updating, clearing, and deleting a channel
– MATLAB analysis and visualization of data
– Monitoring and alerts on channel inactivity (via TalkBack or Twitter)
– Event scheduling with email notifications
– Working with numerous hardware and software platforms, such as Arduino,

Raspberry Pi, ESP8266 WiFi, Particle Photon, Android, iOS, Twitter, Twilio, and MATLAB.

In order to use ThingSpeak, one must have MathWorks account, which can be created for free. Upon that, each user is assigned with two unique API keys for reading and writing to the channels. Each channel is supported to be assigned to a single sensor device. It can have up to eight fields, meaning that eight different values can be transmitted from each device in one channel. Channel and field manipulations are managed through RESTful GET requests.

Each channel has unique ID and name, and can have description, metadata, tags, link to external site, elevation, location data, and YouTube or Vimeo video showing. Channels can be shared for public view, and their data can be exported in CSV format, but also data can be imported to channel in the same format.

SYSTEM DESCRIPTION AND RESULTS

The system consists of Raspberry Pi 3 Model B with Sense HAT board, powered with AC-DC 5V adapter. It has Raspbian OS installed with Python code for collecting and sending data running. It is connected via HDMI to the PC monitor and access to the Internet is made with WiFi connection. The system was mounted on telescope for a short period of time, and the results were monitored on the remote computer.

The application for collecting and sending data was developed in Python. It was supposed to run indefinitely, with pausing of one second between the measurement readings. The system schematic is shown in Fig. 4.

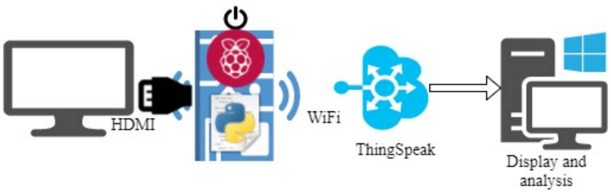

Fig. 4. *The schematic of the system*

The received data charts are shown in Fig. 5. Since this system is at this stage supposed to be proof-of-concept, the data were collected for a small period of time.

a) b) c) d) e) f)

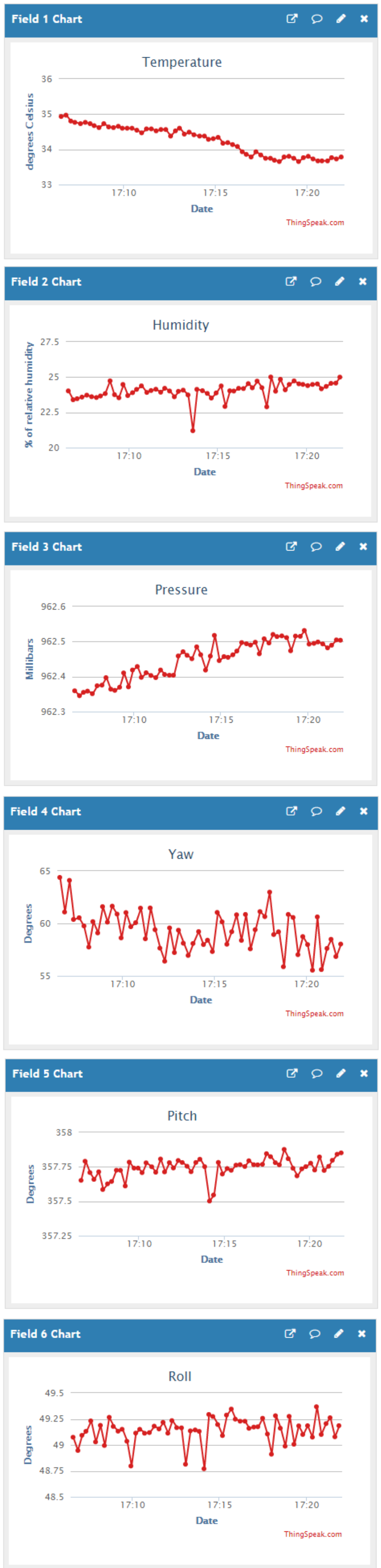

Fig. 5. *The ThingSpeak charts of: a) temperature, b) relative humidity, c) barometric pressure, d) yaw, e) pitch, and f) roll*

For this stage of the system design, we didn't test for the accuracy of the readings, especially Euler angles which would be used to get azimuth and elevation of the celestial object the telescope is pointing at.

ThingSpeak platform has numerous templates for visualization of data correspondences. One of them is the relationship between temperature and humidity. All you have to do is to enter your API key, channel ID, and corresponding fields numbers, and MATLAB will create a chart. For this situation, that chart is shown in Fig. 6.

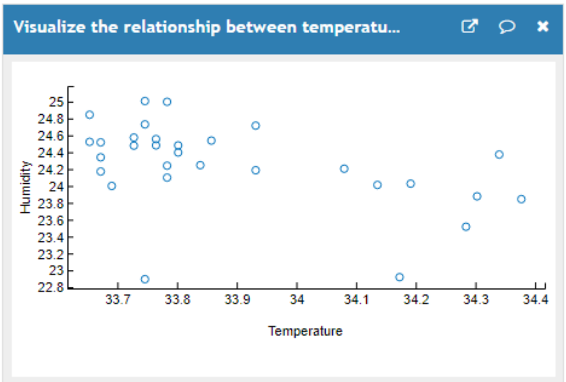

Fig. 6. *The relationship diagram between temperature and humidity*

This system is supposed to become remote station for monitoring weather conditions and orientation of the telescope. Future work includes calibration of IMU sensors, checking for correct readings, analyzing any possible drifts or errors occurring, and developing an application that will calculate azimuth and elevation, and after that, right ascension and declination of the object the telescope is pointing at.

CONCLUSION

The system presented in this paper embodies all the important aspects of IoT concept. It has sensor data acquisition unit with possibilities for data transfer to the cloud-based IoT service.

In this concrete situation, the selection is made of Raspberry Pi 3 Model B with Sense HAT board, Raspbian OS with Python code running, and WiFi connectivity to ThingSpeak IoT platform with powerful MATLAB analytics for data interpretation and visualization.

In this paper we proved that this system is viable and can be easily implemented. It doesn't cost much, the IoT platform is free to use, and available Python libraries and APIs for Raspberry Pi and Sense HAT greatly facilitate the process of data acquisition and transmission.

It remains as a future development to calibrate sensors and check for correct readings, as well as some possible system improvements in the manners of autonomic power supply.

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