A 3D-printed Solar Radiation Shield for Weather Stations

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Abstract

We report on an effort evaluating the use of 3D-printing in the design of weather station components. The first component studied is a solar irradiation shield in the shape of a pagoda to be evaluated in the WIMEA-ICT project designing an affordable automated weather station for rural Africa.

The design environment is based on open source software (OpenSCAD/Cura) and Ultimaker 2, a 3D-printer in the 2000 EUR range,

Our conclusion is that 3D-printing is still much of an art but yet a powerful tool for prototyping before going to large volume production. The resulting files have been made available under a Creative Common license in the Sci-GaIA Open Access Repository. You are invited to print a few copies and join the evaluation activities.

Introduction

The work discussed in this paper is part of the WIMEA-ICT project [1] funded by NORAD. One of the goals of this project is to prototype an affordable automated weather station (AWS) facilitating mass deployment in developing regions, in particular rural East Africa.

The AWS is expected to deliver measurements of the synoptic weather parameters as far as possible conforming to WMO recommendations.

An AWS includes sensors, data processing and communication devices, power supply and enclosures.

This paper takes the enclosure perspective, in particular to evaluate the potential of using 3D-printers for prototyping and possible even for manufacturing in small series.

The first enclosure studied is a pagoda-shaped radiation shield for sensors measuring air temperature and humidity.

Related work include the MMA weather station project at UCAR/IEPAS [2].

Needs and requirements

The challenge when designing a solar radiation shield is to make an enclosure preventing both direct and indirect (reflected) radiation and precipitation to reach the sensor and, at the same time, have enough ventilation around the sensor, preferably passive rathern than forced, so that the ambient temperature inside the shield is as close to the outside ambient air temperature as possible. This is a well researched area and also the subject of WMO recommendations and studies [3,4,5,6]. The design discussed in this paper is a prototype following the recommendations as far as possible.

Additional design criteria include support for mounting the sensors and processing and communication components needed and simple forms to facilitate fast printout.

Design environment

The environment used for the design discussed here include the OpenSCAD 3D-CAD software [7] generating fully editable .scad -files and .stl files used as input to the subsequent printing process. Since the OpenSCAD rendering process becomes time-consuming for more complex designs, we are discussing the option to offer the software via supercomputers in the e-infrastructure environment.

The 3D-printer used in this work is an Ultimaker2 [8], which comes with the free open source Cura tool [9] used for slicing and generation of .gcode-files that are uploaded to an SD-card in the printer .

The pagoda design

The actual design of the pagoda consists of three parts, the pagoda segment stack forming the body, the bottom and the top. The size of the body can be varied by stacking more or fewer segments on top of each other, normally five to ten, depending on how much space is needed inside.

The electronic components in the first generation WIMEA-ICT experimental AWS prototype are mounted on a standard PCB board for prototyping with the size 100*160*1.6 mm. Since this card has to go into the shield, this determines the inner size of the pagoda segment. The rest of the design is determined by the needs for passive ventilation while preventing reflected radiation to enter.

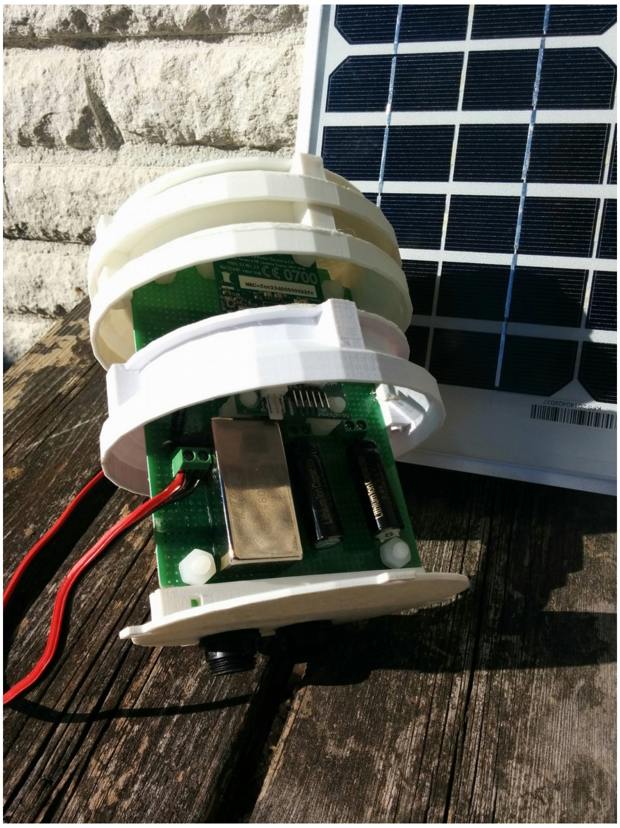
For 3D-printing technical reasons, the segments of the stackable pagoda body are printed upside down. A segment consists essentially of three cylinders and one cone on top of each other with some support structures.

The role of the first cylinder is to make it impossible for reflected radiation to enter between the pagoda segments. It is 2mm high, has a 112/98 mm outer/inner diameter. Then there is a new cylinder, 8 mm high 102/98 mm outer/inner diameter. This is followed by a cone expanding the segment over the next 10mm height from 102/98mm to 126/122mm, and a final 10 mm high, 126/122mm cylinder.

A cube representing the space reserved for PCB board to be contained (101*160*3 mm) is subtracted from the above.

The support structure consist of 4 cubes evenly distributed with 90 degrees between them around the cylinders

The pagoda bottom and top come in different versions containing mounting support for a wireless sensor network mote with some sensors, extra sensors, a power supply and contacts to external sensors.



The figure shows two pagoda segments separated to illustrate the design, top and bottom with support for the PCB board inside.

Manufacturing

The material evaluated for use in this work include PLA [10] and ABS [11] that are the two materials supported by the Ultimaker 2 printer.

After some evaluation tests, ABS was chosen due to better durability properties, including resistance to hot and humid climate, UV radiation, etc. The author has not been able to find information about ABS material qualities such as albedo and emissivity so they remain to be studied as part of an evaluation phase.

The actual printing process has been time consuming, partly because the author entered this work as a novice regarding 3D-printing with little professional support. At a reasonable trade-off between time and quality, each segment took a bit less than 5 hours to print and all sorts of problems surfaced in the process, making some of the printouts useless.

Conclusions

Since the author entered this work as a novice regarding 3D-printing, the project led to massive learning and and several new insights, often unexpected and confusing.

3D-printing seems still to be an art rather than a technical commodity. It is, however evident that it is a powerful tool for fast prototyping, stimulation of innovative thinking and trial and error with reasonably short turn around time.

Since rendering and printing becomes more time consuming with growing complexity of the 3D-models involved, it would probably make sense to offer high power computing resources and high-end printer hubs in science gateways.

The resulting design files have been made publicly available under a Creative Common License [12] at the Sci_Gaia Open Access Repository [13].

Evaluations remain to be done in a coming field test being prepared and will be reported separately. You are welcome to print a few copies of the Pagoda and join the evaluation process.

Acknowledgements

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