LOW COST PRECIPITATION MEASUREMENT IN REMOTE AREAS

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MOTIVATION

High spatial and temporal variability of rainfall puts an increasing demand on sampling frequency and density of monitoring networks. The high cost of commercial devices was one of the main reasons restricting their broader deployment in both scientific and commercial domains. Nowadays, the advancements in low-cost open-source electronics, sensors, and ready-to-use communication platforms have inspired scientists and makers to build their own prototypes of measuring instruments and dataloggers.

The main motivation here was to build a cheap and versatile rain gauge with a long battery life that would enable to share the data in a real time.

Design requirements:

- low-cost design
- energy efficiency
- accurate measurements
- wireless communication
- flexibility – enables to adjust sampling frequency

DESIGN

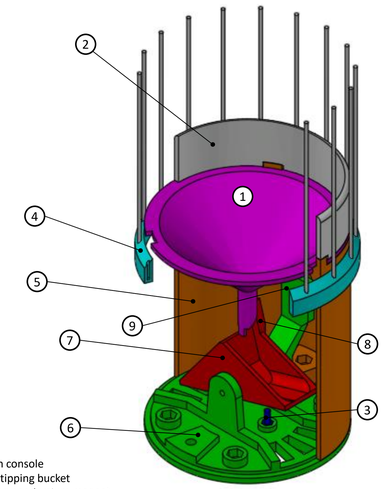
The mechanical parts of the station were fabricated using Prusa i3 MK2 3D printer. The printer uses a fused filament fabrication (FFF) process to additively deposit thin layers of a white ASA thermoplastic material to create a 3D object.

ASA characteristics

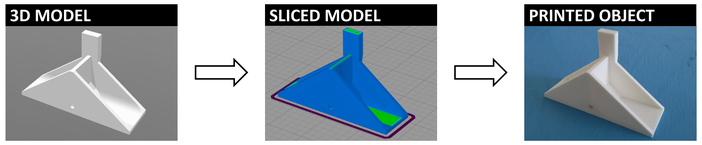
- Acrylonitrile Styrene Acrylate
- High UV resistance
- High strength and low shrinkage
- Printing temperature 220-245°C

Rain gauge description

- two-chamber tipping-bucket rain gauge
- orifice opening: 104 mm
- bucket resolution: 0.5 mm ±0.01 mm
- sensor: magnetic reed switch



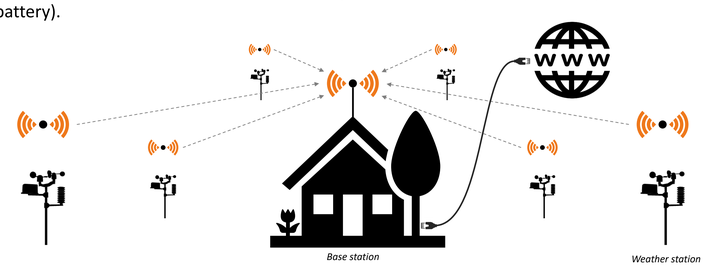
1. funnel
2. splash protection
3. calibration screw
4. bird spike housing (optional)
5. rain gauge enclosure
6. baseplate with console
7. two-chamber tipping bucket
8. console holding neodymium magnet
9. console holding magnetic reed switch



ELECTRONICS

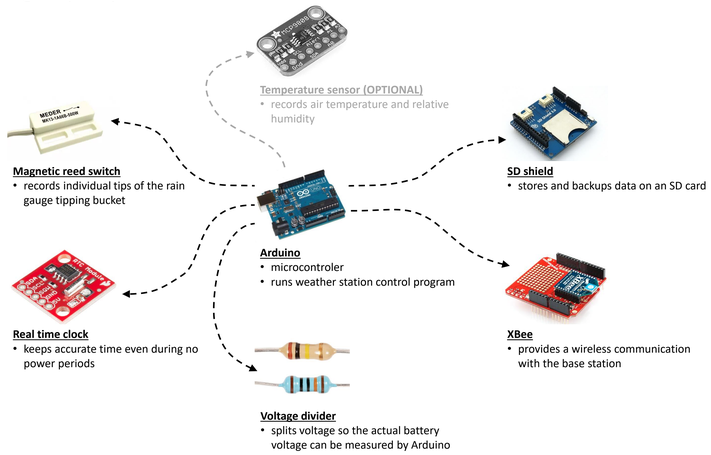
STATION CONFIGURATION

Weather station works best in a tandem with a base station that is connected to the internet. This configuration enables to share data online from an arbitrary number of weather stations without the need to change batteries very often (several years on a 9V battery).



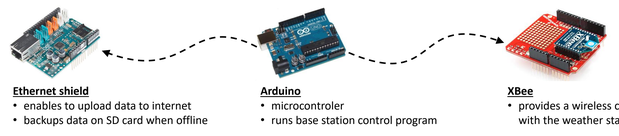
WEATHER STATION (TRANSCIEVER)

Weather station's role is to collect precipitation data. Each tip of the tipping-bucket is recorded, time stamped and saved to SD card. To reduce the power consumption the data is regularly (e.g. 5-min interval) read from the SD card and transmitted to the base station. As the station is powed by a battery, most of the time it is in a sleep mode. Battery voltage is regularly sampled and in case it is low the information is sent to the base station.



BASE STATION (RECIEVER)

Base station's role is to receive data from all the weather stations and imediatelly send them to online storage through the internet. In case internet connection could not be established the received data are stored on SD card. Due to higher power consumption it is connected to power lines and thus situated inside.



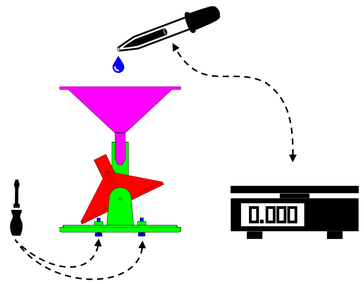
CALIBRATION

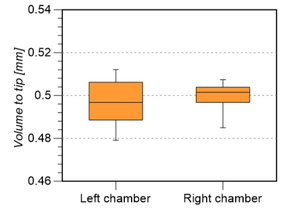
The accuracy and precision of the rain gauge was secured by volumetric and dynamic calibration procedures. The goal of the volumetric calibration was to make sure that each tip of the rain gauge will correspond to the same volume of water. The goal of the dynamic calibration was to quantify the measurement errors under various rainfall intensities.

VOLUMETRIC CALIBRATION

Procedures

- weight laboratory dropper
- produce drops until the bucket tips
- weight laboratory dropper
- calculate volume of water needed to tip the bucket
- repeat 20 times for each chamber
- evaluate and adjust the calibration screws



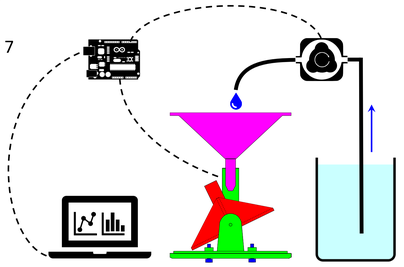


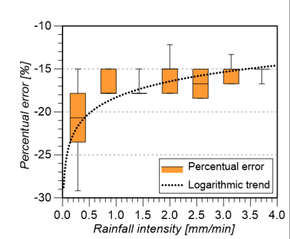
▲ *Volume of water needed to tip the bucket from one state to another. 20 repetitions for each chamber.*

DYNAMIC CALIBRATION

Procedures

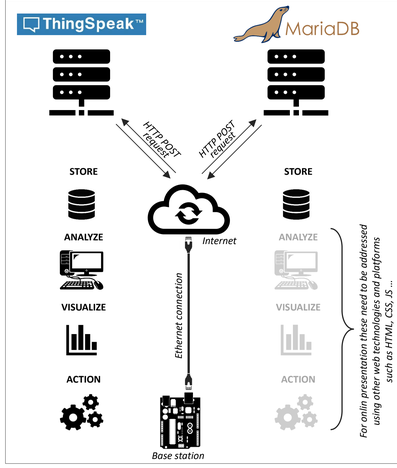
- laboratory pump was used to simulate 7 different rainfall events of a given intensity and a total volume
- 3D-printed rain gauge was used to measure the total volume of the simulated rainfall
- for each intensity a percentual error between the simulated and measured rainfall totals was evaluated
- 5 repetitions for each rainfall intensity





▲ *Percentual error was obtained by comparing the simulated rainfall totals (provided by peristaltic pump) and measured rainfall totals (measured by rain gauge)*

GOING ONLINE



ThingSpeak server

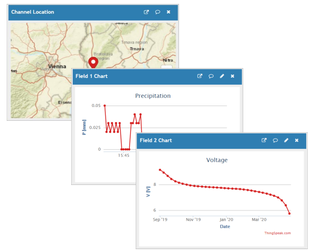
Free IoT online platform for data collection, analysis and visualization in the cloud.

Pros:

- analyze and visualize the data using MATLAB functions and scripts
- Arduino library
- trigger reactions based on data

Cons:

- limitations of the free licence
- no SQL queries



MariaDB server

Open source relational database platform for data storage. Based on MySQL database.

Pros:

- no limits on database size
- can be accessed using any programming language
- SQL queries

Cons:

- need for a dedicated server/hosting
- no analysis, visualisation included – must be done using other technologies