InnoRenew CoE

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Development of sensors for air and rain monitoring

by Jakub Sandak, Jan Vcelak, Laszlo Hajdu

& Anna Sandak, Miklos Kresz, Ana Slavec, Vaclav Sebera

project J7-9404

TITLE OF THE PROJECT: *Protection of bronze monuments in the changing environment*

FINANCED: Slovenian Research Agency (ARRS)

PROJECT GOALS:

- to develop better understanding of the corrosion process of bronze monuments exposed to external weather conditions by developing dose-response model of degradation. The set of data required will be collected during the experimental campaign where four monuments will be monitored by especially designed set of sensors.
- the second objective is to develop IT tools supporting engagement of the public to bronze monuments deteriorations by reporting any damage observed. This will allow better protection of monuments, but also understanding of the visitors preferences and behaviours

dose-response model for corrosion of bronze: previous studies

The effects of climatic and pollution factors on cultural heritage

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Corrosion of *metals*

Bronze Fontana delle Tartarughe a Piazza Mattei (Roma)

Copper Tempio Maggiore Israelitico - Sinagoga (Firenze)

Surface recession (R)

$$R^* (\mu m/year) = 0.15 + 0.000985\,[SO_2]\;Rh_{60}\;e^{f(T)} + 0.00465\,Rain\,[H^+] + 0.00432\,PM_{10}$$

f(T) = 0.060(T-11) when T<11°C, -0.067(T-11) otherwise

Mass Loss (ML)

$$ML^* (g\,m^{-2}) = 0.0027\,[SO_2]^{0.32}\,[O_3]^{0.79} Rh_{exp}\{f(T)\}\;t^{0.78} + 0.050\,Rain\,[H^+]\,t^{0.89}$$

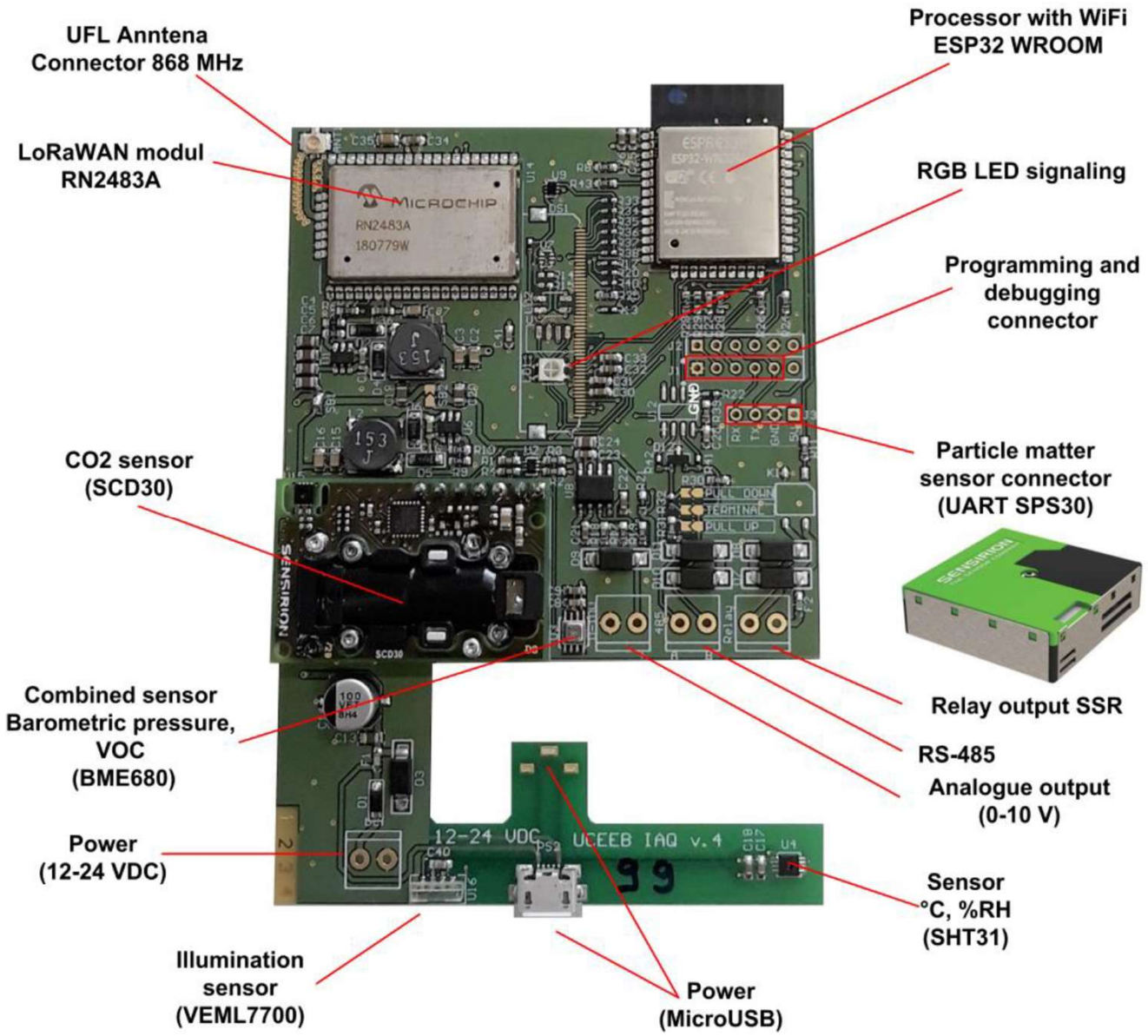
f(T) = 0.083(T-10) when T<10°C, otherwise -0.032(T-10)

https://atmosphere.copernicus.eu/sites/default/files/repository/Gaddi.pdf

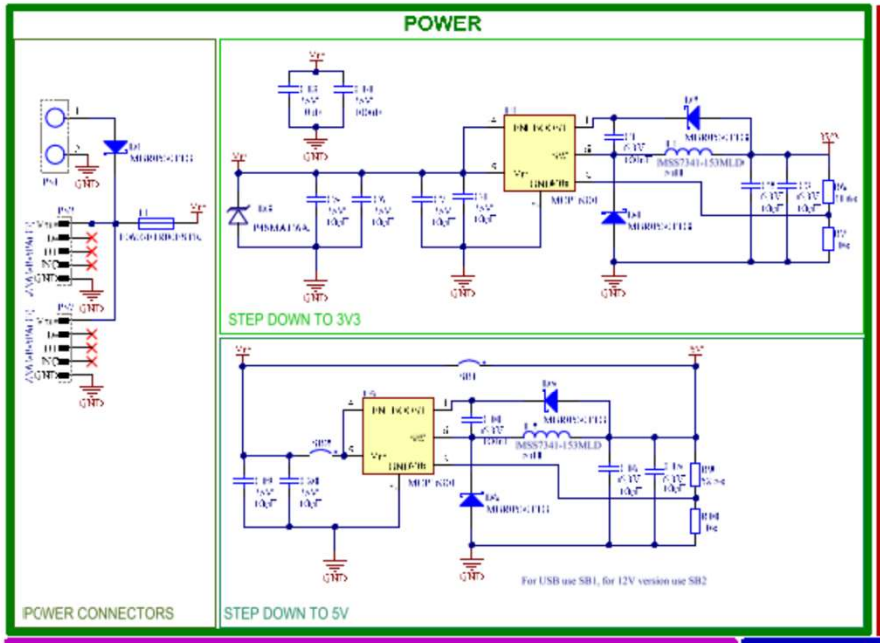
parameters measured by the system: system requirements

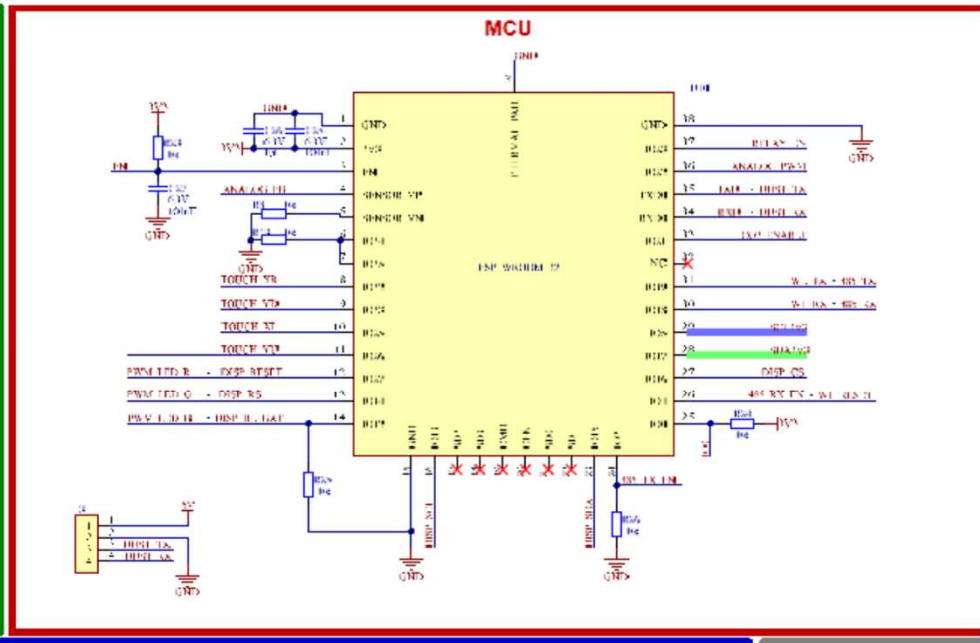
- **air quality:**
  - air temperature
  - relative humidity
  - air pressure
  - CO_2 concentration
  - VOC index
  - particles (PM1, PM2.5, PM4, PM10)
  - UVA radiation
  - UVB radiation
  - UV index
- **rain water quality:**
  - precipitation intensity/volume,
  - water temperature,
  - water pH,
  - oxidation-reduction-potential,
  - conductivity
- **bronze mock-ups condition:**
  - temperature under the surface measured separately for each sample

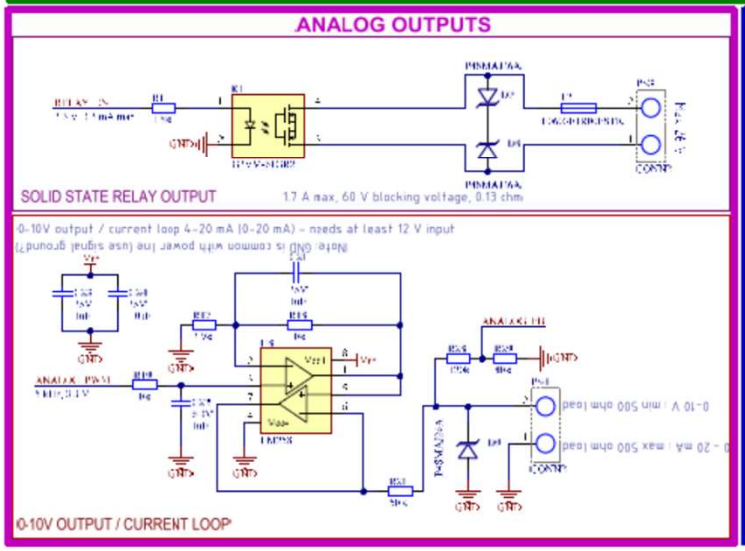
IAQ sensor

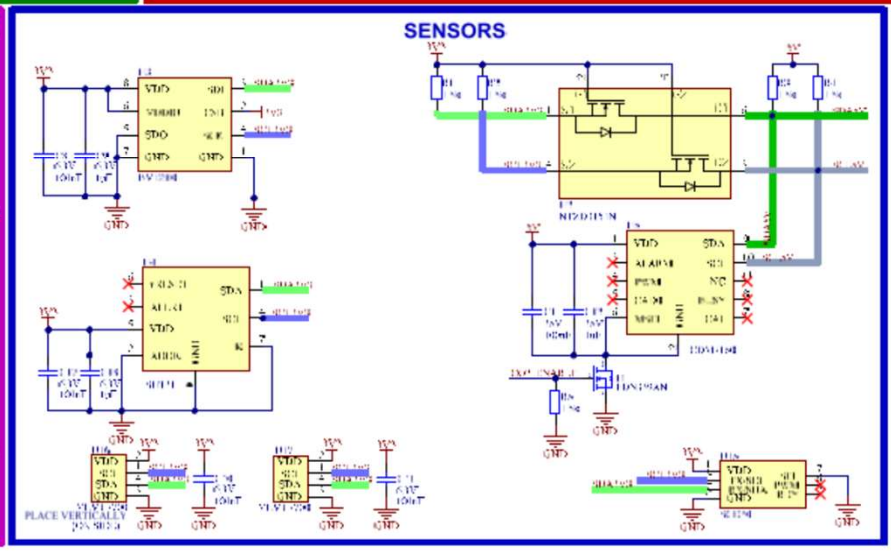

UFL Anntena
Connector 868 MHz
LoRaWAN modul
RN2483A
CO2 sensor
(SCD30)
Combined sensor
Barometric pressure,
VOC
(BME680)
Power
(12-24 VDC)
Illumination
sensor
(VEML7700)
Power
(MicroUSB)
Processor with WiFi
ESP32 WROOM
RGB LED signaling
Programming and
debugging
connector
Particle matter
sensor connector
(UART SPS30)
Relay output SSR
RS-485
Analogue output
(0-10 V)
Sensor
°C, %RH
(SHT31)
MICROCHIP
RN2483A
180779W
SENSIRION
SCD30
12-24 VDC
UCEEB IAQ v.4

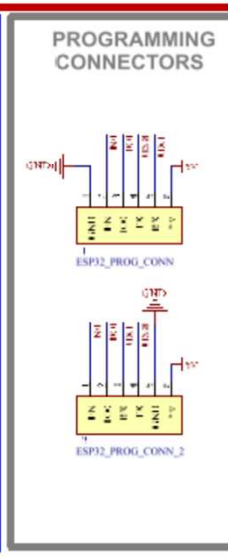
IAQ sensor: electronic design (1)



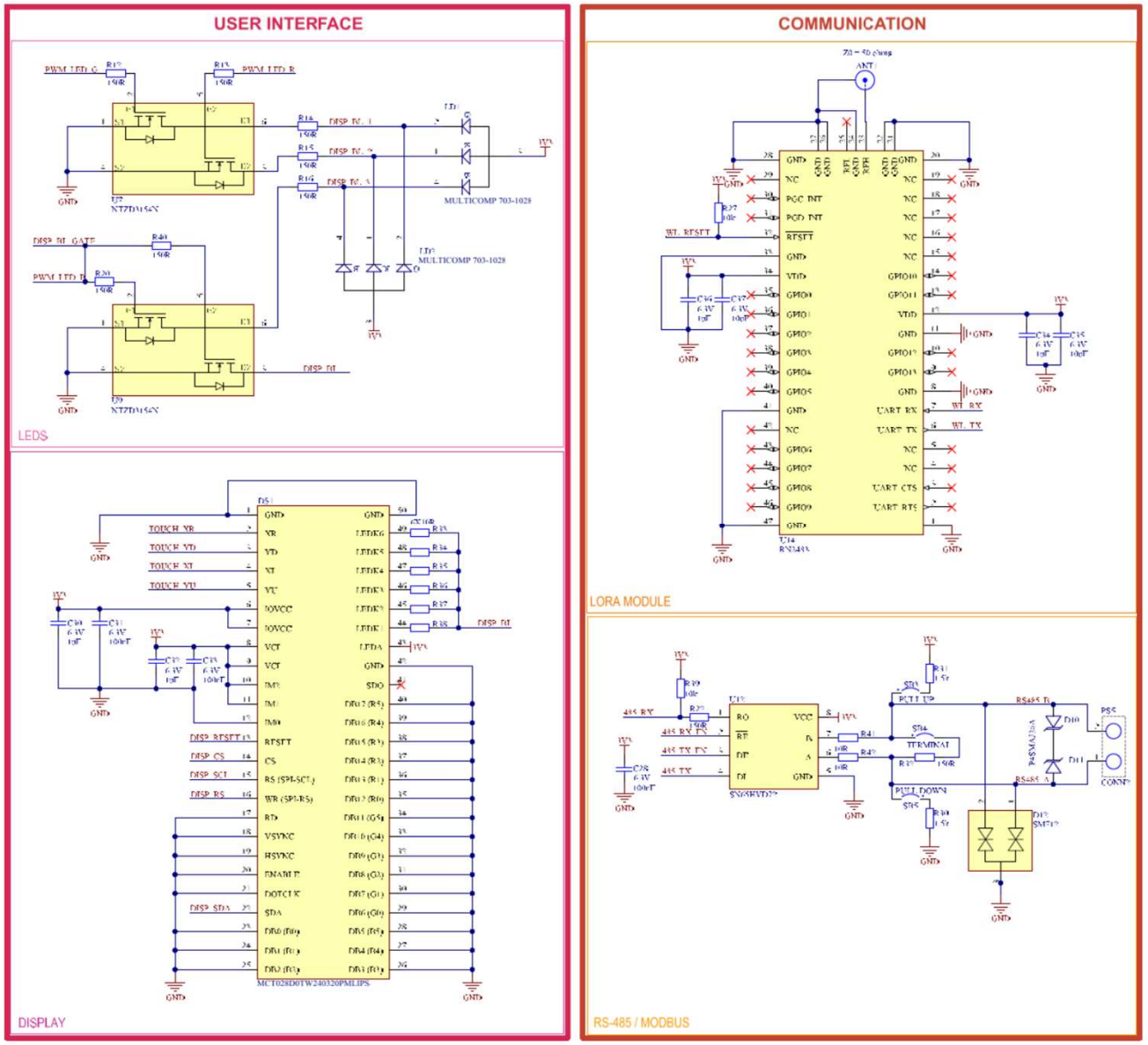






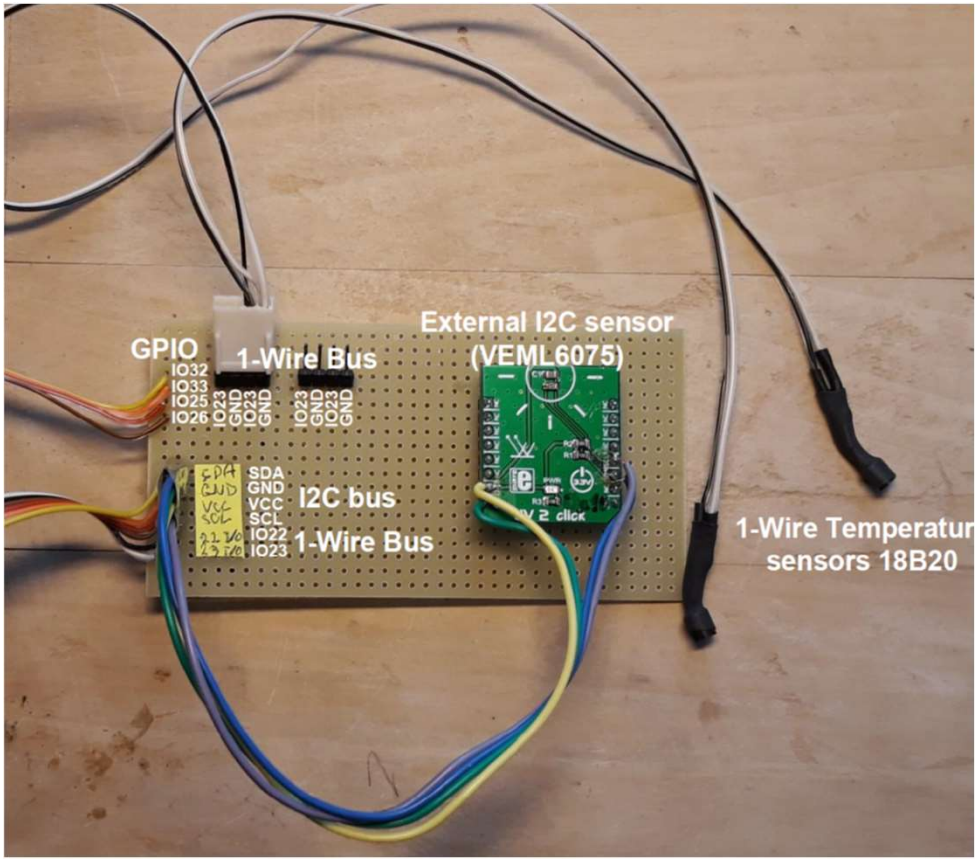


IAQ sensor: electronic design (2)



IAQ sensor board extension

- designed to allow further development of new applications based on IAQ board:
- provide connection to ESP32 controller pins for external devices
- provide further inputs/outputs for the users:
  - ESP32 pins IO22 and IO23 – implemented 1-Wire bus
  - I2C bus, SCL_3V3 (ESP32 pin IO5) and SDA_3V3 (ESP32 pin IO17)
  - 3.3V power supply
  - GND
  - general purpose pins IO25, IO26, IO32, IO33
- use straight away 1-Wire bus thermometers 18B20 and I2C sensors connected to 3V3 I2C bus



IAQ sensor: technical specifications

the platform originally designed for monitoring of indoor environment quality parameters, and thus the default sensor setup is selected with respect to this requirement:

- air temperature -40 – +85 °C
- relative air humidity 0 – 90 %RH noncondensing
- CO2 concentration 300– 5000 ppm
- VOC concentration IAQ index 0 – 500
- barometric pressure 300 – 1100 hPa
- particle matter concentration (PM10, PM2,5) 0,0 – 999,9 µg/m3 (optional)
- illuminance (indication only)

- inputs and outputs:
  - Solid State Relay for external device switching *(max 50 V)*
- communication interfaces:
  - WiFi 802.11 b/g/n 2,4 GHz
  - LoRaWAN – Class A, 14 dBm, SF 7-12, 868 MHz supports ABP and OTAA device activation (optional)
  - RS-485 (Modbus RTU) *(optional)*
- indication multicolor RGB LED for indoor air quality and status of sensor indication
- automatic LED intensity adjustment according ambient light conditions
- power supply: 12 to 24 V DC, 250 mA
- USB 5 V DC, 250 mA

water quality sensor

5.1. Temperature Sensor (Pt-1000)

5.1.1. Specifications

Measurement range: 0 ~ 100 °C
Accuracy: DIN EN 60751
Resistance (0 °C): 1000 Ω

5.2. Conductivity sensor

5.2.1. Specifications

Sensor type: Two electrodes sensor
Electrode material: Platinum
Conductivity cell constant: 1 ± 0.2 cm^{-1}

5.4. pH sensor

5.4.1. Specifications

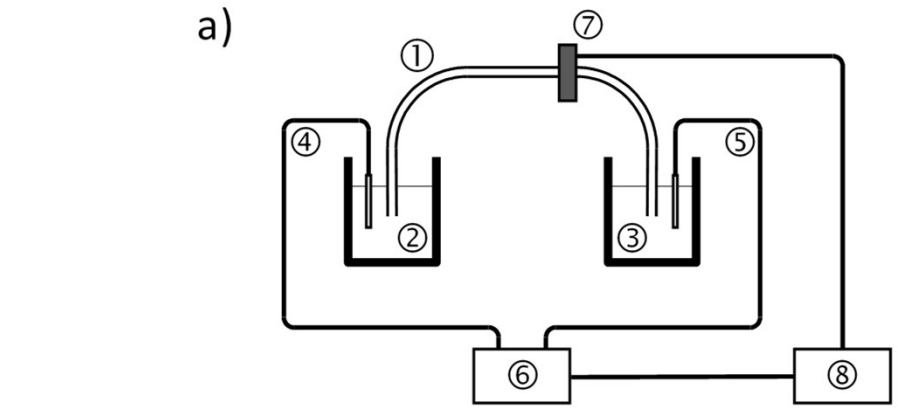
Sensor type: Combination electrode
Measurement range: 0~14 pH
Temperature of operation: 0~80 °C
Zero electric potential: 7±0.25 p
Response time: <1 min
Internal resistance: ≤250 MΩ
Repeatability: 0.017
PTS (percentage of slope): >98.5
Noise: <0.5 mV
Alkali error: 15 mV
Reader accuracy: up to 0.01 (in function of calibration)

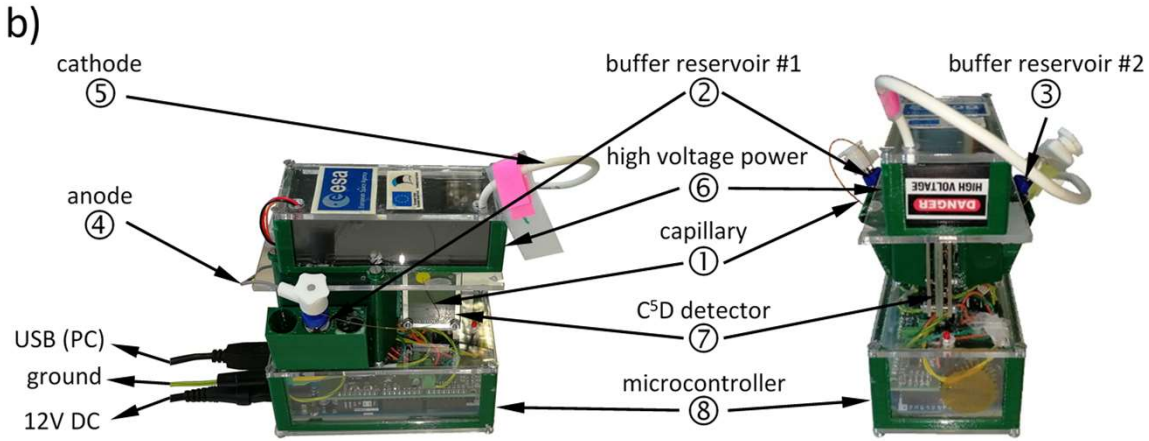
5.5. Oxidation-reduction potential sensor

5.5.1. Specifications

Sensor type: Combination electrode
Electric Potential: 245~270 mV
Measurement range: 0 ~ ±1999 mV
Reference impedance: 10 kΩ
Stability: ±8 mV/24 h

rain water chemical composition: capillary electrophoresis





LOW-COST CAPILLARY ELECTROPHORESIS INSTRUMENTATION FOR ASSESSMENT OF RAIN WATER IONIC COMPOSITION

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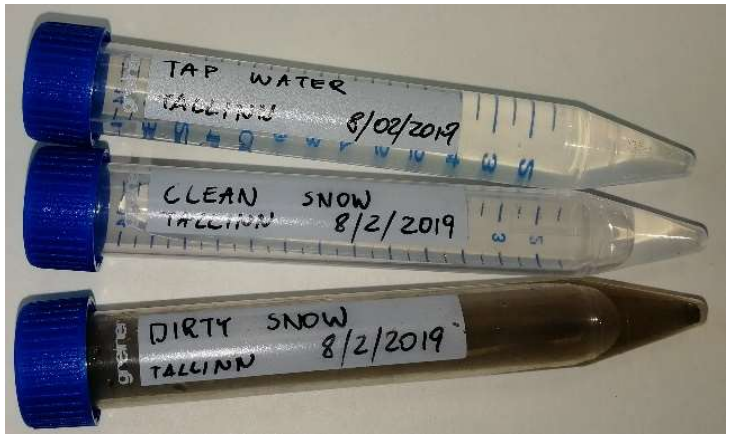
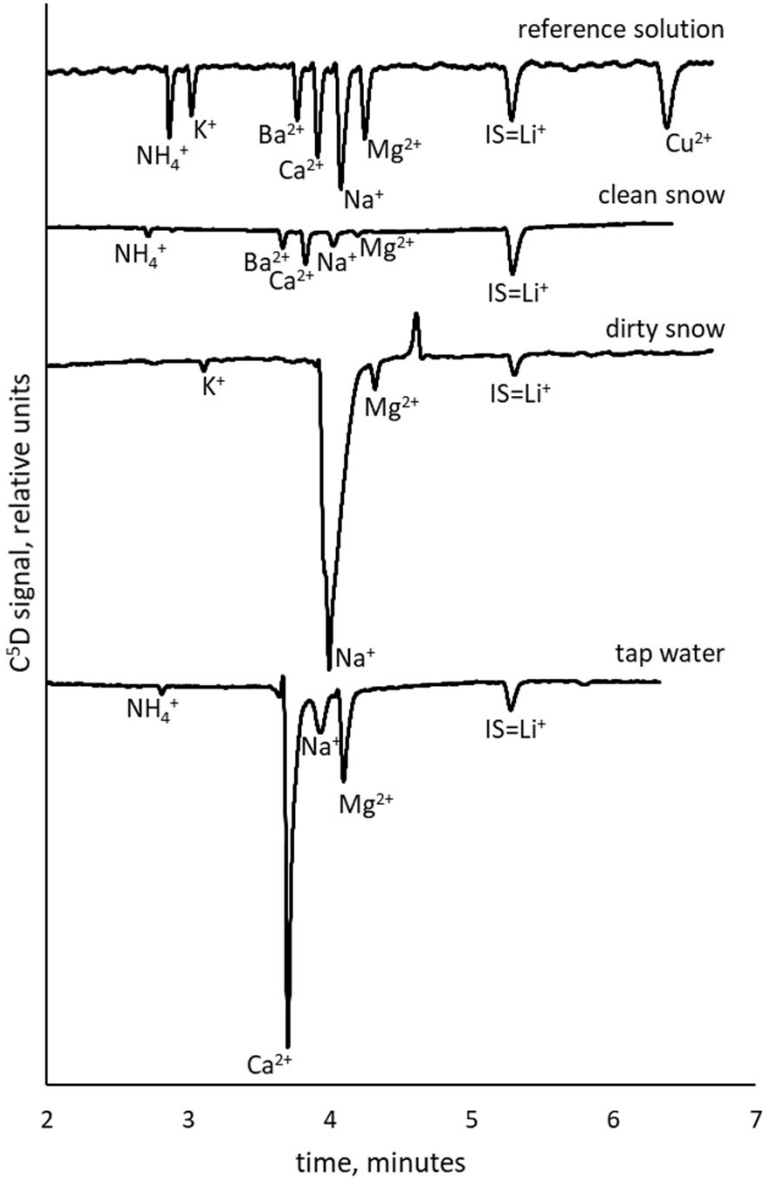
pilot research in Estonia



ANALYTE	PURE SNOW	DIRTY SNOW	TAP WATER
$NH4^+$	12	n.d.	13
K^+	n.d.	49	n.d.
$Ba2^+$	29	n.d.	n.d.
$Ca2^+$	36	n.d.	1031
Na^+	13	2546	128
$Mg2^+$	2	708	357
$Cu2^+$	**n.d.**	**n.d.**	**n.d.**



crowd detection/analysis

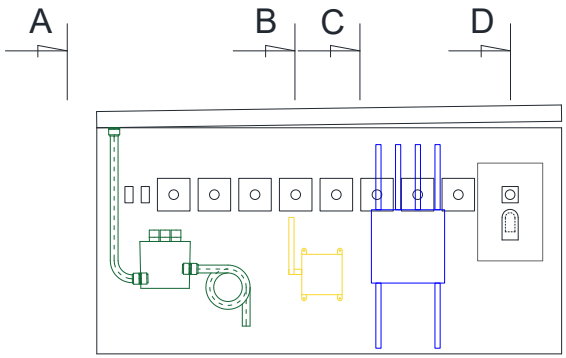
libelium meshlium scanner:

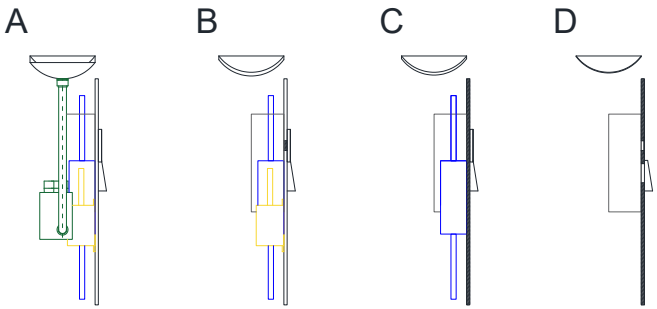
- detects any smartphone, laptop or hands-free car kit (WiFi, BLE or Bluetooth device) which comes into the coverage area of Meshlium
- users have to do nothing to be detected
- measure the amount of people and cars which are present in a certain point at a specific time
- allows the study of the evolution of the traffic congestion of pedestrians and vehicles
- the information read from each user contains:
  - the MAC address of the wireless interface
  - the strength of the signal (RSSI
  - the vendor of the smartphone (Apple, Samsung, etc)

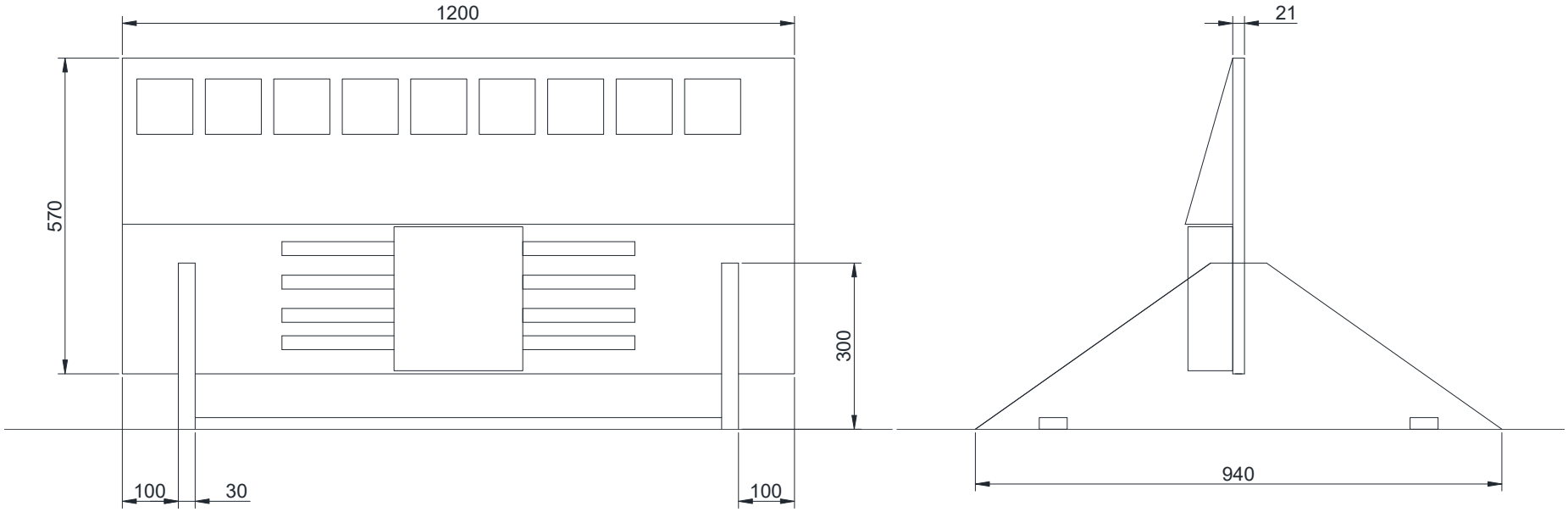
sensors system architecture

- basic MQTT service used to send data from the Plug&Sense SmartWater to Innorenew MQTT (cloud)
- one record for every value of the sensor
- each probe has one separate record in the database

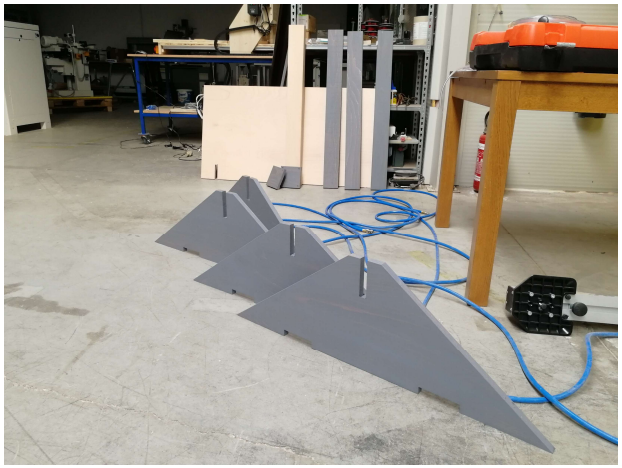
sample stand design

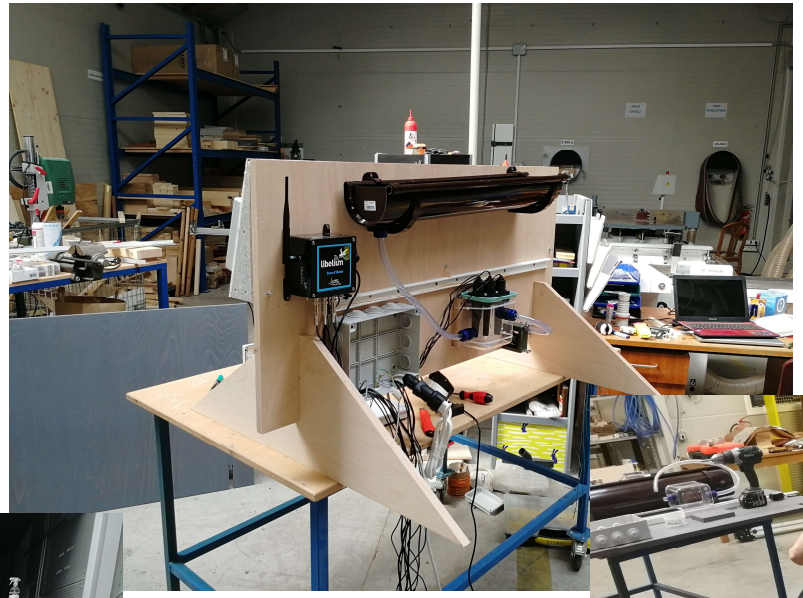


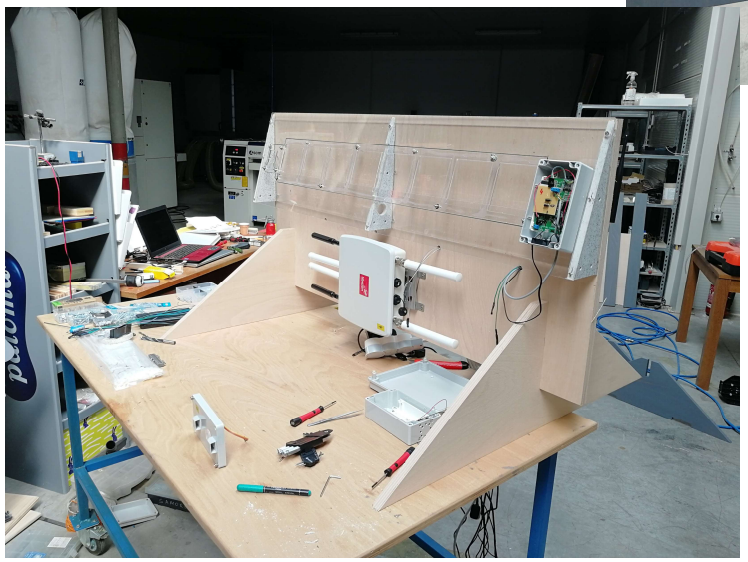




sample stand manufacturing

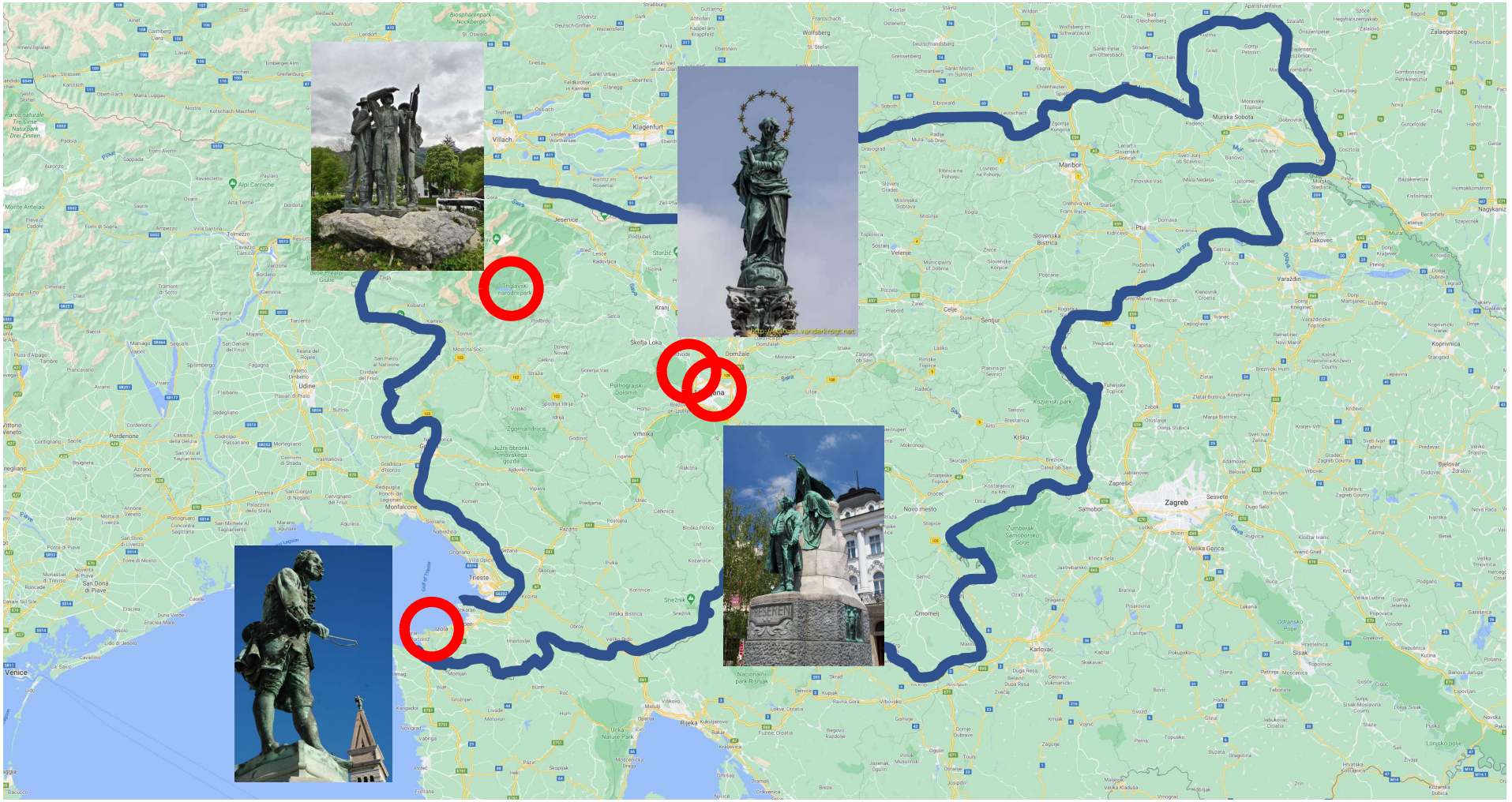






midnight, 8 hours before deploy in Ljubljana

exposure locations



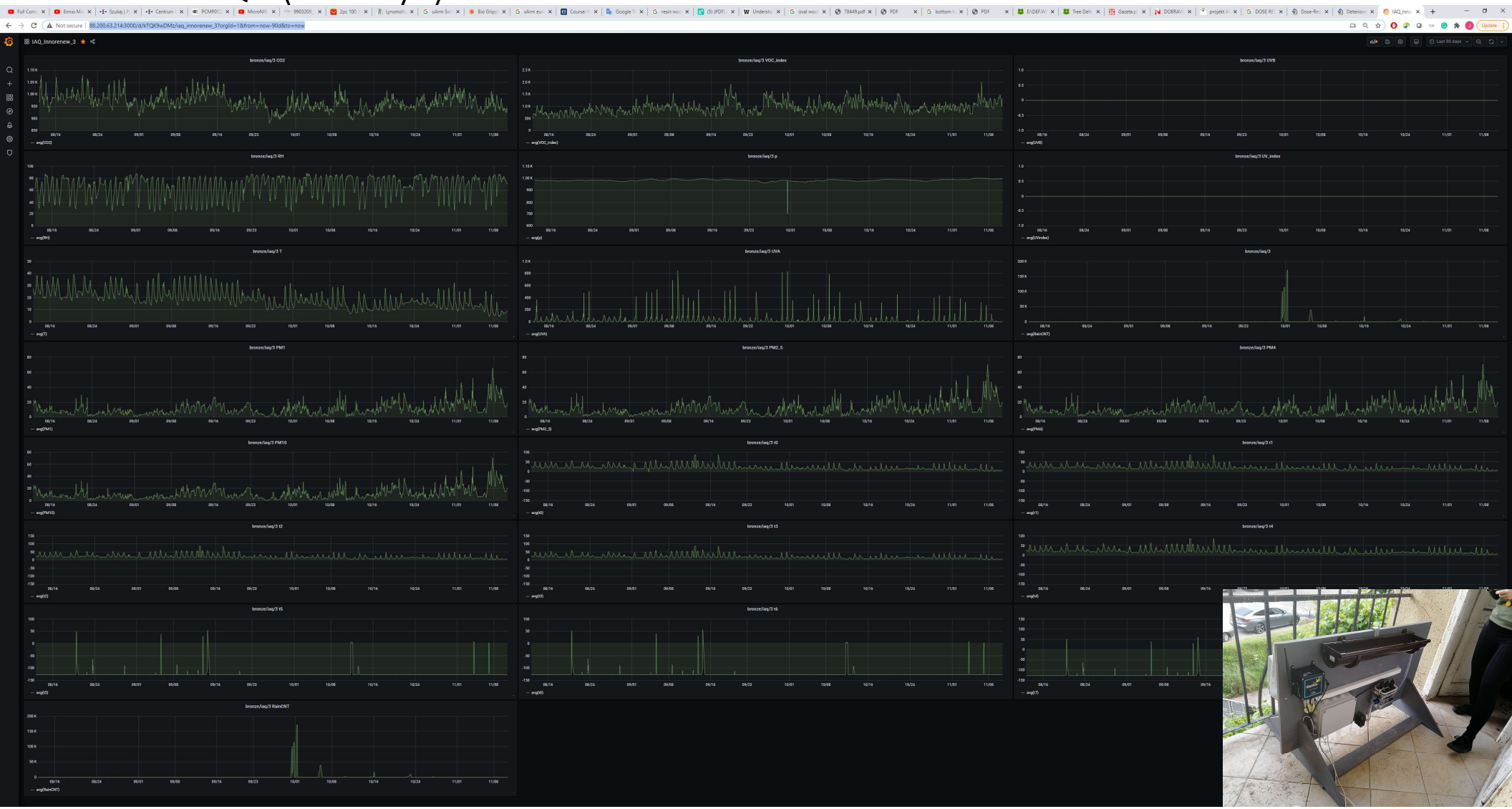
Bohin (Four brave men)

Piran (Tartini)

Ljubljana (Prešeren)

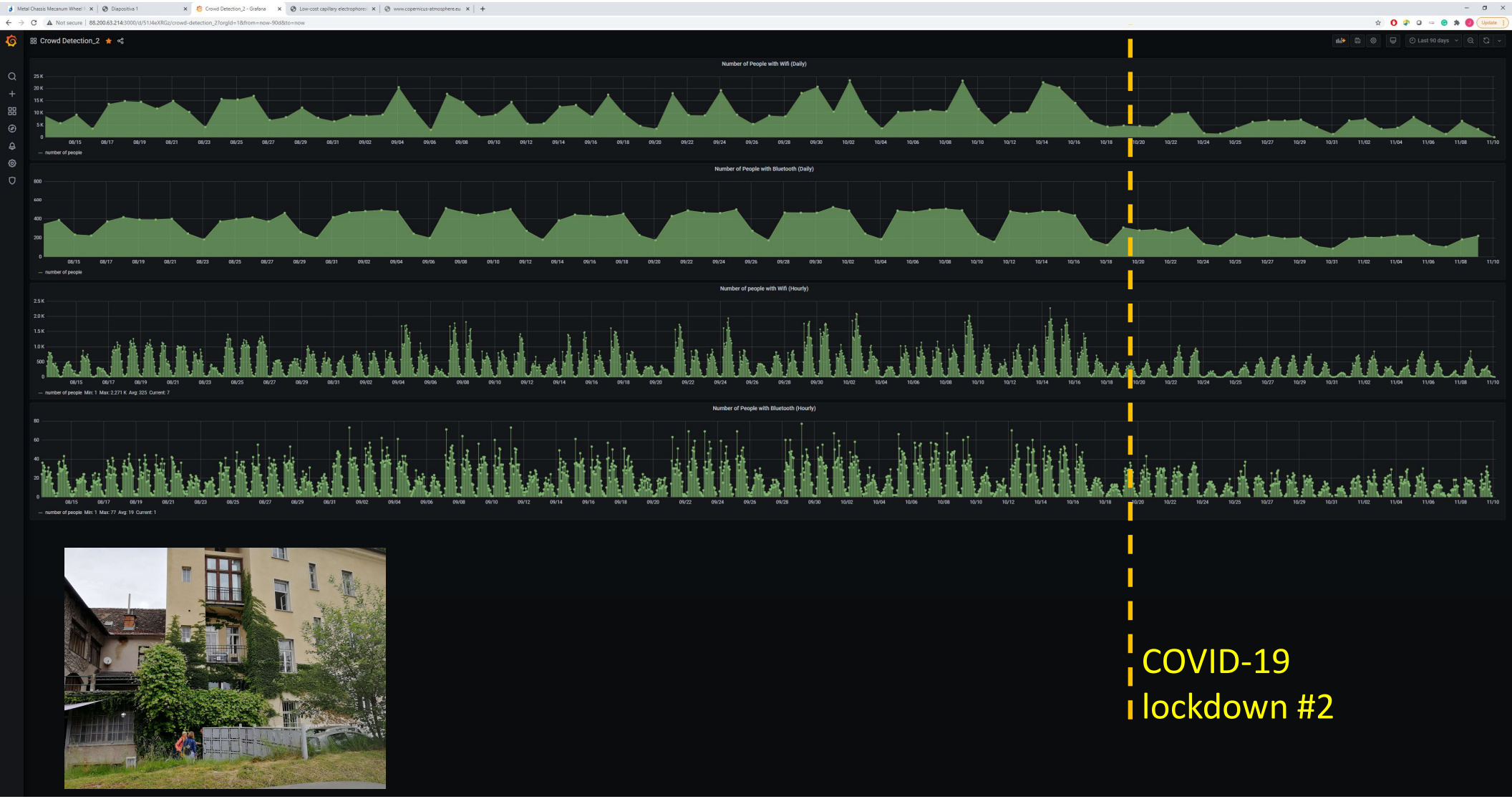
Ljubljana (Marijin steber)

Sensor 3 IAQ3 (90 days)

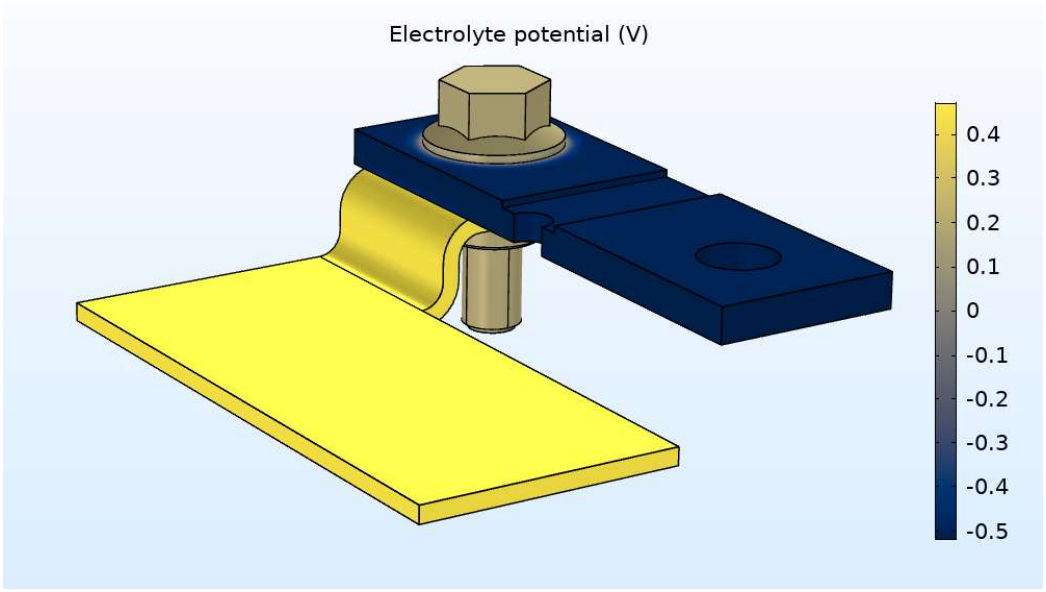


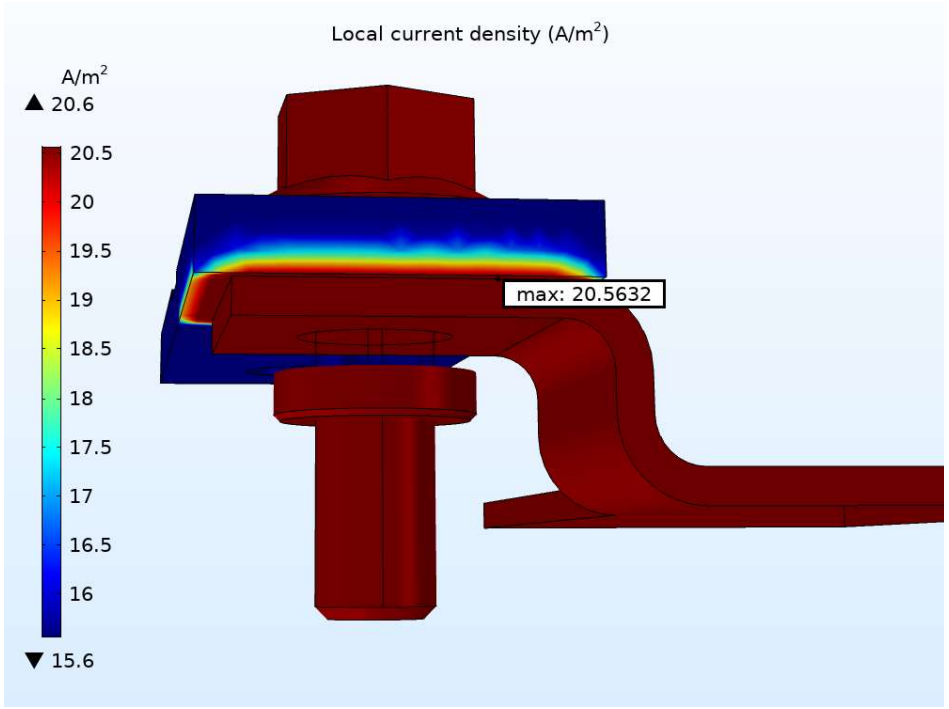
SmartWater3 (90 days)

Crowd Detection_2 (90 days)



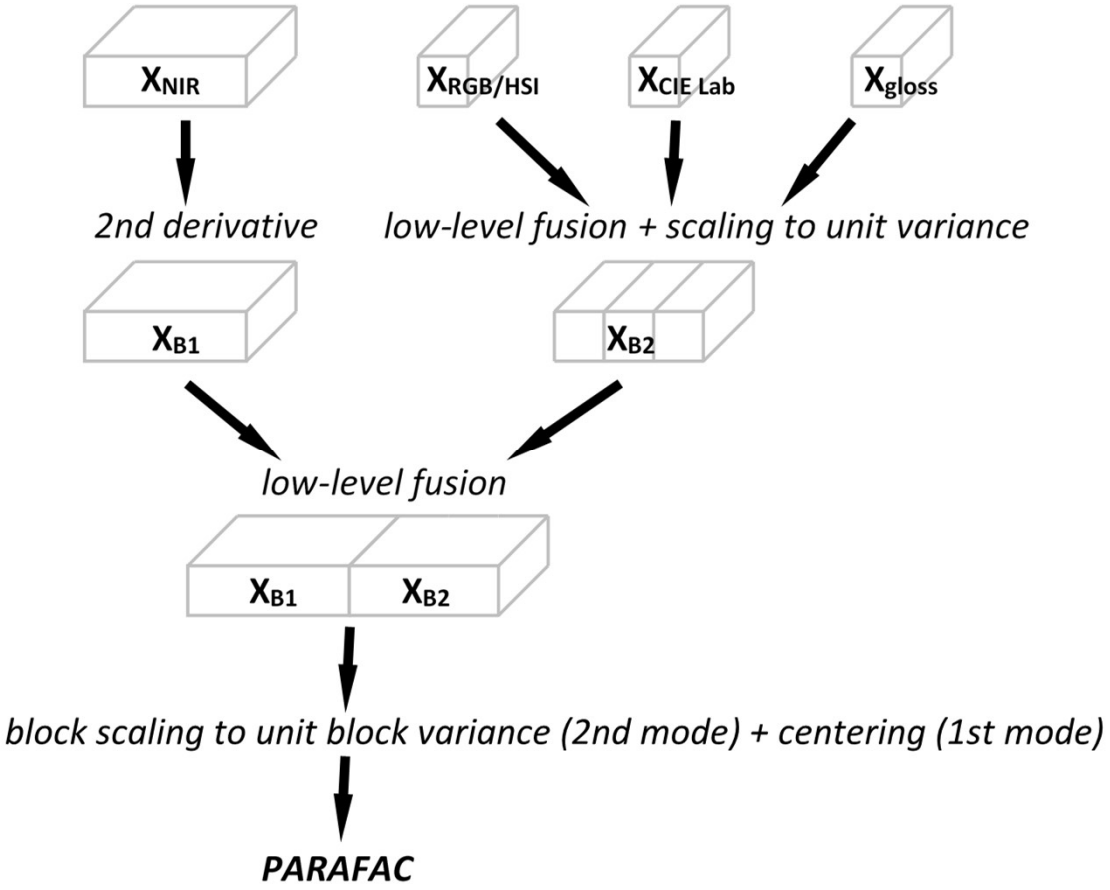
dose-response model for bronze corrosion: FEM simulation





case study: Protecting Against Atmospheric Corrosion with Simulation (https://www.comsol.com/blogs/protecting-against-atmospheric-corrosion-with-simulation/)

dose-response model for bronze corrosion: multivariate analysis



Special issue article

JNIRS

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Chemical and appearance changes of wood due to artificial weathering – Dose–response model

Marta Petrillo[1], Jakub Sandak[1,2,3], Paolo Grossi[1] and Anna Sandak[1,2,4]

summary

We developed an unique and complete system covering all components:

- universal hardware core + simple customization
- custom firmware
- adaptable data transfer protocols
- data storage solution on our own server
- unlimited access for data to allow straightforward mining
- pilot sensor system solution low-cost, but easily transferable for another applications

We will use the data provided by sensors for:

- better understanding of the corrosion kinetics and aesthetical changes for cultural heritage (bronze objects)
- develop customized dose-response models for diverse climatic zones and varying bronze/patina configurations

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Thank you!

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