Facing Air Pollution with Smart Homes

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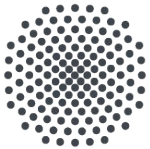

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Challenge

- Analyse data from [luftdaten.info]
- Use external Data Sources for improved results
- Create an analysis that answers questions that are relevant for the society

Motivation

- Stuttgart’s inhabitants are exposed to high particulate matter concentration within surroundings.
- Bad quality air can cause health issues or may lead to death [WHO].
- Minimize the particulate matter exposure to the inhabitants.
- Automatically open smart windows when the particulate matter concentration is low.

Data Sources

- Air pollution data from [luftdaten.info]
  - DHT22 and SDS011 sensor data
- Weather data from [DWD]
  - Wind direction, precipitation, air pressure
- VfB Stuttgart matches from Google (ad hoc)
  - Game days
- Topology data from Topographische Karten (ad hoc)
  - Elevation

Data Processing

- We take temperature,humidity from DHT22 sensor data and PM2.5 and PM10 values from SDS11 sensor data.

- We drop the columns which contains multiple NaN values set

- Removed the records,for conditions under which SDS011 and DHT22 do not work, as per the manual.

  (e.g. Temperatures lower or equal than -10 Celsius)

Data Fusion

- Two alternatives
  - Join by *datetime* with tolerance
  - Standardize the values in both (DHT22 & SDS11) sensors

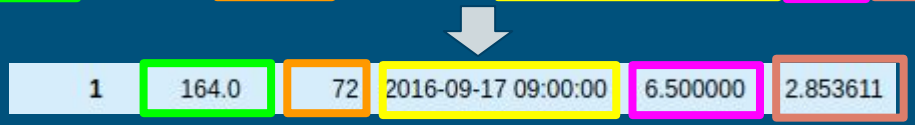
- We chose standardization

- After standardizing the data by taking **average** of all attributes w.r.t timestamp on an hourly basis, we combined them into a single dataset

Data Integration

- Materialized integration
- Through join on timestamp and location
  - Timestamp standardization

	Unnamed: 0	sensor_id	sensor_type	location	lat	lon	timestamp	P1	P2	date
0	370821	164.0	SDS011	72.0	48.773	9.174	2016-09-17 09:05:26.362	5.80	2.90	2016-09-17 09:05:26.362000+00:00
1	370822	164.0	SDS011	72.0	48.773	9.174	2016-09-17 09:02:13.125	5.30	2.63	2016-09-17 09:02:13.125000+00:00
2	370823	164.0	SDS011	72.0	48.773	9.174	2016-09-17 09:07:17.682	3.58	2.62	2016-09-17 09:07:17.682000+00:00
3	370824	164.0	SDS011	72.0	48.773	9.174	2016-09-17 09:09:57.200	4.32	2.55	2016-09-17 09:09:57.200000+00:00



1	164.0	72	2016-09-17 09:00:00	6.500000	2.853611

Example of standardization in the SDS11 dataset, which indicates P1 and P2 values. (P1=PM10,P2=PM2,5)

Technologies Used

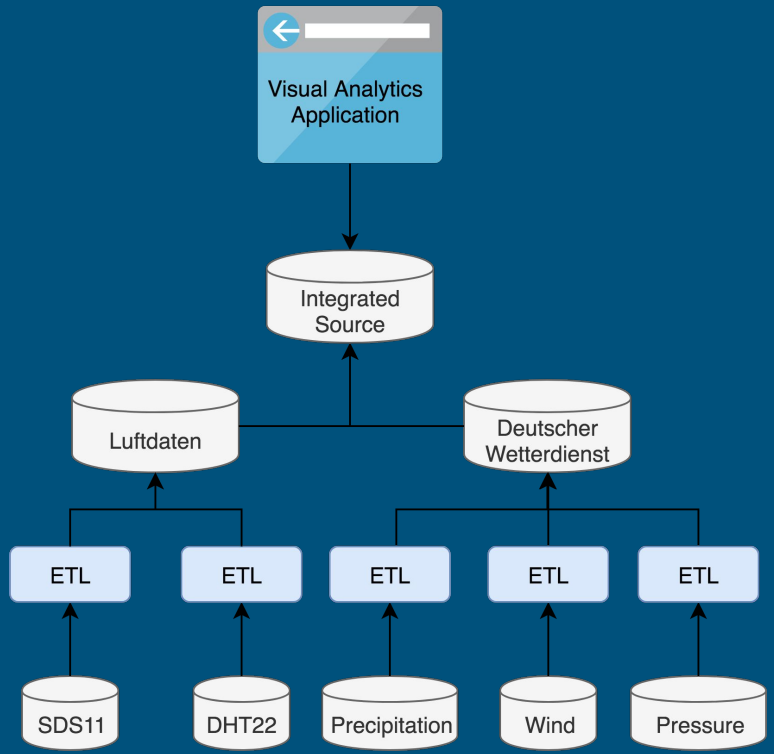
IBM Bluemix :

Python

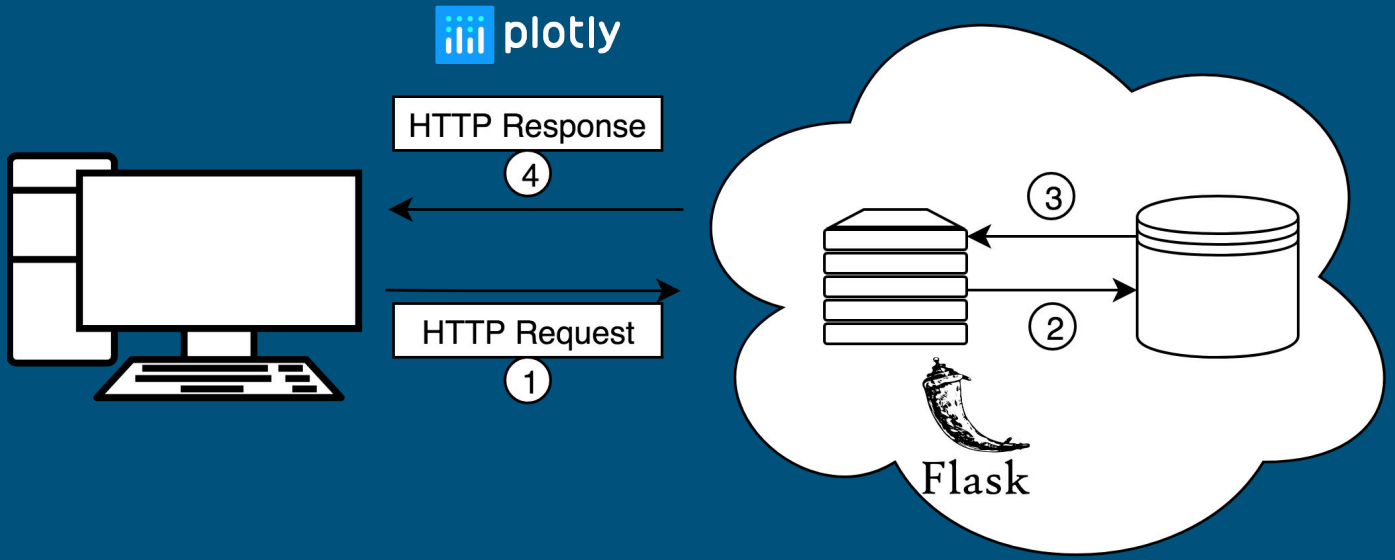
Flask Server

Plotly Graphs with Dash :

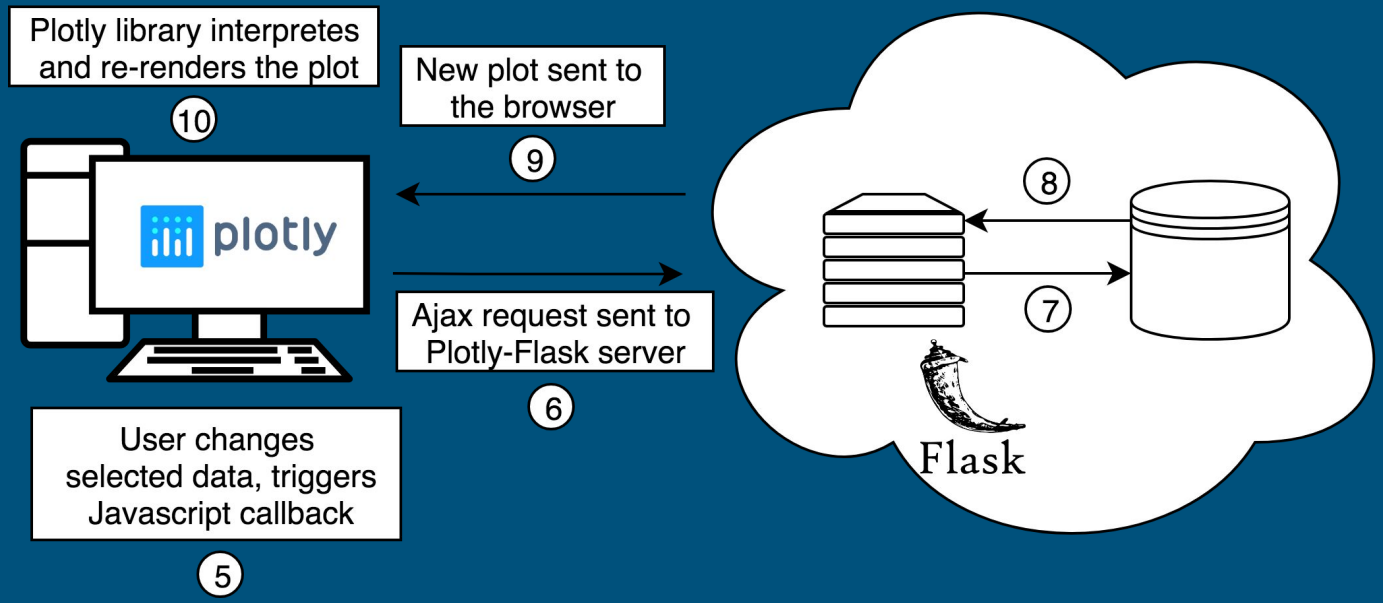
Architecture and Integration



Interaction Model

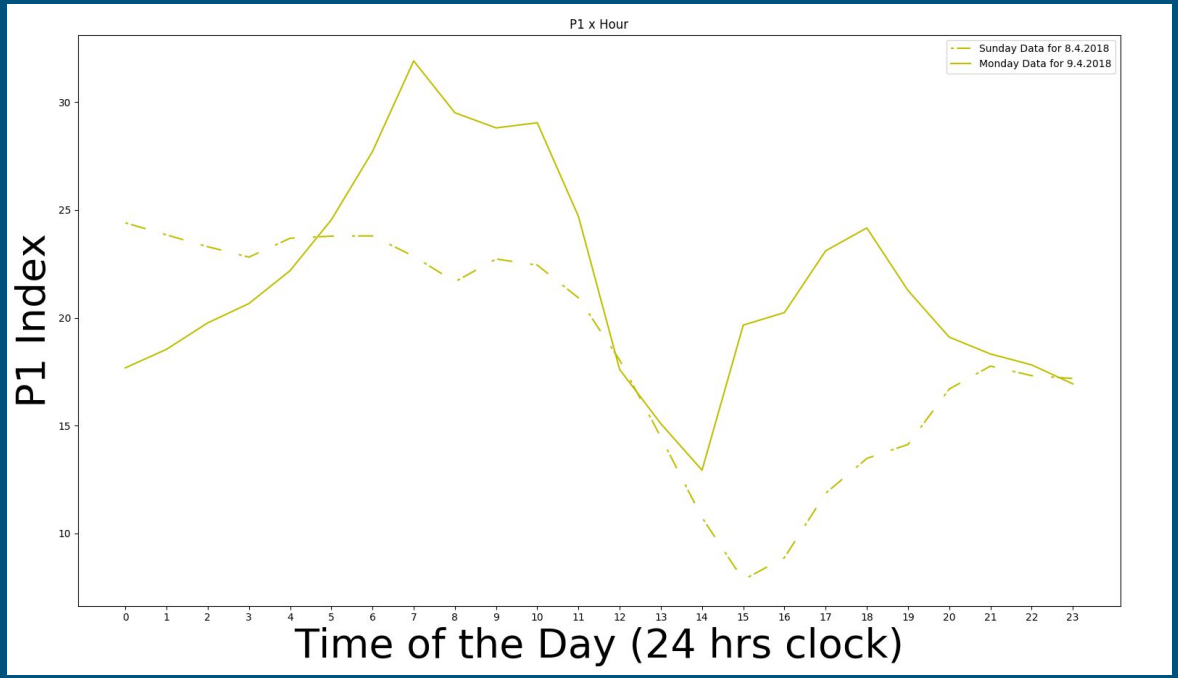


Interaction Model (2)

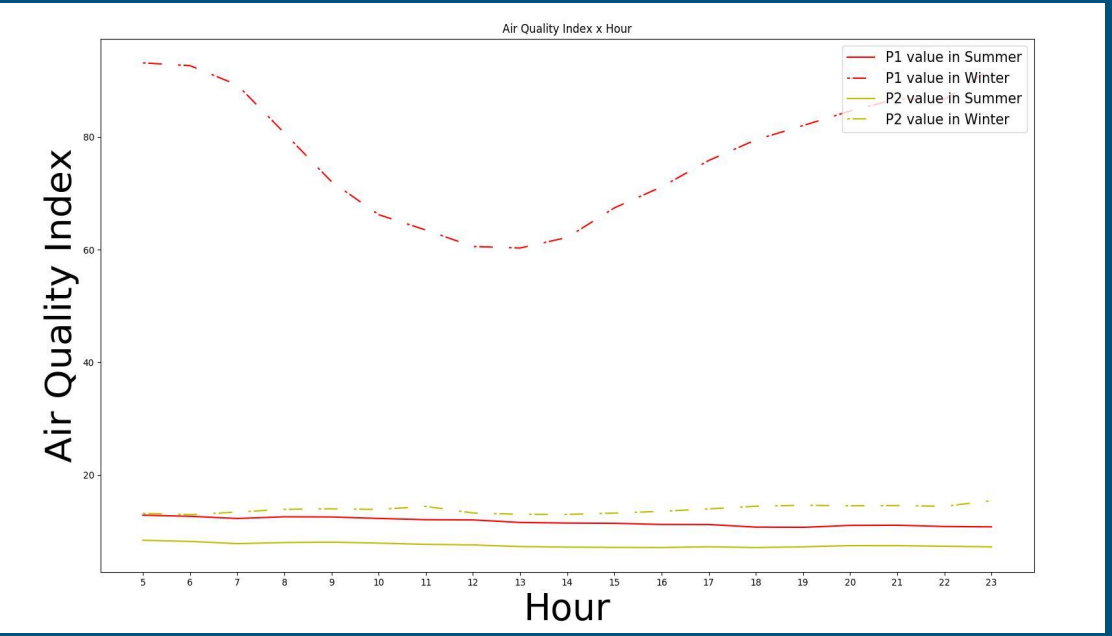


Insight 1: Commuter's traffic

- Air pollution strongly correlates to commute traffic during the day
- The season also plays a strong factor on average Air Pollution



Insight 2: Season



- Average values of PM10 is 4 times higher in winter than in summer
- Average values of PM2.5 is 2 times higher in winter than in summer
- In Winter PM10 values are particularly low during day time

Insight 3: Wind Direction

- The higher the surroundings of the Stuttgart valley are, from which the wind is blowing, the higher is the air pollution (especially the PM10 values)

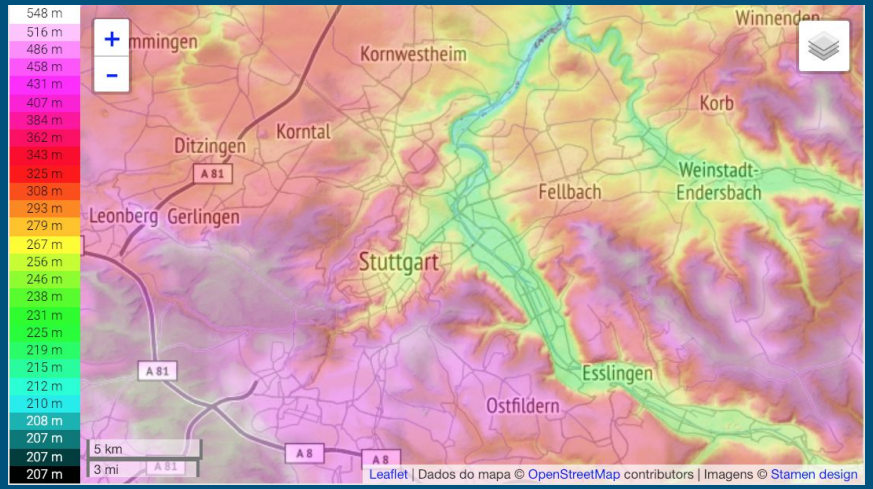
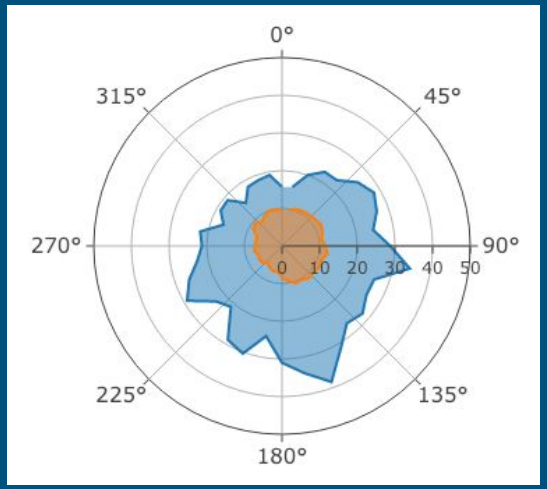


Image collected via [topographic-map]



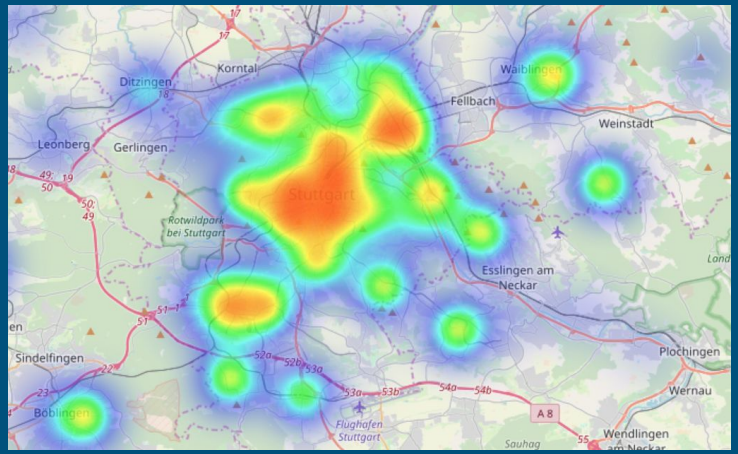
PM10 (blue) and P2.5 (orange) average for different wind directions

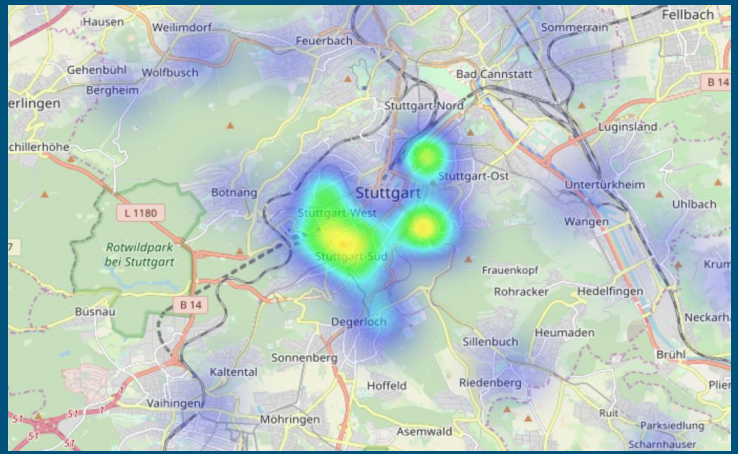
Insight 4: Soccer Games

- Stuttgart's soccer stadium is close to the city center

- On game days, the air quality in Stuttgart is not as good as on non-game days

VfB Stuttgart home game (Sat, 1/09/18, 6pm).





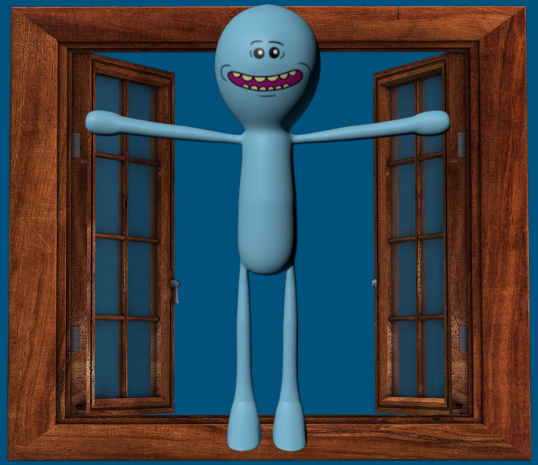
No VfB Stuttgart home game (Sat, 25/08/18, 6pm).

Plots show average P1 values for a specific hour
Higher values indicated in red

Smart Windows improve indoor Air Quality

- Open windows when outdoor particulate matter concentration is low.
- Opening times are optimized based on our insights :
  - Insight 1: Do not open windows during rush hours.
  - Insight 2: In winter the values are particularly low during day time.
  - Insight 3: Values are lower, when the wind direction is beneficial.
  - Insight 4: Avoid opening windows during soccer games(if you stay nearby).

Smart Windows: Idea



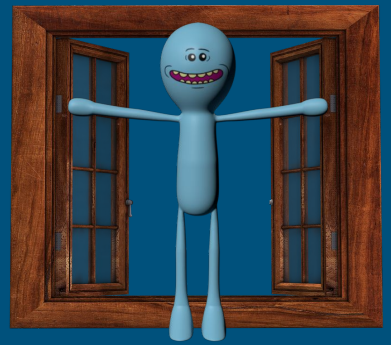
- Prevent Stuttgart’s inhabitants from breathing **polluted air**.
- Based on insights identify the **optimal** time of the day to open the window.
- Allow for window openings while inhabitants are **not at home**.

Smart Windows: Approach

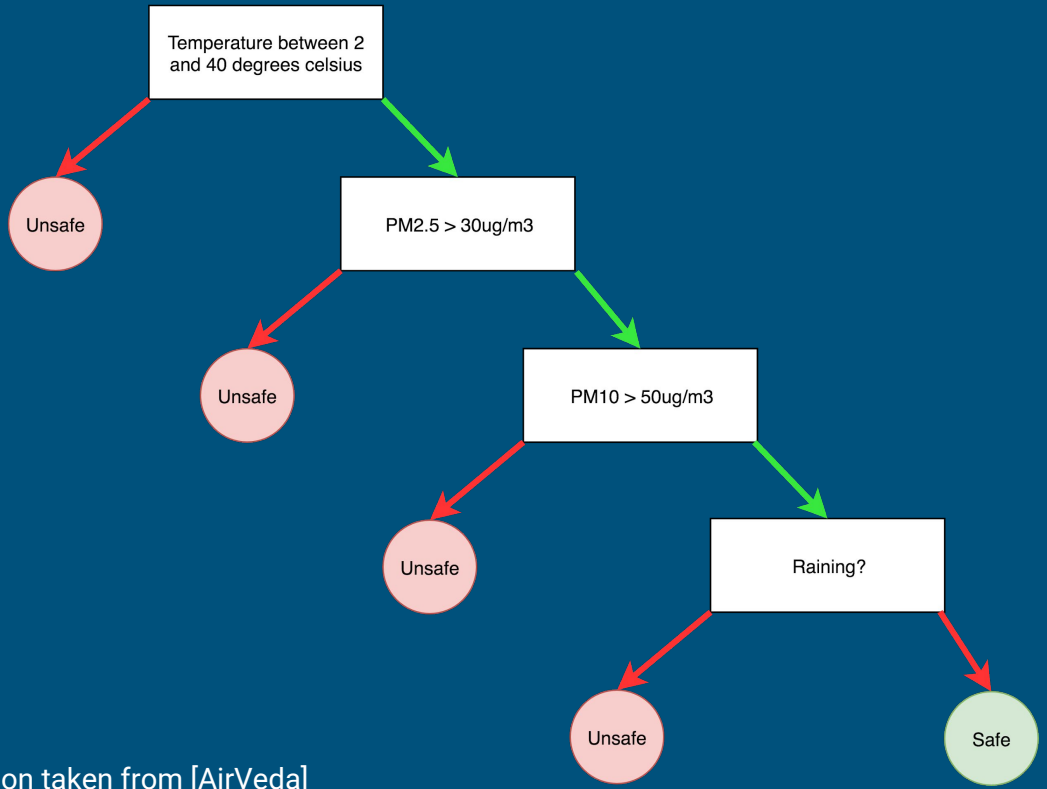
- Using an algorithm, we can automate windows to open and close when air quality is good.

- Using the correlations displayed before (rush-hours, weekdays)

- Visualize common useful information (precipitation values, temperature,P1,P2)

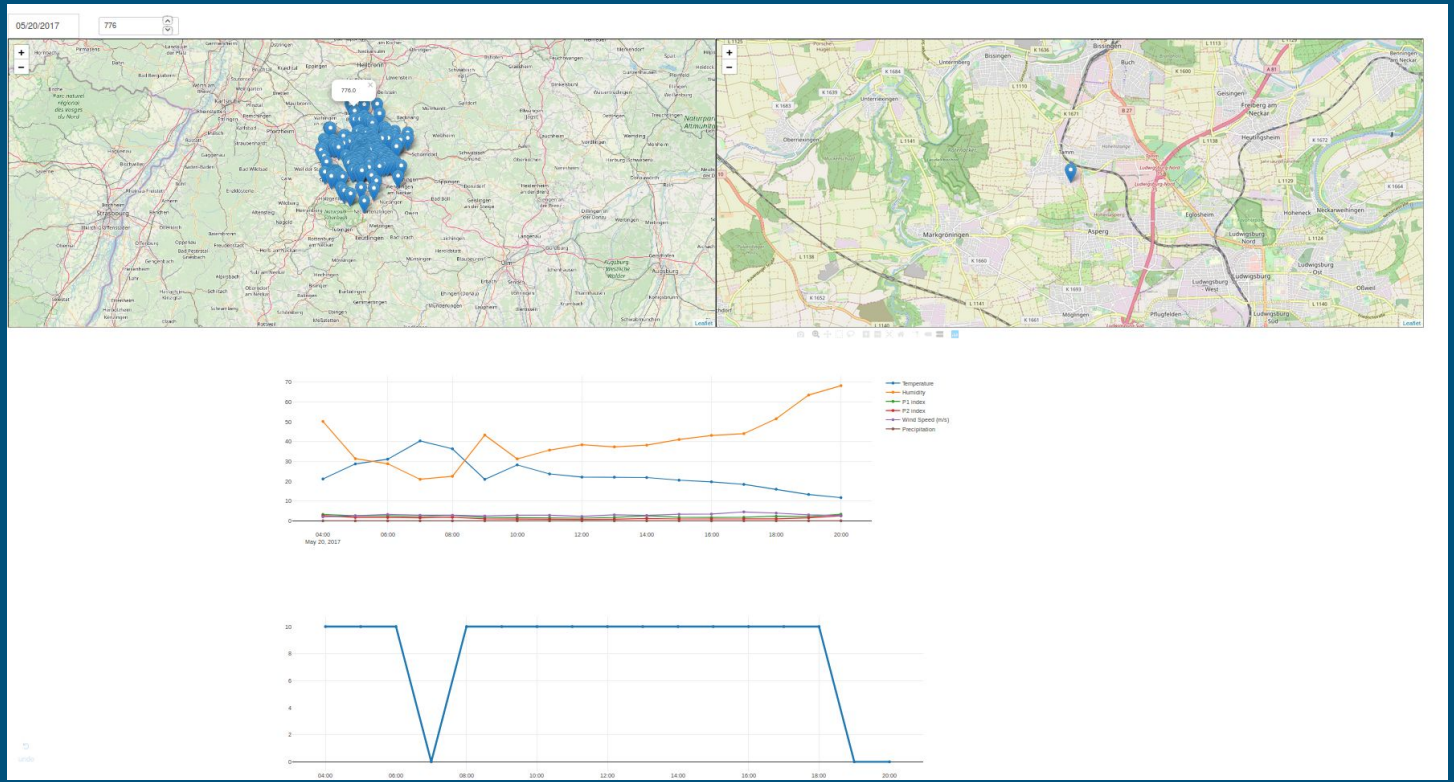


Smart Windows: Algorithm



*PM10 and PM2.5 information taken from [AirVeda]

Demo


05/20/2017
776
Temperature
Humidity
P1 index
P2 index
Wind Speed (m/s)
Precipitation

Conclusion

- We have analysed approximately 178k+ rows of data regarding air quality
- We obtained 4 main insights:
  - commuter’s traffic, soccer games, season, and wind direction.
- Smart Windows open daily when the outdoor air quality is best.
- Better life quality due to less respiratory diseases caused by polluted air breath (such as asthma).

Future Work

What is do be done to implement the smart window?

- Integrate with Raspberry Pi for automating it with the window to open/close.

How can the formula be improved?

- Data of gases like NO2,SO2,CO,O3 should be integrated and considered in the formula.

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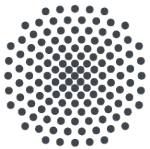

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- [DWD] Deutscher Wetterdienst - Climate Data Center. ftp://ftp-cdc.dwd.de/pub/CDC/observations_germany/climate/ (last access in 06/02/2019)
- [Topographic-map] http://de-de.topographic-map.com/places/Stuttgart-8132395/ (last access in 26/02/19)
- [WHO] Exposure to Air Pollution (Particulate Matter) in outdoor air. World Health Organization. http://www.euro.who.int/__data/assets/pdf_file/0018/97002/ENHIS_Factsheet_3.3_July_2011.pdf?ua=1 (last access in 26/02/19)
- [AirVeda] Understanding Particulate Matter and How It Impacts Our Health https://www.airveda.com/blog/Understanding-Particulate-Matter-and-Its-Associated-Health-Impact?seo_data=%5Bobject%20Object%5D (last access in 26/02/19)