What is Timelab?

- A non-profit organization founded in 2010
- Located in the beautiful city of Ghent, Flanders
- A facilitator for “makers” to collaborate and share knowledge
- Offers:
  - CityLab; incl. 3D printers, laser cutters, CNC wood router...
  - Creation-projects; incl. this ADEM project
  - Workshops, boot-camps and (art) residencies
  - Co-working café and Friday lunches
- Supported by the city of Ghent and the Flemish government
What is the ADEM project?

- Collect and share real-time air quality information
- Technology
  - Create a device to collect particulate matter (fine dust) data
  - Create a web service to collect data and publish information
- Community
  - Community-driven project development
  - Public awareness of air pollution and risks (survey, campaign)
  - Open hardware, open software, open data
  - Fostering community around the project
Loss of life expectancy

- Average loss of life expectancy in months
  - due to PM$_{10}$ air pollution
  - PM$_{2.5}$ is more dangerous
- Belgium right in the center
  - detailed maps indicate East/West Flanders and Antwerp to be even worse
- Based on data from 2000

Type of pollutants

- Everything larger than PM$_{10}$ gets trapped by the body early (*hurray for nasal hairs!*)
- PM$_{10}$ – Inhalable particles
  - between 10µm and 2.5µm
  - settles in bronchi and lungs
  - airborne for hours
- PM$_{2.5}$ – Respirable particles
  - 2.5µm and smaller
  - settles in alveoli (gas exchange)
- Ultrafine particles
  - 0.1µm and smaller
  - can find its way to your bloodstream
  - airborne for weeks (*hurray for rain!*)

https://en.wikipedia.org/wiki/Particulates
Air quality in Ghent

- Ghent is second largest city in Flanders
  - University city with population of 260,000 and 65,000 students
  - Lots of people use bicycles throughout the day
  - Port of Ghent and industry known source of air pollution
  - 2 highways close to city center (one stretching into center)

- Only 2 official air pollution stations with fine dust meters
  - Strategically placed to meet European levels
  - Yearly averages are useless, micro-measurement is key!
  - Air quality is not just PM, but PM is the least known variable today

- City council (incl. green party) is taking environment seriously!
Design goals

- Goal?
  - Create an open device that can be locally built and repaired
- How?
  - Affordable general purpose hardware components
  - Open hardware, open software and open data
  - Modular design that is easy to customize (sensors, drivers)
  - Reuse of existing Open Source libraries
Hardware design

- Micro-controller / WIFI – *Sparkfun ESP8266 Thing*
- $I^2C$ Sensors
  - Fine dust meter – *PPD42NS*
  - Accelerometer – *MPU6050*
  - Humidity sensor – *HTU21D*
  - Air pressure sensor – *BMP180*
  - GPS – *GY-NEO6MV2* 
- UART to $I^2C$ conversion – *Arduino Pro Mini (ATMEGA328P)*
- RGB Led / Buzzer / LiPo Battery
Shinyei PPD42NS
Firmware design

- Arduino-based framework (CI testing with platformio)
- Components can be swapped/added by alternatives
  - Possibly using I\textsuperscript{2}C id bus scanning / driver selection
  - Accepting contributions through GitHub
- Small test-examples for individual drivers/libraries
- Code-readability is key!
  - Abstraction through device drivers and wrappers
  - Simple state-machine with state-transitions
Current device status

- Hardware design
- Component evaluation and testing
- Initial PCB design + first casing design
- Prototype 1 (solder-less breadboard)
- Prototype 2 (solder-less breadboard); add Arduino Pro Mini
- Second PCB design + second casing design
- Prototype 3 (soldered breadboard); real-life testing
- ...
- Profit!
Various issues in the process

- Too few I/O pins for all components
- Imperfect signal from PPD42NS
- Underpowered components
  - GPS and PPD42NS may need 5V
- Onboard I²C of GPS was impossible to get working
- Various issues with ESP stability and timing sensitivity
  - Influences I²C communication (protocol analyzer!)
  - WIFI troubles (mostly captive portal / disconnects)
  - Infrequent crashes
Possible future functionality

- Collection of bicycle road quality information (i.e. bumps)
- Include more air quality sensors (incl. NO\textsubscript{x}, SO\textsubscript{2}, CO, O\textsubscript{3}, ...)
- Support (outside and in-house) stationary devices
- Auto-calibration of devices when they pass each other
- Mobile app to guide runners/bikers to most healthy routes
- Correlate air quality to sources and weather conditions
- Billboards showing real-time air quality at “hot” spots
How can you help?

If you are interested to...

– develop on embedded platforms *(Arduino/C++)*

– visualize real-time sensor data *(environmental or data-scientists)*

– help install the device and train users

– create awareness by helping with campaigns

You are welcome

– no prior knowledge required

– device team meets every wednesday-evening

– ADEM progress meetings every month

– just come by at Timelab and shape the future!
More information

- **ADEM project**
  - Website – [http://ik-adem.be/](http://ik-adem.be/) (dutch)
  - Email – ja@ik-adem.be
  - Twitter - @ik_adem

- **Timelab vzw**
  - Email – hello@timelab.org
Interesting links

- Real-time Air Quality Index maps
  - http://aqicn.org/map/europe/
- ETH Zurich OpenSense project
  - http://www.opensense.ethz.ch/trac/
- Ultrafijnstof en rochelroutes
  - http://www.rochelroutes.nl/
- MEP, it’s time for cleaner air!
  - https://www.youtube.com/watch?v=JmdPbXW-BTw
- Wikipedia information
  - Particulate matter: https://en.wikipedia.org/wiki/Particulates
  - Diesel exhaust: https://en.wikipedia.org/wiki/Diesel_exhaust
## Bill of Materials

<table>
<thead>
<tr>
<th>Component</th>
<th>Type</th>
<th>Non-bulk price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microcontroller</td>
<td>Sparkfun ESP8266 Thing</td>
<td>€ 15,95</td>
</tr>
<tr>
<td>Accelerometer</td>
<td>MPU6050</td>
<td>€ 2,83</td>
</tr>
<tr>
<td>Barometer</td>
<td>BMP180</td>
<td>€ 2,04</td>
</tr>
<tr>
<td>Battery</td>
<td>LiPo 3,7V 500mAh</td>
<td>€ 2,00</td>
</tr>
<tr>
<td>Buzzer</td>
<td>KY-006</td>
<td>€ 1,44</td>
</tr>
<tr>
<td>Fine dust meter</td>
<td>PPD42NS</td>
<td>€ 15,90</td>
</tr>
<tr>
<td>GPS</td>
<td>GY-NEO6MV2</td>
<td>€ 11,66</td>
</tr>
<tr>
<td>Humidity sensor</td>
<td>HTU21D</td>
<td>€ 3,24</td>
</tr>
<tr>
<td>RGB Led</td>
<td>NeoPixel WS2812</td>
<td>€ 2,40</td>
</tr>
<tr>
<td>UART-to-I²C convertor</td>
<td>ATmega328P Pro Mini</td>
<td>€ 3,00</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>€ 60,46</strong></td>
</tr>
</tbody>
</table>
Venturi effect

- Ensuring airflow on moving devices
  - *so we can remove the resistor (heat pump) to save battery*
  - Large intake hole creates underpressure at bottleneck, sucking air into the device
Usual suspects

- Air quality is affected by
  - Industry, power plants
  - Buses (diesel*), cars (incl. electrical cars), subway/trains, trams
  - Airplanes
  - Household heating
  - Agriculture

- But also
  - Weather conditions (wind, rain, air pressure)
  - Streets and buildings (air flow)
  - Indoor conditions (ventilation, candles, cooking*, smoking*)
  - Natural sources (wildfire, volcanoes, dust storms, ...)
Air-quality awareness projects

- **2010**: Air-quality monitoring on trams in Zurich (ETH Zurich)
  - Measuring $O_3$, CO, $NO_2$ and ultrafine particles
- **2014**: AIRbezen in Antwerp (Universiteit Antwerpen)
  - 700 strawberry plants measuring ferromagnetic fractions
- **2015**: Ivy-plants in Ghent (Universiteit Antwerpen)
  - 240 ivy-plants measuring finedust particles
- **2016**: CurieuzeNeuzen in Antwerp (Vrije Universiteit Brussel)
  - Measuring $NO_2$ using small collection-tubes
Concentration of PM$_{10}$ in Europe

## European air quality standards

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Period</th>
<th>Europe AQ</th>
<th>Permitted exceedings</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM$_{2.5}$</td>
<td>1 year</td>
<td>25 µg/m³</td>
<td></td>
</tr>
<tr>
<td>PM$_{10}$</td>
<td>24 h</td>
<td>200 µg/m³</td>
<td>35 / year</td>
</tr>
<tr>
<td></td>
<td>1 year</td>
<td>40 µg/m³</td>
<td></td>
</tr>
<tr>
<td>CO – Carbon monoxide</td>
<td>24h / 8h</td>
<td>10 mg/m³</td>
<td></td>
</tr>
<tr>
<td>SO$_2$ – Sulphur dioxide</td>
<td>1h</td>
<td>350 µg/m³</td>
<td>24 / year</td>
</tr>
<tr>
<td></td>
<td>24h / 8h</td>
<td>125 µg/m³</td>
<td>3 / year</td>
</tr>
<tr>
<td>NO$_2$ – Nitrogen dioxide</td>
<td>1h</td>
<td>200 µg/m³</td>
<td>18 / year</td>
</tr>
<tr>
<td></td>
<td>1 year</td>
<td>40 µg/m³</td>
<td></td>
</tr>
<tr>
<td>O$_3$ – Ozone</td>
<td>24h / 8h</td>
<td>120 µg/m³</td>
<td></td>
</tr>
<tr>
<td>Benzene</td>
<td>1 year</td>
<td>5 µg/m³</td>
<td></td>
</tr>
<tr>
<td>Pb – Lead</td>
<td>1 year</td>
<td>0.5 µg/m³</td>
<td></td>
</tr>
<tr>
<td>As – Arsenic</td>
<td>1 year</td>
<td>6 ng/m³</td>
<td></td>
</tr>
<tr>
<td>Cd – Cadmium</td>
<td>1 year</td>
<td>5 ng/m³</td>
<td></td>
</tr>
<tr>
<td>Ni – Nickel</td>
<td>1 year</td>
<td>20 ng/m³</td>
<td></td>
</tr>
<tr>
<td>Polycyclic Aromatic Hydrocarbons</td>
<td>1 year</td>
<td>1 ng/m³</td>
<td></td>
</tr>
</tbody>
</table>

[http://ec.europa.eu/environment/air/quality/standards.htm](http://ec.europa.eu/environment/air/quality/standards.htm)
### WHO air quality guidelines

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Limit</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particulate matter (PM(_{2.5})) 24 h mean</td>
<td>&lt;25 µg/m(^3)</td>
<td>WHO Air Quality Guideline;</td>
</tr>
<tr>
<td>Particulate matter (PM(_{10})) 24 h mean</td>
<td>&lt;50 µg/m(^3)</td>
<td>WHO Air Quality Guideline;</td>
</tr>
<tr>
<td>Carbon dioxide (CO(_2))</td>
<td>&lt; 1000 ppm</td>
<td>ASHRAE 62.1-2013;</td>
</tr>
<tr>
<td>Sulphur dioxide (SO(_2)) 24 h mean</td>
<td>&lt; 20 µg/m(^3)</td>
<td>WHO Air Quality Guideline;</td>
</tr>
<tr>
<td>Nitrogen dioxide (NO(_2)) 1h mean</td>
<td>&lt; 200µg/m(^3)</td>
<td>WHO Air Quality Guideline;</td>
</tr>
<tr>
<td>Ozon (O(_3)) 8 h mean</td>
<td>&lt; 100 µg/m(^3)</td>
<td>WHO Air Quality Guideline;</td>
</tr>
<tr>
<td>Carbon monoxide (CO) 8 h mean</td>
<td>&lt; 75 ppm</td>
<td>ASHRAE 62 1-2013;</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>&lt; 0.1 mg/m(^3)</td>
<td>ASHRAE 62 1-2013;</td>
</tr>
</tbody>
</table>