**Invisible Cities – Air Quality**

Group Project Report

Group 3 – Qiuwen Ju, Tom Keel, Zixin Lyu & Jay Wilson

**Project outputs**

|  |  |
| --- | --- |
| Website scripts |  |
| Website address | **https://naughty-kepler-88ce41.netlify.com/#a** |
| Presentation file |  |
| Supporting scripts |  |
| Supporting data files |  |
| Links to supporting sites and technologies |  |

**Contributions**

|  |  |  |  |
| --- | --- | --- | --- |
| **Task Name** | **Major contributors** | **Additional contributors** | **Relevant report sections** |
| Concept development | Quiwen, Lyu, Jay |  | Introduction, Objectives,  Early decisions |
| Data preparation | Lyu | Jay | Technologies |
| Data Integration | Tom, Lyu | Qiuwen | Technologies, Challenges and solutions |
| Home page | Qiuwen, Jay | Tom | Static, Styling |
| Spinning globe page | Tom | Jay | Interactivity, Later additions |
| World map page | Tom, Lyu | Jay | Interactivity, Technologies |
| Street pollution page | Qiuwen, Tom |  | Static |
| Collaboration & hosting | Tom |  | Technologies |

**Introduction**

Our project visualisation educates visitors to our website about the levels of air pollution in major cities and the consequences for the people that live there. The global scientific measurements that make up a city’s air quality index are accompanied by simple cartoon depictions that provoke an instinctive response in visitors and a short history of air pollution reveals how slowly authorities respond to incidents. The goal is to produce a reaction in anyone who looks at this information – that we must do more to provide clean air in urban environments anywhere in the world.

**Objectives**

This project starts with an assumption that no-one thinks too much about the air we breathe. Starting with the home page of the website we knew we had to first draw attention to the air itself to capture a visitor’s attention and then get them to focus on our primary aim which is to raise awareness about how serious a problem air pollution (Diaz-Sanchez, Proietti & Polosa, 2003) can be in cities.

To strengthen the importance of this issue we chose to use live data to avoid anyone dismissing the pollutant measurements as history. We also chose to use global records and have a global map, making assumptions that the population of most cities would have a large international contingent and that website visitors would want to compare pollution levels in different cities that they knew as well as their own. Our website should also briefly educate people about the science behind the air quality index (AQI), made up of the different visible and invisible components that pollute the air, and describe their effect on human health.

We planned to have a spinning globe as an attractive alternative image, displaying information secondary to air pollution. This could be a contributing factor, such as a country’s lack of green spaces or level of industrialisation, or an effect, such as life expectancy or birth weights (Carrington, 2019). An bonus for the website would be achieved if the data displayed on the spinning globe displayed historical information from places where the AQI measurements were not available on the main map, either because no air pollution measurement stations existed or because the national government did not release the data.

A minor objective is not to let anyone assume that authorities act quickly (even when deaths occur within weeks) to toxic levels of air pollution, so a historical timeline is provided of air quality disasters and and the delayed government or corporate response to those disasters. We also included some topical historical films on the timeline to include cultural responses to declining air quality from anthropomorphic activities.

The layout of the website would have clean lines without clutter because we wanted visitors to focus on the information without being distracted. Website navigation would be kept simple by using non-linguistic coloured glyphs to click to view different pages.

**Literature review**

Ten years is a long time in visualisation tools. An old computing paper (Wang, 2005) about GIS and traffic simulation includes only references to two commercial packages from large software companies, ArcGIS ArcView and Autodesk 3D-Studio Max, but less than ten years later no commercial software is mentioned in air pollution monitoring (Snyder et al, 2013) and it seems that government departments and their suppliers are pouring time and effort into developing their own visualisation software.

Regarding the subject, as recently as twenty years ago research (Wilkinson, et al. 1999) reported no link between asthma in children and their proximity to roads, this may contribute to why legislation is slow to respond to more recent public concern.

**Early decisions**

Different topics were discussed at first. Our team had ideas such as displaying information about transport or green spaces within a city, but interests were divided until we explored linking these topics together and discovered the idea of air quality. Once this became our theme we discovered that it was a more passionate topic – all of us live in cities and we have all had direct experience of breathing clean and polluted air.

Visually our aims were more diverse. At first we wanted a 3D spinning globe, 3D streets displaying airborne particles blown by the wind past a family, live pollution information accessed using air monitoring stations around the world, satellite maps of pollutant levels where there were no monitoring stations, and child-like cartoon faces forming lasting memories for website visitors.

**Interactivity**

Spinning globe – hover over any country to highlight its land area in a different colour. The colour could be related to the percentage of GDP contributed by the industrial sector or the life expectancy in that country. Neither of these is expected to correlate with the air pollution measurements in a city but one is a cause of pollution and the other is adversely affected by it, the aim is just to get our visitors thinking more widely about the problem.

World maps and clicking on individual cities – some cities have more pollution data about them than others and we wanted to make it obvious to the user how to select these cities. Clicking on the major cities with a square icon instead of a circle icon provides the extra information available for them, such as pollutant readings from the city in the past twenty-four hours. The pop-up information includes a coloured cartoon face for an instinctive reaction.

Historical sliding bar – the history of air pollution is littered with slow reaction from local and national authorities after an incident has occurred. The technical content in this history tour is reduced so that readers consider the impact on human life more, and for the same reason there are cultural references to festivals, films and fashion.

**Static**

Home page – the first powerful image seen by the visitor sets the mood for the topic of urban air pollution. The people are tiny within the bus on the bridge, the bridge is but a slim strand crossing a ponderous murky river and over the distant riverbank tower huge buildings hidden behind haze and clouds. The aim is to indicate the size of the problem without any indication of an answer.

Splash-page text – a slim sans-serif font is used to for a modern look to match many contemporary websites. For example, <https://www.copernicus.eu/en> (primarily EU satellite earth-measurements and research) is an example of the recent fashionable use of sans-serif font. It uses bright blue and green colours on its home page to promote our planet’s attractive vitality, which our home page does not have nor do. In contrast, another website concerned with air pollution, <http://aqicn.org/city/beijing/>, looks old-fashioned because it uses serif font, unchanged from the early days of the internet.

Street level image – after Tom realised that Unity would not (due to time and resource constraints) help users visualise airborne pollutants blowing along a street adversely affecting a cartoon family we decided to display a static 2.5D image of pollution levels around a city centre. Qiuwen used data for the streets around UCL to show the varying air quality along the major and minor roads around campus.

*Qiuwen – MapBox/ Leaflet*

**Styling**

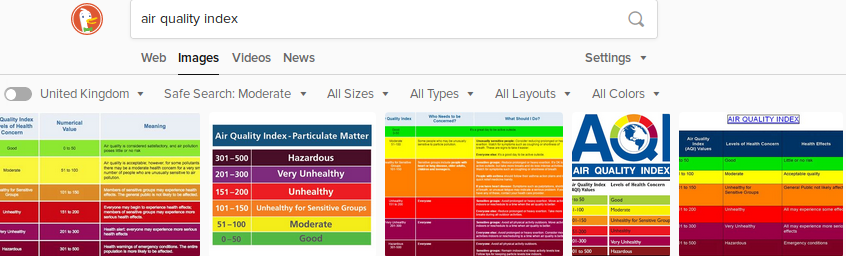
Photograph selected by Qiuwen – dominant brown and greyish-blue are used to indicate pollution on our home page, selected. These colours match the tones in Chai Jing’s “Under The Dome” documentary about pollution in China, displaying grey urban skies in outdoor scenes, subdued blue lighting on stage in a dimly-lit theatre and a brown and beige cartoon explaining how pollutants enter our bloodstream.

Home page title – a slim sans-serif font is used to for a modern look to match many contemporary websites. For example, <https://www.copernicus.eu/en> (primarily EU satellite earth-measurements and research) is an example of the recent fashionable use of sans-serif font. It uses bright blue and green colours on its home page to promote our planet’s attractive vitality, which our home page does not have nor do. In contrast, another website more directly concerned with air pollution, <http://aqicn.org/city/beijing/>, looks old-fashioned because it uses a serif font, unchanged from the early days of the internet.

The warning message under the title is there to emphasize another objective of this project; our team is not just practising our website visualisations and displaying skills at obtaining and presenting data so that we get good marks on the course, we are also keen to see environmental change happen in our world. Not as controversial as Greta Thunberg, the Swedish teenager who used the incident of the cathedral fire at Notre-Dame in 2019 to urge European politicians to act rapidly on climate change (IN, 2019), but we hope our website adds to this momentum. Jay provided the text for the home page, the sentence about paying for food and water but not air coming from an unpublished original card game that he created to educate his young teenage children about money and life.

There are different shapes for some cities, square markers attract the viewer’s attention that more information is available. There are no instructions to hover over a square representation of a city but our expectation of a user’s implicit interaction (Atterer, Wnuk & Schmidt, 2006) is that someone will move to and click an object on a screen because the limited functionality of a mouse permits them to do little else.

We selected the same colour index to indicate air quality as used on a quick search of existing websites images as illustrated by this screenshot from the DuckDuckGo search engine.



Green is good air quality, going through a reverse rainbow-like sequence back to red before using violet and brown for the poorest air. The cartoon faces have a similar sequence, going from green (happy) to orange (neutral) to red (sad) but finishing on grey for the worst pollution to indicate that someone’s life is severely affected. The cartoon faces were hand-drawn by Jay to add a natural look and emphasize that air pollution readings affect real people. They link numerical measurements to the effect that polluted air has on someone’s health and life-expectancy.

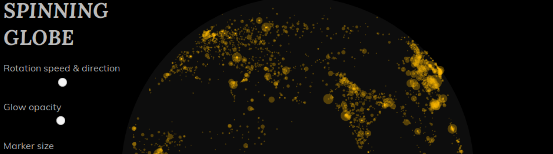
We provided cartoon faces for maximum impact. A person’s response “generalises equally well to upright cartoon faces as to human or cat faces despite their very different low-level image properties” (Tong, Nakayama, Moscovitch, Weinrib & Kanwisher, 2000) and we wanted to make sure our website was memorable. This contrasts with other air quality websites which have plenty of information but do not usually attempt to raise an instinctive emotional response to create immediacy and memories for the viewer.

**Technologies**

Tom introduced our team to GitHub and documented common command-line git instructions to ensure everyone kept in step. He also introduced us to Webstorm, a multi-tasking IDE (Integrated Development Environment) that inspects code, renders a webpage in the manner of Chrome/ Firefox/ Opera browsers, includes command-line Git support and is free for thirty days use.

And Tom got our website deployed from GitHub on to Netlify. Netlify offers a one-stop-shop method of developing a website but we did not explore this because we were more experienced with GitHub already. We lost control of the domain name by using Netlify, at the time of writing it is the mostly meaningless [https://naughty-kepler-88ce41.netlify.com/#a](https://naughty-kepler-88ce41.netlify.com/" \l "a) but again, it is free to use.

At the beginning there were two options for our 3-D spinning globe. The dedicated example Jay found at <http://planetaryjs.com/examples/quake/index.html> seemed promising because it had similar elements to those we wanted to display: data elements displayed on a rotating sphere with a side-bar explaining the visualisation, but Jay and subsequently Tom discovered that the display was difficult to alter. Tom recommended we worked with Mike Bostock’s D3 globe as displayed by Patrick Stotz’s example here <http://bl.ocks.org/PatrickStotz/1f19b3e4cb848100ffd7>



but we did not want cities spinning, we wanted users to be able to select them from a static map. We would use the spinning globe to display country information about the level of industrialisation or life expectancy*.*

Lyu found and researched the sister websites, <http://aqicn.org/city/beijing> and <https://waqi.info/> and set up the API keys and downloads from air pollution monitoring stations that our website runs on. Where possible she enhanced the live measurements on these websites by collecting previous readings from the past twenty-four hours to display in an inset on the main page. This data was available for two hundred major cities. The data had to be collected and saved to speed up the response of the webpage, because if the API were triggered to collect the past day’s data only when a user clicked on a city there would be a two minute delay before anything was displayed. There are issues collecting information like this on a laptop, it took several attempts and one consequence is that this part of our webpage will quickly get dated.

*Lyu - API*

Satellite data from the Copernicus project for related readings – leaf area index and ozone – were also accessed using API but as explained elsewhere we did not use them.

Jay used GIMP to digitally enhance and standardise the photographs of the cartoon faces he drew on paper. All faces were scaled to fit the same 128x128 png (Portable Network Graphic) file, given a flat colour of green, amber, red or grey, and each of the four colours was put on three backgrounds of white, black and alpha (transparent).

*Tom - website tools, languages*

**Challenges and solutions**

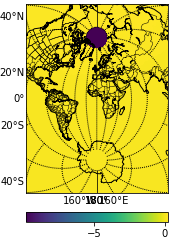
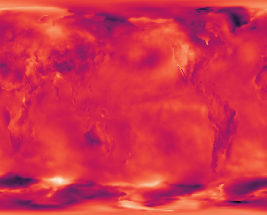
Because we were attempting so many firsts with this project we made many decisions that we later changed or dropped entirely.

We had never worked together before and the difference in our experience levels showed when we tried to collaborate using GitHub (<https://github.com/>). The normal pattern of command-line edits, commits and merges did not go well and Tom changed the way we worked to using less global updates so that it was not so disruptive.

We used two API successfully, one from a Chinese website published in English (<https://aqicn.org/api/>) and the other from the Copernicus programme run by the EU (<https://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus>). Together, the first API covered the publicly available air pollution data for all the world’s major cities and the second API covered ozone levels around the globe measured by satellite (ESA, European Space Agency, online) where no ground measurements were made or published. These measurements from space are important because the AQI for the two largest African cities – around twenty million inhabitants each – is unknown as neither Egypt nor Nigeria publish results for Lagos nor Cairo.

However, what we could do with the data downloaded from these two API was very different. The ground-based measurements provided live data readings at hourly or daily intervals. This gave Lyu the opportunity to provide two visualisations: a simple reading for cities where daily measurements was taken or a graph of the past twenty-four hours for cities with hourly measurements. However, it was necessary to use her laptop as a staging post to save the previous day’s API data to GitHub because updating the webpage with live data directly from the API caused a two minute delay before the information was displayed. Querying GitHub files made the webpage much more responsive.

Using the data from a satellite was more challenging. ESA stores the petabytes (!) of data transmitted by their Sentinel satellites in several data hubs for international researchers to access it. Obtaining an API key for the Copernicus data service involved a week-long wait before it would work. Jay downloaded and displayed a sample .GRIB file (of temperature anomalies in 1979, a careful look shows that the red map is centred on the Pacific Ocean) and a 2017 ozone measurement that was the last taken by an instrument on Sentinel 3 (the yellow map shows a very unlikely ozone distribution and may explain why no further downloads are available from that source).



More recent measurements of ozone and LAI (Leaf Area Index, a scale of 1-10) were downloaded in 300MB+ .nc format files and Python frequently crashed reporting a “Memory Error” while trying to create a dataframe.

We found that 3D globes are not easy to add information too. Tom discovered that an attractive rotating globe with earthquakes (<http://planetaryjs.com/examples/quake/index.html>) was difficult to modify. And the vector graphics approach used by D3 (<https://www.d3indepth.com/geographic/>) is not suitable for a raster map, but raster data is what satellite instruments collect as they orbit over the planet beneath them. The website <https://www.maptoglobe.com/> provides a globe-making service using raster image files but with stitching visible across the back.

The raster form of the Copernicus data is ideal for selecting a patch of the Earth’s surface to display a 30km square patch (equal to 900 square kilometres) of ozone or LAI values centred on a city, and ESA provides a Climate Data Object (CDO, but not Microsoft’s CDO) program that performs exactly this function in a single bash command, for example to display wind-speed patterns around the eye of a hurricane without a the need for spotter aeroplane, but the program would not have run on a simple web-server.

The 3D street visualisation in Unity proved unsatisfactory. Producing a video with moving airborne particles did not work without proper timing so it was decided to produce a 2.5D version in Mapbox. This was not an easy choice to make because it meant that we lost the opportunity for a video of a cartoon family being affected by air pollution, making the normally invisible particles visible. Chai Jing had also resorted to a similar device when attempting to convey the effects of PM2.5 and PM10 (represented by cartoon characters of snarling hedgehog-like soldiers attacking the body’s defences) on the trachea, lungs and cardiovascular system. It is only a representation of an urban form of biological warfare but it would have helped convey something that is hard to comprehend: the accumulated effects of air pollution are inescapable and surprising. In May 2019 The Guardian’s front page led with a warning about the invisible threat of air pollution and chose to highlight the rise in birthweight of babies born in Beijing after the clean-up for the 2008 Olympics.

The remaining issues were smaller and easier to solve. An initial design decision to use a webpage that scrolled up and down incompletely from one section to the next was dropped because the transition produced an unattractive step from one background to another, we switched to using a scrolling horizontal line that replaced one display with another completely .

Displaying different red tones across the globe to show the difference between levels of pollution failed to provide enough difference for our eyes to spot the different values so Lyu and Tom changed the scale to colours that went from red to green – a wider colour spectrum that naturally indicates where the cleaner air is.

**Later additions**

Tom thought of linking a generic cause such as industrialisation to the AQI readings and Jay thought of the general effect of lengthy exposure to polluted air on life expectancy, which ranged from fifty-two to eighty-four years in 2017 (Worldbank, 2019).

**Potential**

A major improvement would be for the website to harvest all its own data from API. In some cases this would be possible with online storage to hold twenty-four hours of air pollution station measurements. It would require further development to work with satellite data for ozone and LAI because Copernicus data is only available by downloading large discrete files and the data collection routine would have to be able to download by date rather than by name. There is a potential fix for both the two issues of pre-loading the twenty-four hour ground-based air pollution data and running the CDO program using the Linux command-line – by using a separate server hosted online in the current environment of AWS and Azure cloud computing.

**Conclusion**

The choice of using air quality for the topic ‘Invisible Cities’ provided plenty of added motivation to present it in the best light. Choosing the data (AQI and pollutant measurements) to display and the source was clear to make, but it was more difficult to choose between the tools available to display the information.

For the two major items that did not work only one solution was found: the 3D Unity street visualisation was successfully replaced by Mapbox showing the pollution of London’s very well monitored city centre. But the raster data from Copernicus did not transfer so easily to an interactive website and would have been limited to displaying recent 2D ozone information on a flat map. It would be necessary to use extra hosted services to process the files (or store multiple pre-processed images) to display ozone levels for a particular city.

Our website sticks to its topic well and the small number of options available on the user interface means that visitors navigate easily and do not make mistakes. The ideas created within our group benefited from having diverse backgrounds (Stenmark, 2003) with a common goal and once we had a focus – air quality – progress was swift and focussed. It was not easy to balance the aim of displaying scientific measurements with the other aim of evoking sympathy from visitors and we had to think carefully about how to keep these aims together. Unlike many websites with high scientific content there is only the human story on the front page containing air quality incidents over the past century with little indication of what direction the subject will take, hopefully it provokes curiosity.

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