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How digital art can provide key information and raise awareness about the effects of mobility on sustainable development

THIS IS WHAT WE BREATHE

Advisor:
Professor Cristina Pronello

Candidate:
Tommaso Cherubini

To my sister

Abstract

Art has always been a mirror of society and people, the growing global awareness on environmental sustainability issues has led many artists to address the issue through their works.
At the same time, Digital Art has had great development and advancement in the techniques and concepts covered, especially due to breakthroughs in the use of Artificial Intelligence and Generative Art.
The project was implemented in the context of a curricular internship at the start-up Mobyforall, a company that provides innovative integrated technology solutions to public and private operators with a data-driven approach.
In this thesis, a research is carried out on artists engaged in the theme of environmental sustainability, their techniques, and the issues they deal with in their quest to make an impact on society. Research is also conducted on Digital Art, describing some of its forms, mechanisms and techniques used.
The main objective is the development of an art project to support public awareness and information on issues related to environmental sustainability and pollution. Various tools and techniques were used for data collection, processing and visualization, starting with the Air Quality Index, moving through Python programming and arriving at TouchDesigner visual programming software and Plutchik's Wheel of Emotions theory.
The end result is a video product that collects real-time data on air pollution and modifies an abstract generative graphic visual based on the emotion-related colors of Plutchik's Wheel of Emotions.

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1. Introduction

Art has always represented a mirror of society and people, reflecting their aspirations, challenges, problems and solutions encountered in a given historical period. In the current global context, the growing awareness of the environmental situation and the practical problems that people all over the world are experiencing due to the lack of respect for the environment and the unsustainable development carried out in recent decades, are leading to an increasing awareness of the need for sustainable development that embraces every sector of society. This is pushing art in unprecedented directions, with artists from all over the world embracing the challenge of creating works that have a positive impact on the environment, but above all that succeed in increasing public awareness and information on issues related to the preservation of our planet and to an alternative (sustainable) development.
At the same time, Digital Art is growing with all its new artists, their methods, and their visions. The technological progress is giving to creative minds new tools every year and they are exploiting it to find new aesthetics, new expressions, and new narratives.

The objective of this thesis is the production of an artistic work to support public awareness and information on issues related to environmental sustainability, pollution, and green mobility. This project was created to serve as an artistic support for raising public awareness, an activity carried out by the startup in which the internship leading to the creation of this project took place.

This thesis was written in the context of a curricular internship at the start-up Mobyforall, a company that provides innovative integrated technology solutions to public and private operators with a data-driven approach. The Mobyforall app, integrated with existing survey systems, opens a communication channel that enables transport companies to collect structured feedback on the level of service provided. The aim is to analyse and make individual behaviour more sustainable by involving users through direct participation in Living Labs.
The support that this project intends to give to the startup's work is to convey an "emotional message" to the users of the proprietary mobile application (from now on called “app”), so as to increase their inclusion and sense of participation.

The end result consists of an abstract video, whose shapes, movements, and colours are produced and modified based on data collected in real time via

public application programming interfaces (APIs). The main information used is the Air Quality Index (AQI) a sophisticated tool that has been developed to communicate the health risk of ambient concentrations (Kanchan, Gorai and Goyal, 2015). U.S. Environmental Protection Agency's (EPA) AQI is defined with respect to the five main common pollutants: carbon monoxide (CO), nitrogen dioxide (NO2), ozone (O3), particulate matter (PM10 and PM2.5) and sulphur dioxide (SO2) (Kanchan, Gorai and Goyal, 2015).
This index has a range from 0 (minimum pollution) to 500 (maximum pollution) and is divided in 6 categories:

- 0-50: Good, 51-100: Moderate;
- 101-150: Unhealthy for sensitive groups;
- 150-200: Unhealthy;
- 201-300: Very unhealthy;
- 301-500: Hazardous;

Based on these categories, different colour palettes and parameters controlling the movement of the abstract were developed, so as to create a connection between the AQI value, the category to which it belongs and a particular graphic and movement style.
For the connection between AQI and the colour palette, reliance was placed on the Plutchik wheel of emotions, a model that relates colours and emotions. In 1980's Robert Plutchik divided emotions into eight main categories. Half of these emotions are positive emotions, and the other half are negative ones (Mohsin and Beltiukov, 2019). More details on the palette will be given later on in a specific chapter.

This thesis will be divided into several chapters. In the first one, the state of the art will be analysed by discussing various topics, the connection between art and sustainability, the various methods and tools used to date for New Media Art (i.e. art that includes artworks designed and produced by means of electronic media technologies, from generative art to AI, from data-driven art to immersive works). The second chapter will cover the objectives of this research and the methodology used. In addition to the objective already briefly mentioned above, the methodology, divided into several phases and followed by the analysis and development of this project, will be described. The phases carried out are:

- Data Collection and research: the study of pollutants, the study of AQI and the research of best APIs with the code structure to automatically download data in real-time;

- Data preparation and cleaning: the selection of just the interested data, filtering the not necessary data and storing the important information with Python;
- Creation of the visual work: use of the TouchDesigner software for the visual programming of the abstract video;
- Incorporation of the Python code into TouchDesigner for data use and manipulation of the visuals;
- Color setting: creation of the colour palettes connected to the Plutchik's wheel of emotions;
- Real-time manipulations: control of the movements and the shapes, selection of the palettes based on the data received in real-time.

Once this second phase has been completed, the results of this research as well as its conclusions will be presented in separate chapters.

2. The state of the art – Digital art and artists committed to sustainability

In the last decades the emergence of new technologies has brought a revolutionary change in the artistic landscape and new expressive possibilities were opened, enabling an unprecedented combination of art, technology and science.
Thanks to the manipulation of sound and light, New Media Art (NMA) redefined the concept of creative development, generating ever-changing and transforming works, interactive experiences and using real-time data and information.

In this chapter the intersections between art and environmental sustainability and between art and the digital world will be explored.
Concerning the first one, the main artists that are sensitive to the issue of environment will be discussed, writing about their approach and how they try to have an impact on society through their works.
Concerning the second intersection, methods, tools and techniques of artists in the world of Digital Art will be examined to highlight the creative context in which this research takes place and to explore the new narratives that are coming to life.

The TouchDesigner software, the visual programming environment used for the graphic development of this project, will also be briefly described, giving an overview of its functionalities and main uses.

The Air Quality Index (AQI) will be analysed, the main pollutants on which it is calculated and the categories into which its value is divided according to the risk to which people and the environment are exposed.

In the last part of this chapter, the Plutchik's Wheel of emotions will be examined, it is a theory that classifies emotions and connect them to colors.
It was used in the project to connect the detected AQI value to a specific list of colours, to direct the emotions of the viewer of the video towards positive or negative emotions according to the value just collected.

2.1 The research for environmental impact through the artistic activity

The popularity of Sustainable Development has increased a lot in recent years, and with it also the research of solutions to the problems facing our planet. There are so many companies, associations and public institutions engaged in the research, analysis and decision-making related to this subject. Some of the most important are the ones that have set out the rules to be followed to achieve ethical and sustainable development.

The main examples are the 2030 Agenda for Sustainable Development and the Sustainable Development Goals (SDGs) of the United Nations (UN). The former is a document drafted by the General Assembly of the UN on 25 September 2015 and is a plan of action for people, planet and prosperity. It seeks to strengthen universal peace and freedom. In it, the 17 SDGs and their 169 targets are described in detail. They are integrated and indivisible and they try to balance the three dimensions of sustainable development: the economic, social and environmental (*Transforming our world: the 2030 Agenda for Sustainable Development | Department of Economic and Social Affairs*, no date).

They were formulated to stimulate action over the next 15 years in areas of critical importance for humanity and the planet. The 193 UN member states have adopted the Agenda 2030 for Sustainable Development and they committed, between 2015 and 2030, to end poverty and hunger everywhere; to combat inequalities within and among countries; to build peaceful, just and inclusive societies; to protect human rights and promote gender equality and the empowerment of women and girls; and to ensure the lasting protection of the planet and its natural resources.

They also committed to create conditions for sustainable, inclusive and sustained economic growth, shared prosperity and decent work for all, taking into account different levels of national development and capacities.

In this speech, art occupies a different role, that provides a different perspective, offering innovative approaches to address sustainability problems and surprising with creative outcomes.

Engaging directly with specific audiences and with pressing issues, the artists produce works that range in their intent from encouraging reflection, conversation, and learning to developing concrete solutions (Lineberry and Wiek, 2016).

Art forms that want to relate to sustainability aim to touch people's feelings, to impress the public with a different vision and to increase the awareness on issues the artists care aobut.
Art has the appeal, in an artwork is contained a series of complex concepts hidden by a simple and fascinating exterior. Despite the extremely profound message, this simplicity is probably the factor of attraction of art.

Art also has the communicative power to do so, as pointed out by Roosen, Klöckner, and Swim (Roosen, Klöckner and Swim, 2017): '*Visual art can enable effective communication. The beneficial consequences of being exposed to art may also help the audience to feel more responsive and motivated to engage in problem-solving or applying proposed solutions*".

The cross between sustainability and art has attracted the creativity of innovative artists that decided to made their mission to raise the awareness of their audience, creating works that have an impact on the viewer and stimulate the environmental sensibility.
Through their art, these artists are stimulating the debate on the role of human beings in the sustainable development, attracting their fans and bringing them closer to important themes in this historical period.

2.1.1 Olafur Eliasson - The artistic reconstruction of natural environments

One of the icons of the marriage between art and sustainability is Olafur Eliasson, a Danish-Icelandic visual artist famous all over the world for his immersive works that transform great environmental challenges into works of art. Combining art and science, the artist creates multi-sensory experiences that highlight some of the problems concerning the planet, creating a strong emotional impact on the visitor. His human-made environments situate the human subject and human

experience at their center, inviting the spectator to experience atmospheres and environments anew (Hornby, 2017).

Through his installations, Eliasson has the great ability to create a bond between the viewer and nature, in fact in his exhibitions the sensation is that of being in front of nature itself, as if he had not been the intermediary that brought about a given phenomenon, problem or spectacular visual effect in front of the eyes of the viewer. The works' emphasis on an ecology of individual encounter and feeling situated the experiencing subject at their centre (Hornby, 2017). Perhaps this is its great strength, acting as an intermediary between the public and nature, in a silent and at the same time spectacular way, often creating installations that make use of the most complicated sciences, but which are simple and as natural as the ecosystem that surrounds us.

Not only by explicitly thematising the issue of the environmental crisis, Eliasson's works seem to materially express the requests of theorists who wonder about how art can actively respond to the need for a change of perspective that characterises current events (Melina, 2023).
The artist, through amazement, accompanies society in the change of perspective, towards a greater awareness of the problems related to the planet, towards perhaps an activation of his audience, towards an awareness that passes through art and emotions.

Ice as a symbol of the relationship between man and nature

"Ice Watch", an installation curated by Eliasson and the geologist Minik Rosing in 2014, is a great example of what has been said so far. For this exhibition, conspicuous blocks of ice from the Greenland Glacier were transported to Copenhagen, Paris, London, as shown in figure 1, to be displayed in public as a concrete and evident representation of the accelerated melting of glaciers due to climate change.

Similarly, in the weeks leading up to March 2006, six tons of glacial ice were collected from Jökulsárlón – the largest glacier lagoon in Iceland, situated on the country's southeast coast. These six tons were transported in refrigerated containers from Iceland to Berlin, to be exhibited in the Neugerriemschneider art gallery.

In the last couple of decades, the lagoon has received attention in the context of climate change as it provides a visible indicator of rising earth surface temperatures (Hancox, 2013).
The artist, in each of his works, tends to lead his audience towards a critical behavior, observation, analysis and study of their own sensations in front of a work. Most of his installations are large, spectacular and impactful, the viewer almost cannot help but be transported into Olafur Eliasson's parallel world, a world in which it is necessary to think, question and reflect on what is before one's eyes , interact with it, come to your own personal conclusions.

In this case, for example, as soon as the glacier is taken from its site and transplanted into the cultural institution, it begins to signify more than glacial ice. It might signify the growing contemporary concern with global climate change. It might represent the world's extremes of meteorological conditions. It might point towards the technological 'development' of the humans and their ability to intervene in 'nature' and create 'artificial' environments. It might unveil the human propensity to use 'natural' resources for cultural, decorative, educational and extravagant ends. It might raise ethical questions (on the part of the artist, the gallery and the viewer) regarding the economic and environmental costs of transporting the ice, maintaining it within a refrigeration unit within the gallery, and displaying it for a visiting public. It might be indicative of a history of cultural institutions that have desired to capture, master, objectify and rationalize 'nature'. It might signify apocalypse, hell or beauty (Hancox, 2013).

Source: olafureliasson.net

Figure 1 - "Ice Watch" installation of Olafur Eliasson in London.

Waterfalls as a symbol of the majesty of nature

The works "Waterfall" (2016) in the gardens of Versailles in France and "The New York City Waterfalls" (2008) on the Brooklyn Bridge are other examples of the artist's quest to merge art, architecture and nature. In these cases, Eliasson reconstructs a natural phenomenon through engineering and architecture, placing it at the center of a man-made landscape.

The works are impressive, especially "The Waterfall", shown in Figure 2, in which an artificial waterfall rises monumentally over the gardens of Versailles emerging from the Grand Canal, as if to show the majesty of nature itself when compared with the human creations around it. At the same time, it seems that the artist wants to show how a waterfall is a complex and difficult engineering and architectural work for human beings to recreate.

Similarly, in "The New York City Waterfall", inaugurated in 2008, the artist made another artificial waterfall emerge from the waters of the East River, supported by

one of the supporting pillars of the iconic Brooklyn bridge. Also in this case it is possible to observe the contrast and, at the same time, the union between nature and human intervention, between architecture and water flows, between what the planet offers (such as rivers and waterfalls) and what man creates as bridges and mechanisms that manage water flows, in this case emulating nature itself.

Also, in this particular situation, the artist is undoubtedly able to communicate the connections between the environment and nature, experimenting in an innovative way with the possible reproductions of the natural world and at the same time creating a strong impact on the public.

Source: olafureliasson.net

Figure 2 - Installation "Waterfall" (2016) of Olafur Eliasson in the Gardens of Versailles.

The Weather Project

The artist's most famous work remains "The Weather Project" (2003), in which he used smoke, light, and mirrors to fill the cavernous space of the Tate Modern's Turbine Hall with fake sunshine and fog.

The Weather Project's artificial sun was constructed using a semicircular steel frame fitted with a projection screen, behind which shone two hundred monofrequency lamps. The enormous windows were blacked out with vinyl and paint, and the ceiling, which is thirty-five meters above the floor, was covered with hundreds of offset mirrors that completed the half-sun-reflection, half projection and doubled the hall's dimensions. Only the black and yellow colours were visible (Hornby, 2017).

Moreover, in this work, shown in Figure 3, Eliasson artificially creates a natural phenomenon, through humidifiers, iron, projections, lamps and a great and long research. The spectator is invited to reflect on the recreated environment, which is deliberately and clearly exposed as artificial, not hiding the materials and mechanisms behind it, rather revealing them and making them accessible to the eyes of the viewer, to stimulate individual reflection.

The artist guides the public in a profound reflection on the construction of spaces, on the emulation of nature, on the sensations one feels in a closed space such as that of the Turbine Hall, within which, however, an open environment has been recreated. Inside a museum room, the artist has managed to enclose the experience of observing the sky, of contemplating the sun, of wondering.

The welcoming climate of a natural landscape that collides with the artificiality of its reconstruction inside a room, the warm, comfortable, enveloping colours of The Weather Project that collide with the cold and unwelcoming climate of London just outside the Tate Modern.

Source: olafureliasson.net

Figure 3 - "The Weather Project" installation by Olafur Eliasson at Tate Modern.

2.1.2 Daan Roosegaarde - Technopoetry: art as a practical solution to environmental problems

Daan Roosegaarde believes that ecological and energy systems are currently in decline and that there is a need to establish new links between people, the environment and technology around the world through "technopoetry".

This term means the action of transforming creative design into a technological product, made available to the public to raise awareness and attract citizens towards a different vision of life.

As he stated, his projects are "*social projects that explore the relationships between people, technology and space*" (Ruiz and Pérez, 2018), stimulating citizens to reflect through his works, the artist tries to guide his audience towards sustainable development and a behaviour that is in continuous relationship with the environment, the spaces we live in, nature.

Roosegaarde has a more functional approach to his work, aiming to convey his message through the practical use of his projects in people's everyday lives. His works are an intersection between technology, design and sustainability, a pragmatic and progressive connection between smart cities and a poetic vision of the environment in which we live.

A vision in which art and engineering share everyday spaces, in which creativity and aesthetics respond to the needs of urbanisation and sustainable mobility, intertwining with new technologies to create a seductive solution to the challenges that our society faces every day.

He struggles to define himself as an artist, but, quoting his words, he commits to "*making our world more understandable, interactive and open. That's why – besides museums, fairs and stuff like that – most of my installations are in public spaces, like a pedestrian tunnel or highways – places of our daily life*" (Finke and Roosegaarde, 2013).

Smart Highway

His "Smart Highway" project, for example, as we can read on his website, consists of sustainable roads. The highway charges during the day and lights up for several hours at night to create an iconic highway experience and increase safety.
The goal was to make smart roads using light, energy and information that interacts with the traffic situation (Studio Roosegaarde, 2013).

The project aims to make motorways an intelligent and interactive network, reducing the environmental impact and increasing safety and efficiency. One of the most important features is that of intelligent lighting, which adapts to the needs of motorists and traffic. Another detail is that of the "Dynamic Paint", tracks along the roadway which, through integrated sensors, light up to warn motorists of possible ice or snow. The project is shown in Figure 4.

Source: www.studioroosegaarde.net

Figure 4 - Daan Roosegaarde's "Smart Highway" project

Smog Free Tower and Smog Free Project

Another important chapter in Roosegaarde's artistic and technical development is the "Smog Free Project", which on the official website of his studio is described as "a campaign for clean air led by Daan Roosegaarde to reduce air pollution and provide an inspirational experience of a clean future.

The project includes a series of urban innovations, such as, the "Smog Free Tower", shown in Figure 5, which provides a local solution of clean air in public spaces. It has been combined with workshops with governments, students and the clean-tech industry to work together and make a whole city smog free" (Studio Roosegaarde, 2019).

Important to notice how, in this case, art and design mix with practical awareness-raising tools, that are committed and outside the usual artistic activity. In fact, the project also includes workshops and lessons to inform and involve citizens on the problem of air pollution.

The main piece of the project is the "Smog Free Tower", which consists of a 7-meter tall aluminium tower needing only 1170 watts of green electricity and using

patented positive ionisation technology to produce smog free air in public spaces, allowing people to breathe and experience clean air for free.

Source: www.studioroosegaarde.net

Figure 5 - Daan Roosegaarde's "Smog Free Tower".

Here is another example of a committed artist, with a practical, technical approach aimed at efficiency and environmental sustainability. Roosegaarde, through its obsession for the interaction between spaces, people and technology, creates connected and intelligent solutions that improve public spaces in their efficiency and, above all, make them more sustainable by reducing the environmental impact of urban spaces.

2.1.3 Refik Anadol - Data and Artificial Intelligence as an Artistic Tool

Refik Anadol is a Turkish-American artist, architect and designer. His works make use of extremely complex Artificial Intelligence (AI) algorithms, huge datasets of images and powerful data processing machines. Anadol can be considered a great innovator, in fact, in his projects, he and his studio collect and process millions of images through complex computational processes to create impactful and immersive visual experiences.

His strength lies in the fusion between the real and the abstract, translating huge flows of real, tangible information into spectacles of light, colour and sound that are the result of the machines' interpretation of these data.

Always committed to highlighting the challenge of climate change and highlighting the extraordinariness of nature, his works result in immersive and highly immersive installations, creating new environments that fuse the tangible with the intangible.

Artificial Realities: Coral

"Artificial Realities: Coral presents Refik Anadol Studio's ultimate visualisation of years-long research on compiling a comprehensive dataset of coral images with the aim of raising awareness about climate change through art" (Anadol, 2023).

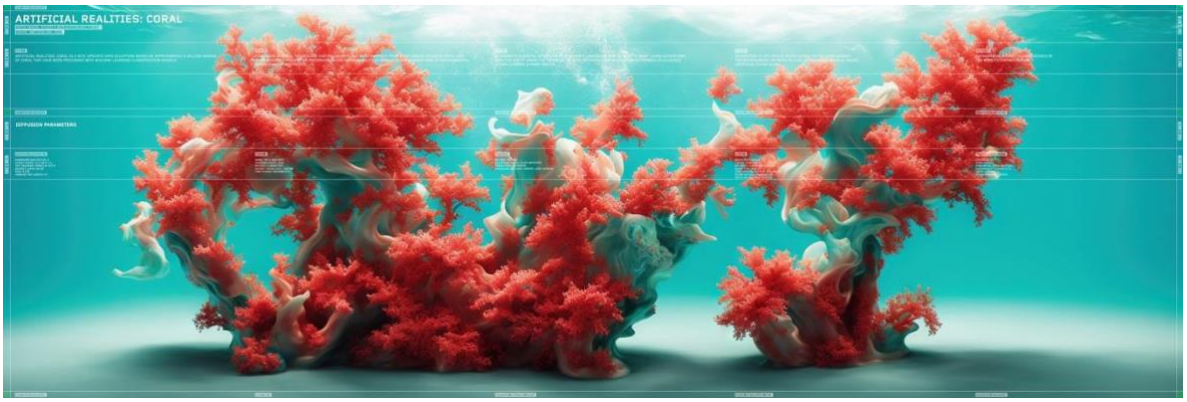
The work first exhibited at the World Economic Forum 2023 has around 100 million photos of corals as raw data and is composed of 3D-printed AI Data Sculptures. Anadol in this work, as in most of its piecies, uses machine intelligence and big data to search for a new and stunning aesthetic form of art, with the aim of highlighting the magnificence and enchantment of the underwater world.

The work consists of two main steps: in the first step the studio performed a training of an AI using millions of archive images of the ocean floor as raw data. This was done through neural networks, specifically using the StyleGAN2 model, a type of generative adversarial network developed by NVIDIA,
From this training, the Artificial Intelligence (AI) generated new abstract images, representing its vision and imagination of the corals through highly complex algorithmic connections.

In the second step, Anadol and his collaborators made use of the AI model called Stable Diffusion, a deep learning, text-to-image model released in 2022. This model is trained with more than 5 billion images, to which archival coral images

were added through a process called “fine-tuning”. The process consists of a second training of a pre-trained model, to direct the machine towards the desired results.

The end result, of which an example can be seen in Figure 6, consists of new enchanting realistic images of marine corals, totally generated by AI. This result underwent an additional super upscaling process to reach 6K resolution and was displayed on two LED screens of 12M x 4M and 6M x 4M at the World Economic Forum.



Source: www.refikanadol.com

Figure 6 - Refik Anadol's "Artificial Realities: Coral" artwork.

Machine Hallucinations – Nature Dreams

In 'Nature Dreams', one of the works in the 'Machine Hallucinations' series, the artist's studio opens up to a celebration of nature and the planet through advanced technology and his own personal, enveloping aesthetic.

This work, shown in Figure 7, creates an incredible fusion of the natural world and digital experimentation, resulting in a totally immersive and sensorial experience where the viewer is overwhelmed by sensational colours, movement and lights.

The exhibition, which the artist calls AI Data Sculpture, utilises over 300 million publicly available photographs of nature collected between 2018 and 2021 at Refik Anadol Studio. Combined, this represents the largest raw dataset of nature ever gathered for an artwork, which was then used to train a GAN AI algorithm (Anadol, 2021).

The final result is an incredible abstract interpretation of nature, performed by a machine, once again highlighting the connection between organic and artificial, between computer and nature.

Source: www.refikanadol.com

Figure 7 - "Machine Hallucinations: Nature Dreams" Anadol's AI Data Sculpture.

Wind of Boston: Data Paintings

The work "Wind of Boston" is an example of how artistic flair can transform environmental data into a meditative and immersive experience.
"Wind of Boston: Data Paintings is a site-specific work that turns the invisible patterns of wind in and around Boston into a series of poetic data paintings within a 6' x 13' digital canvas".

The project makes use of information as primary material by collecting wind data in the form of speed, direction, gust patterns, timing and temperature, which are then studied through complex data analysis processes to give life to a work in motion, with the typical aesthetics of the Turkish-American artist, who once again creates an impressive conjunction between reality and abstraction, between natural and artificial.

Once again, through algorithms, Anadol manages to emphasise the magnificence of nature by enclosing it in an immersive and sensorial digital work.

2.2 Digital Art

Digital Art or New Media Art is defined as the use of technology, in its most diverse and extravagant forms, as a tool for artistic and creative expression.

"Originally referred to as computer art, then multimedia art and cyberarts (1960s-1990s), art forms using digital technologies became digital art or so-called new media art at the end of the 20th century" (Paul and Arnold, 2016)..

Adérito Fernandes-Marcos defines a work that is part of this discipline as a "Digital artefacts", or "artistic applications" as they are usually called, and he aims at displaying information content by materializing concepts in a digital format" (Fernandes-Marcos, 2007).

The beginnings of thoughts about this artistic expression have their roots at the same time as the advent of computers in our society, in the 1960s-70s. Jack Burnham can be taken as an example: he pushed the exploration of the relationship between art and information technology to an unprecedented point. In 1970, he curated the exhibition "Software, Information Technology: Its New Meaning for Art", at the Jewish Museum in New York. This show was the first major U.S. art-and-technology exhibition that attempted to utilise computers in a museum context (Shanken, 2002).

Burnham, already in 1969, expressed his interest in how a dialogue evolves between the participants, the computer program and the human subject, so that both move beyond their original state (Shanken, 2002).

These topics were then addressed more and more by artists and critics after him. In fact, these concepts pushed the creativity of contemporary artists to the extreme, leading them to majestic and highly successful works, thanks to the exploration of this dialogue and interaction of human emotional and sensory reactions to the artistic product generated through machines.

Many artists have sought these sensations in the years to come, not only as a study but precisely as an ultimate goal: that of ecstasy in front of something new, aesthetically appealing and extraordinarily detailed. This can be achieved thanks to the power of processors, algorithms and, in recent years, of the Artificial Intelligence (AI). A practical example already covered in this thesis is Refik Anadol, which has made immersive, enveloping and fascinating aesthetics its strong point, achieved through the power of algorithms and neural networks combined with creative flair.

From the 1970s to the present day, technological progress has made great strides. However, only since the mid-1990s new media art (NMA) has become an important force for economic and cultural development internationally, establishing its own major institutions (Shanken, 2016).

Indeed, in those years, "Collaborative, transdisciplinary research at the intersections of art, science, and technology has also gained esteem and institutional support, with interdisciplinary PhD programmes proliferating around the world" (Shanken, 2016).
In the same historical period, mainstream contemporary art (MCA) has been a great mass success, disproportionately increasing the economic market, thus sales, as well as the popularity of its artists and media echo.

"The perennial debate about the relationship between electronic art and mainstream art has occupied artists, curators, and theorists for many decades" (Shanken, 2016).

We can now state that artists such as Anadol certainly occupy a position in the middle, strong in having found their own space that intersects the complexity of science and technology with the strength and conceptual power of their aesthetics. It is no coincidence that the Turkish-American artist exhibited his work "Unsupervised" at the Museum of Modern Art (MoMA) in New York City.

Very interesting is Christiane Paul's reflection on born-digital and Post-digital, delving into detail on Digital Art. The curator and author of the book "Digital Art" points out that today, in every museum, it is almost certain to encounter works of art in which there has been the use of digital technological means at some point in their production, even if those are not exhibited through digital means. These works, however, are exhibited in a 'classical' manner, as would have been the case if only analogue means had been used in their creation

(Paul and Arnold, 2016).

The same applies to concepts, aesthetics, technologies' impact in the final result and in the feelings conveyed to the public. There are in fact creative processes that use technology solely as a tool that speeds up and improves the development of the work, but which does not alter or impact the final result, works in which the artificial hand is not at all visible to the eye of the final spectator. In others, defined by Christiane Paul as "born-digital" (Paul and Arnold, 2016), the presence of digital tools in the creative process alters the result to such an extent that it becomes one of the main concepts of the artwork itself.

Generative art, which we will discuss, exemplifies this. It relies on algorithms and machine processing for its output. It encompasses AI-driven graphics, abstract creation, and interactive art through digital media, bridging artists and audiences. Another interesting concept, which Christiane Paul adopts from the point of view of artists, curators and theorists, is that of "Post-digital" and "post-Internet", with which she describes as "a condition of artworks and 'objects' that are conceptually and practically shaped by the Internet and digital processes-taking their language for granted-yet often manifest in the material form of objects such as paintings, sculptures, or photographs" (Paul and Arnold, 2016).

Following this concept, the digital and the Internet stop being mere tools but are accepted as an integral part of society's thinking, incorporated into everyday life and thus also in the artistic process; they form a "New Aesthetic" (Bridle, 2011). This New Aesthetic contributes and helps the artist right from the creative thinking step, opening up new horizons of observation and inspiration based on conceptual visions and virtual graphics never considered before the digital was accepted and incorporated into our society and everyday life.

In the next section, Generative Art will be analysed in more details. It is considered one of the main categories of Digital Art. It is important to emphasise, however, that many of the generative artists combine generative art with other techniques, making use of real-time data, interactivity, immersivity, etc., finding connections and exploiting different mechanisms, algorithms and technological processes at the same time. The world of New Media Art is constantly evolving and leaves ample room for experimentation and research, thanks mainly to the ongoing technological progress. Due to the context and technologies used in this thesis project, it is considered important to give some additional definitions and notions concerning precisely generative art.

2.2.1 Generative Art

"Generative art refers to any art practice where the artist uses a system, such as a set of natural language rules, a computer program, a machine, or other procedural invention, which is set into motion with some degree of autonomy contributing to or resulting in a completed work of art" (Galanter, 2003).

As Galanter tries to explain in the article just quoted, this type of art is based on the use of codes, algorithms, and mathematical formulas that enable a work of art to change over time.

Through programming and the use of complex software, generative artists set rules, guidelines and parameters to the machine that set up the system, "but the outcome itself emerges from the system rather than from the artist" (Tempel, 2017), the visual and/or sound contents in output are constantly changing and out of the control of the programmer, we can therefore say that we have an autonomous or semi-autonomous life (Tempel, 2017).

This is an art that requires mathematical knowledge, computer programming and often also skills regarding Artificial Intelligence (AI). These skills, in most cases, bring with them the need to have powerful machines, a lot of computational power and, in the case of visual arts, hardware that allows the testing and display of very heavy graphic contents.

In most of the works enclosed in the category of Generative Art, starting from those of its pioneer and inventor Georg Nees that was the first to exhibit computer-generated drawings, in Stuttgart in February 1965 (Nake, 2018), there is always an element of uncertainty (Tempel, 2017). This element can come from the collection of data in real time, which therefore is not under the control of the system and cannot be predicted, but also and above all from the randomisation of algorithms. More specifically, the Gradient Noise is often used on a graphic level, it is a type of noise used as a procedural texture that allows you to have an irregular wave of values that never repeats and which can be softened, made more chaotic and modified in other ways through a series of numerical parameters.

Generative Art has several application clusters, among which the major ones are: Electronic Music and Algorithmic Composition, Computer Graphics and

Animation, Industrial Design and Architecture, video creation for live events and performances (Galanter, 2003)
In conclusion, this type of artistic discipline is based on the great contribution that an artificial system can give to the final artistic result through unpredictable autonomous algorithms, that can be provided, for example, by real-time data, random mechanisms and noise.

2.2.2 Data-driven-art

Data-driven-art is another category of New Media Art, in which data is used as raw material, adding it into mechanisms, IT processes, algorithms and scripts to explore the various facets. This exploration navigates the themes and concepts that these data bring with it, but also the infinite possibilities for visualisation and reproduction that it opens up. As Mihály Lakatos describes perfectly: *"Big data being a relatively new concept, the art as well as the new kind of aesthetics based on this is also a fresh movement within the global art world. Artists from all around the world have been transforming streams of data into abstract aesthetic forms. Their works sometimes function as a commentary on the world we live in, an artistic examination of contemporary phenomena, other times data is transformed into such forms that it becomes an experience into itself."* (Lakatos, 2020).

One of the major exponents of this artistic expression is the Japanese multimedia artist Ryoji Ikeda. The Gifu-born artist is known for his large-scale installations in which he represents data through sound and visual media. His art is also an example of immersive art, for how he creates the inter-sensual experience of getting in touch with digital data (Lakatos, 2020). The artist, who considers himself both a composer and a visual artist, brought the work "Dataverse" to the Venice Biennale in 2019, considered by himself as the culmination of his research, lasted more than twenty years. In this work, he processes huge databases from the most varied sources such as NASA and CERN, transforms text into visualizations and musical tracks, and gives shape to data, in his personal vision, with his artistic aesthetics. The resulting video, projected on large screens at the event in Italy, immerses the audience in a seemingly endless flow of overwhelming data.

"The universe Ikeda created is infinite, and the overflow of data points and the limitless expanses of rapidly flashing and flowing information makes us suddenly aware of our smallness within the expanding universe; we are only one piece of data in a boundless expanse of data." (Berman, 2019).

Ikeda can be considered the clearest exponent and example of Data-driven-art, his art encompasses the very essence for its ability to transform data into sensations, for its capacity to immerse the viewer in a world that - without artistic intermediation - would be an endless series of tables and numbers. Combining visual, sound and immersive installations, the artist gives life to data, finding a sensory and perceptive means to convey a message to the viewer, and does so in an exemplary way, as in the installation data.tron [8K enhanced version], which was set up in Ars Electronica Center in Linz, AT, between January 1, 2009 and December 31, 2010. In this installation 8 high-capacity projectors combined with a 9.2ch sound system filled the whole gallery hall with data, literally immersing the visitors in the work. An image of this installation is visible in Figure 8.

Through their large scale and the possibility of immersion offered, these works reflect the huge amount of digital data that surrounds us in our daily lives: data become visualised both literally and figuratively (Lakatos, 2020).
At the intersection between representation and simulation of the real world, through the use of different media, through multisensory stimulation, the artist gives the possibility to the public to get in touch with information and data that would be impossible to understand, translate and assimilate in a traditional way.

Source: www.ryojiikeda.com

Figure 8 - Ikeda's "data.tron [8K enhanced version]" installation in Ars Electronica Center.

2.3 TouchDesigner

TouchDesigner software is a visual programming environment for the production and execution of multimedia projects. Developed and marketed by the Canadian company Derivative, thanks to its immense range of tools and features, it is one of the leading programs for multimedia installations, interactive art, live performance and video mapping. It falls into the category of "visual programming" programs, i.e., platforms that make it possible to create multimedia projects without the need for programming skills. Despite this last assumption, the software allows you to integrate scripts in various programming languages, such as Python, which was used in this project, so as to open up to infinite development possibilities. In this sub-chapter we will analyse the various potentials and functionalities of this platform and what makes it efficient for the digital arts.

Visual Interface

TouchDesigner has a visual node interface, i.e., interfaces made up of elements that can be connected to each other, each with specific characteristics and functions, which allow the user to manage the creation, collection, and data flow,

but also the interaction with other software and tools external to the platform. This is one of the features that makes TouchDesigner innovative and functional: the ability to interact in real time with tools and elements of the real world, both incoming and outgoing. This feature makes the program very efficient for managing live shows, performances, events and more, because it allows you to control lights, projections, controllers, lasers, screens, and audio systems from a single interface, being able to automate processes, connect them, make them reactive and interactive.
As we will see later in the methodology chapter, TouchDesigner is a great resource for projects that need to control, launch and automate several processes simultaneously.

Customised programming

As anticipated, although the software was developed to allow everyone to approach the so-called "Creative Coding", or the artistic approach to programming, it allows the user to integrate Python scripts into projects, giving the possibility to alternate the visual interface with pure code programming without any problems in the interaction between them.

Multimedia support and real-time data

Within the environment, it is possible to manage images, video, audio and 3D models, separately or together. It is also possible to manage data in real time, as it will be done in the project described by this thesis, through sensors, detectors, MIDI controllers and many other tools.

Operators
Operators are the nodes in the visual interface of the software and allow all actions and functions to be performed.
There are six different classes of operators: COMPs, TOPs, CHOPs, SOPs, DATs and MATs (Derivative, 2022a).

- COMPs: are miscellaneous components, they consist of a mix of other operators that then allow, for example, 3D objects to be created;
- TOPs: are 2D Texture Operators that handle all 2D image operations, they allow you to create textures and graphic patterns, such as the Noise TOP that will be used and explained later;
- CHOPs: these are Channel Operators that manage different types of channels, controlling motion signals, animation, audio, etc;

- SOPs: Surface Operators that manage 3D 'primitives', such as points and polygons;
- DATs: Data Operators that allow text, programming code, tables and scripts to be inserted into the software;
- MATs: Material Operators that manage materials and shaders.

2.4 Air Quality Index and atmospheric pollution

In order to be exhaustive and to be able to move on to the next chapter in which the methodology will be presented, a fundamental topic involved in the thesis needs to be discussed, the air pollution.
Air pollution is one of the main problems affecting human health, the planet and its preservation through the atmospheric pollutants dispersed in the environment. It compromise the quality of the air, having disastrous effects on human living conditions, ecosystems and biodiversity. It is one of the main contributors to climate change.

The Air Quality Index (AQI)

The Air Quality Index (AQI) summarizes the data on the concentrations of air pollutants in a given survey location using a numerical value.
The index is based on the measurement of particulate matter ($PM_{2.5}$ and PM_{10}), ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and carbon monoxide (CO) emissions (The World Air Quality Index, no date).
It is a tool that is used to have a level of air pollution that is widely understandable, even to non-experts. This indicator ranges from 0 to 500; as the value increases, the level of air pollution is higher and therefore the risks for human health of people living in the surveyed area increase too.

Different air pollutants

Pollutants are particles in the atmosphere that are harmful to the environment, air quality and human health. The main substances used to calculate the AQI are:

- Particulate matter ($PM_{2.5}$ and PM_{10})

A mixture of solid particles and liquid droplets found in the air, the number 2.5 and 10 indicate the maximum diameter in microns; $PM_{2.5}$ is particularly dangerous because it penetrates the bloodstream and lungs. Most of the particles are the

result of chemical reactions of pollutants from power plants, industries, and automobiles (US EPA, 2016b)

- Nitrogen Dioxide (NO_2)
NO_2 primarily gets into the air from the burning of fuel. It forms from emissions from cars, trucks and buses, power plants, and off-road equipment. It causes lung irritation and worsening of respiratory diseases (US EPA, 2016a)

- Carbon Monoxide (CO)
Carbon Monoxide (CO) is a gas that is released when something is burned, it is colourless and odourless and can cause many health problems when inhaled in large quantities. The main source of CO production is vehicles and machinery that burn fuel.

- Sulfur Dioxide (SO_2)
Sulfur dioxide is also mainly produced by the burning of fossil fuels by power plants and other industrial facilities. It is harmful to the respiratory system, especially for people with asthma and children (US EPA, 2016c).

- Tropospheric ozone (O_3)
Secondary pollutant that is formed due to chemical reactions of volatile organic compounds (VOCs) or nitrogen oxides (NO_x). As specified on the EPA website, it can be "good" or "bad" for the environment and human health: in fact, it protects against ultraviolet radiation from the sun, but it also causes many lung and respiratory problems.

AQI scale and risk categories

From the waqi.info site (The World Air Quality Index, no date), used in this project for the survey, it is possible to read that the AQI scale used for real-time indexing is based on the latest standards of the United States Environmental Protection Agency; from the AirNow.gov site (AirNow.gov, no date) it is possible to find the table which divides the AQI values into risk categories. Each category corresponds to a different level of health concern, for example, values from 0 to 50 represent good air quality, while a value above 300 represents hazardous air quality.

These values are associated with colours, which however were not used in this project, as the Wheel of emotions of Plutchik was used for the connection between AQI values and colour palette, to experience a sensory connection

between pollution and emotional impact that the project covered in this document wants to have on the viewer.

We therefore have six different categories, depicted in Figure 9:
AQI: 0-50, representing little or no risk;
AQI: 51-100, in which the air quality is acceptable;
AQI: 101-150, where sensitive groups may have problems;
AQI: 151-200: where members of the population may experience problems;
AQI: 201-300: in which a health alert is found;
AQI: 301-500: in which an emergency situation is encountered;

Daily AQI Color	Levels of Concern	Values of Index	Description of Air Quality
Green	Good	0 to 50	Air quality is satisfactory, and air pollution poses little or no risk.
Yellow	Moderate	51 to 100	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.
Orange	Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is less likely to be affected.
Red	Unhealthy	151 to 200	Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.
Purple	Very Unhealthy	201 to 300	Health alert: The risk of health effects is increased for everyone.
Maroon	Hazardous	301 and higher	Health warning of emergency conditions: everyone is more likely to be affected.

Source: www.AirNow.gov

Figure 9 - AQI risk categories.

Various concepts have been touched upon in this chapter, sustainable art that sees its artists engaged in seeking an impact on society to guide it towards a development that takes climate change into account, the artistic disciplines that make use of digital tools and how they do it, the TouchDesigner visual programming environment, and finally air pollution and AQI were mentioned. All these topics will be preparatory and useful for understanding the next chapter, which will discuss the objectives and methodology used in this project.

2.5 Plutchik's wheel of emotions

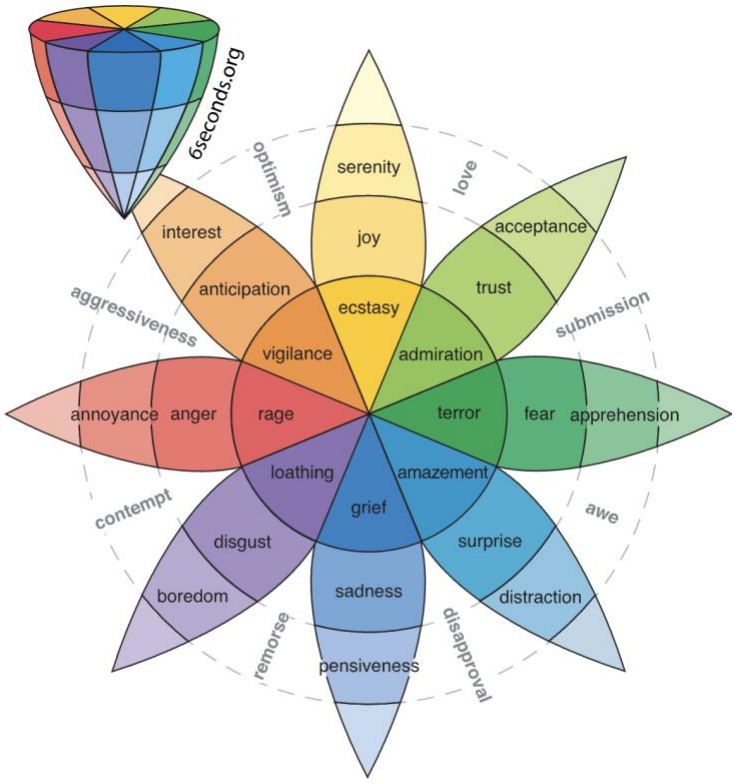
Robert Plutchik was a psychologist, professor emeritus at the Albert Einstein College of Medicine and adjunct professor at the University of South Florida.

His theory proposes the idea that it is possible to classify eight main emotions that human beings experience: anger, fear, sadness, disgust, surprise, anticipation, trust, and joy.

Plutchik's wheel of emotions, depicted in most cases with a coloured flower as in Figure 10, is used as a tool to identify and summarise emotions to their primary classes.

The categories defined by the psychologist are half positive and half negative and they are seen as opposite to each other. Anger and fear, joy and sadness, loathing and admiration and so on. He created a circular model with a wheel-shaped mechanism, where the most intense emotions are in the centre of it and as you move away from the core the emotions become milder (Mohsin and Beltiukov, 2019).

Each subgroup of emotions has been assigned a colour, which has the task of graphically describing these emotions. The colours also fade as one moves away from the centre of the model, while they are more intense in the centre of it.



Source: www.6seconds.org

Figure 10 - Plutchik's wheel of emotions.

3. Objectives and methodology

The main objective of this project is the production of an artistic visual work that has the purpose of raising the awareness of the user regarding fundamental themes like pollution, climate change, health problems related to air quality, the need for sustainable development and sustainable mobility.

This work seeks an unusual means of achieving public awareness, an innovative way that does not make use of textual or verbal information, does not attempt to convey certain principles, problems, possible solutions through the medium of words or text. Rather, this work faces the challenge of reaching the emotions and personal sensitivities of those who benefit from it, thus being an artistic and emotional approach to infographics. This means giving the graphic visualisation of clear, simple, scientific information, but not in such a way that it is rationally understandable or represented in a logic manner. Rather, the mode of visualisation is linked to feelings, emotions, and the message to convey.

Based on the state of the art, through concrete examples, the aim is to turn an environmental challenge such as pollution and poor air quality into an immersive experience. The aim is to make the spectator experience the problem, making him/her feel part of the problem and therefore also awakening a willingness to take an active part in the search for a solution.
Data, in this work, are used as raw material, downloaded, analysed, filtered, and transformed into something different. Air pollution data are analysed in real time to transform them into an emotional message.
Through colours, abstract shapes and movements, an attempt is made to show both the beauty, tranquillity, peace of the senses and serenity of nature, and the chaos, trepidation, anxiety and dismay of smog, traffic, pollution, and the frenzy of an individualistic society that loses its connection to the planet and thus its respect for the environment it lives in.

Through Plutchik's wheel of emotions, colours become a means of sensory communication, a tool for conveying emotions and precise sensations. By combining colours with fluid movements and sinuous shapes or with jerky movements and angular shapes, the project aims to transform data into an abstract real-time video that succeeds in arousing emotions by sensitising users and trying to create a change in behaviour and attitude.

The last important thing to emphasise in order to fully understand this project, is that it has two modes and channels of final display: one with a more informative and interactive purpose, and the other with a more 'artistic' purpose and aimed at conveying a more powerful message.

The first mode/channel allows the user to input a location, in the form of an address or the name of a city. Based on this entered information, the programme generates a visual that transforms the values obtained from the survey stations in that specific area into a graphic work. This is precisely for information purposes, allowing the public to interact in the first person, feeling part of the work and above all having the opportunity to contribute to its operation.
This mode of participatory work helps to create a bond between the artwork and the public, in which the viewer becomes an integral part of the artistic process in its final exhibition phase. This is of fundamental importance, both because of the participation, but also because in the earlier stages of the project's development, the flair and creativity of the person developing the work are combined with the desire to include the viewer in the final act within the work itself. It is therefore at the same time a way to immerse the spectator in the artist's mind, but also a path in which the artist, during the steps of the work's creation, puts himself/herself in the spectator's shoes and tries to make him feel involved and immersed.

The second mode/channel is based more on a very precise message that the author wants to convey: "We are all together the authors of our destiny, pollution hurts some parts of the world more than others, but this cannot be a justification for not acting or assigning blame. We must all strive together to move towards a more sustainable world. We are all citizens of the same planet."
In this regard, this alternative of visualising the work leaves no room for the public to select the place to be visualised. Because this would give the work an individualistic, personal, limited feel in a certain sense.

On the contrary, it is intended to give a sense of community, of togetherness. It was therefore decided to collect real-time data from all air quality stations around the world. These are collected, filtered, and categorised according to the 6 different AQI categories described in Chapter 2, section 2.4.
From the resulting database, one measuring station at a time is then randomly extracted with its AQI value. Based on this, the visual shown on the screen is set, without making the location from which the survey originates visible.
In this way, there will be a continuous series of changes in the final video, ranging from positive AQI values, with their soft movements, enveloping colours, and

sinuous shapes, to negative AQI values, with their jerky movements, aggressive colours and angular shapes.

By doing so, the developer of this project hopes to trigger a specific thought in the audience, namely that the world situation is heterogeneous and unequal. There are places that boast excellent air quality and thus good health of their population, while other communities are in serious trouble due to pollution and poor air quality.

No one can set himself/herself up as a judge, no one knows fully what the internal causes that have led to this situation are, nor can it be said that the fault lies solely with those who live in those places; in fact, often it is probably the exact opposite.

It is therefore everyone's responsibility to strive to make the situation fairer, to participate so that all communities around the world can live in good health and air quality, regardless of where they are born and grow up. Sustainable and green development is possible if done together, sharing tools and goals.

In the next chapters, the four phases of the project will be explained:

- the search for open-source information and data, studying the most important institutions dealing with pollution and sustainability;
- data collection, for the use of concrete and up-to-date real-time data;
- data cleaning and analysis, to make the collected data suitable for use in a generative art project;
- development of data-reactive visualisation, modelling graphics based on the data.

The project will be explained using as a basis the option in which the location is the input, then specifying later the differences in the code and workflow of the option in which the choice of location is random.

3.1 Documentation and research

To start a project like this, the first thing needed is certainly the collection of necessary information and data, to be used as raw material. It is also necessary to decide on a unit of measurement, an index that allows air quality to be

assessed unambiguously throughout the world, so that homogeneous and comparable data can be obtained.

For this purpose, it was decided to use the Air Quality Index (AQI), calculated, and made available by the U.S. Environmental Protection Agency (EPA). This index is used to repost daily air quality and associate it with six different categories that underline the level of health concern.

This index, as mentioned in the previous chapter, has a range from 0 to 500, where the lower the value the better the air quality.
Data are collected daily from measuring stations around the world and these raw measurements are converted into different AQI values for each pollutant through methods developed by the EPA. The highest value is reported as the AQI value of the day for that specific measuring station (U.S. Environmental Protection Agency, 2023).

There are various pieces of information available to those using the public APIs described in the previous chapter. These APIs can be queried in different ways, depending on the information held by the requester and the information needed in response.
It is possible to query the service by sending the name of a city or an address as input; it is also possible to send geographic coordinates as input (lat/lng base) or execute a geolocalised request based on the IP address of the sender of the request, otherwise one can request all stations with their data within a certain space bounded by a box (aqicn.org, 2022).

The web service responds with a range of information related to the survey station(s), of which the most interesting data in this contest are the unique station identifier, the AQI value, the time when it was surveyed, the city and other information about the survey station.

An explanatory table with all the response information and the type of this information is shown in Figure 11.

Field	Type	Description
status	String	status code, can be ok or error.
data	Object	Station data
idx	Number	Unique ID for the city monitoring station.
aqi	Number	Real-time air quality information.
time	Object	Measurement time information.
s	String	Local measurement time time.
tz	String	Station timezone.
city	Object	Information about the monitoring station.
name	String	Name of the monitoring station.
geo	[Number]	Latitude/Longitude of the monitoring station.
url	String	Webpage associated to the the monitoring station.
attributions	[Object]	EPA Attribution for the station
iaqi	Object[]	Measurement time information.
pm25	Object	Individual AQI for the PM2.5.
v	Number	Individual AQI for the PM2.5.
forecast	Object[]	Forecast data
daily	Object[]	Daily forecast data
pm25	Object	PM2.5 forecast
pmp10	Object	PM10 forecast
o3	Object	Ozone forecast
uvi	Object	Ultra Violet Index forecast

Source: www.aqicn.org

Figure 11 - APIs response data

3.2 Data collection

In this section we will describe the steps that allow the program to download the necessary data, apply a process of cleaning these data to use only those necessary by discarding incorrect or incomplete data, use these data to perform calculations and arrive at new information to be used in the next steps.

3.2.1 Input of a location

First, the user must be allowed to enter the desired location, this is the first and only data required that makes the entire work interactive and participatory, creating a connection between work and active viewer.

The input is made through the "Parent Parameters" section of the TouchDesigner (TD) software (*TouchDesigner Software*, 2017). This section allows parameters to be visible and usable throughout the project but, above all, these parameters are retrievable, settable and usable through Python code inserted in particular nodes of the project.
In practice, the "INPUT_PLACE" parameter, visible in Figure 12, will function as a global variable; the moment its value is changed in TouchDesigner, a series of scripts are triggered, and the end result of which is the modification of the visual based on the place entered as input.

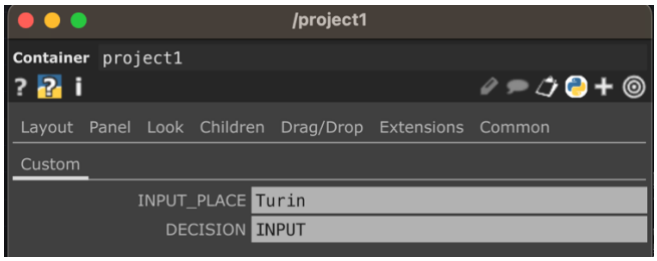


Figure 12 – Location input parameter

Through the 'Parameter Execute' node in TD, it is possible to run a script when the value of a parameter changes.
This is shown in Figure 13, when the parameter "Inputplace" changes, the "onValueChange" method is triggered, within which the "API_Call_INPUT" node is launched. Inside this last node is the Python script containing all the algorithms that will be described later, thanks to which data concerning the AQI will be downloaded, to be then processed and used.

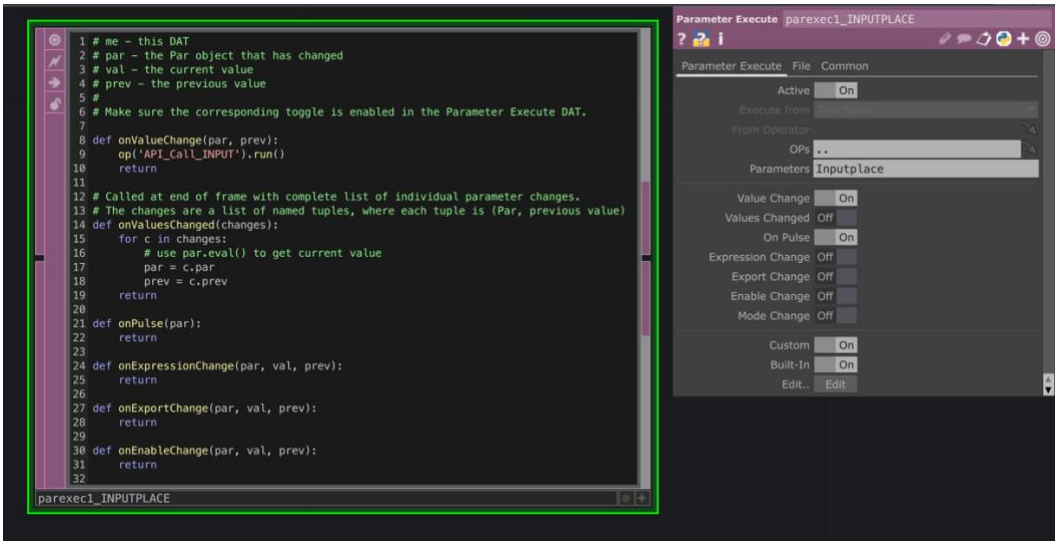


Figure 13 – Parameter Execute in TouchDesigner

This value entered by the user is immediately captured by the newly launched Python code, as shown in Figure 14, in the variable 'city_name' for later use.

```
#1 Location taken from TD input
city_name = parent().par.Inputplace.eval()
```

Figure 14 – city_name variable with value inserted by the user in TD

3.2.2 Google Maps Geocoding APIs

Following receipt of the place entered as input by the user, it is necessary to know the coordinates in latitude and longitude of that place. To extrapolate this information, Google APIs called Geocoding APIs were used.

These libraries allow the conversion of a place in string form such as an address or the name of a city into latitude and longitude coordinates (Google, no date). Thus, by executing a request that has as input the string saved in the variable 'city_name', it is possible to receive as a response a lot of information concerning that location, among which the latitude and longitude coordinates are of interest to us.

3.2.3 Air Quality Programmatic APIs

Having got the desired coordinates, it is now possible to calculate the geographical area within which the air measurement stations will be considered. We started with a radius of 20 kilometres (km), then drew a square whose 4 vertices are 20 km from the coordinates of our interest.
At this point, a request was made to the Air Quality Programmatic APIs, using the bottom-left and top-right vertices of this square (aqicn.org, 2022).

The web service responds with a list of detected stations and the respective data and readings of these stations. At this point, if the number of surveyed stations is at least 2, the data is saved and the script can continue, otherwise the process of calculating the box and request is repeated by increasing the radius until there are at least 2 survey stations within the geographical area.

3.3 Data cleaning and analysis

Now that the list of AQI values is available, a small data cleaning process needs to be implemented to ensure that there are no null or incorrect values (e.g., negative, or greater than 500).

The data received in the response is in JavaScript Object Notation (JSON) format, which was then converted into the Python type dictionary, so that the necessary information could be easily extracted.
It is then sufficient to loop over the AQI values in that dictionary, checking for nulls or out-of-range values. This procedure is shown in Figure 15.

```
for item in lista_stazioni:
    aqi = item.get('aqi')
    if aqi and aqi != '-' and 0 < int(aqi) < 500:
        lista_aqi.append(int(aqi))
```

Figure 15 – Data cleaning

3.3.1 AQI average value and category selection

Having completed the previous step, simply divide the sum of the recorded AQI values by the number of them to find the average of the Air Quality Index recorded in real time in the concerned geographical area.

This average will be used for the modification of the visual work but, to this end, it is necessary to place it in one of the categories described in Figure 9. This, it is sufficient to check in which of the six ranges the AQI value is placed and select the respective category. The ranges are saved in the variables shown in Figure 16.

```
range_1 = range(0, 51)
range_2 = range(51, 100)
range_3 = range(101, 150)
range_4 = range(151, 200)
range_5 = range(201, 300)
range_6 = range(301, 500)
```

Figure 16 – AQI category ranges

Once this step is also completed, the selected category, together with the location and AQI value are sent back to TD for editing the graphics.

3.3.2 Random alternative

For the alternative in which the choice is not left to the user, the entire process carried out so far is replaced. In fact, there is no use of the Google Maps Geocoding APIs, but instead a request is directly made to the Air Quality Programmatic APIs using very broad limits that allow for the selection of all measuring stations. In this way, available data on air pollution worldwide is downloaded within seconds. This information is then divided into categories, again based on the ranges shown in Figure 16.

One of the categories is then randomly selected, followed by the random selection of the location and the respective AQI value. These data will be sent to TD for editing the graphics.

3.3 Development of a data-reactive visualisation

In this sub-chapter, the development of the graphic part of this project will be analysed in detail. As in the previous steps, a lot of code and computer logic have been carried out.

The project was developed using the TouchDesigner software, which collects data in real time, analyses, and classifies them. Based on these data, options and parameters are then modified in order to vary the graphic factors of a visual artwork. Through this software, choices made by the developer and end user are also managed, and of course the actual visualisation is also developed, with graphic and stylistic choices related to it. This project, in its totality, is visualised in Figure 17, in the classic node visualisation style of TD's visual programming graphic interface.

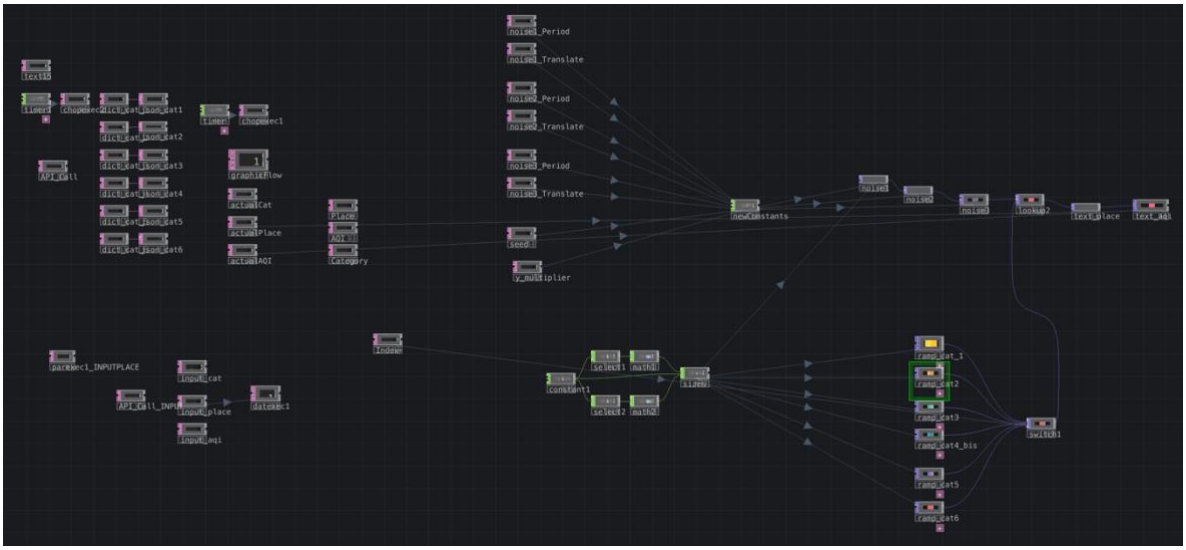


Figure 17 – TouchDesigner project

The logical flow of the graphical design begins with the initial decision in which one of the two options described above can be selected: one in which the choice of location is random, and the other in which the choice is up to the user.

This decision is made via a global parameter in TouchDesginer, called "DECISION". This parameter can take either the value "INPUT" or the value "RANDOM"; based on this, all subsequent processes will vary, launching scripts of a different nature, taking into account different variables, arriving at different graphical results. The parameter can be observed in Figure 12.

Depending on the decision made in this step, two different paths will open up, launching two different logical processes; thus, we will now have two different explanations, one in the context where the choice falls under the "INPUT" option (3.3.1) and the other where the choice falls under the "RANDOM" option (3.3.2). Both paths will then meet again when all data and settings have been set and it is necessary to use them to modify the real-time graphics style.

3.3.1 The place is selected by the user

In the event that the user choses the place, the first step is still in the global project parameters in the TouchDesigner interface. In the window visible in Figure 12, following the entry of the string "INPUT" as the value assigned to the parameter "DECISION", it is necessary to enter a place or an address in the parameter "INPUT_PLACE". The place specified will be analysed and air quality data will be downloaded based on that location.

When this parameter changes, the Parameter Execute node shown in Figure 13 is triggered. At this moment, all Python processes described in Chapter 3.2 are started, resulting in the final extracted data of place name, relative Air Quality Index (AQI) and corresponding category.
These data are then used to update the Text DAT type operators in TouchDesigner, as shown in Figures 18 and 19, and then we continue with the subsequent processes to modify the graphics based on them.

```
op('input_cat').text = str(FINAL_categoria)
op('input_place').text = str(city_name)
op('input_aqi').text = str(media_aqi)
```

Figure 18 – Data sent from Python code to TouchDesigner

Figure 19 – Data received and stored in TouchDesigner

3.3.2 Random Place Choice

In the event that one wishes to initiate processes leading to the visualisation of the design without the user choosing it, but rather giving freedom to the random choice of location, it is necessary to fill in the global parameter 'DECISION' in TouchDesigner with the text value 'RANDOM'. In this case, a timer is immediately activated which switches from 'Off' to 'On' state every 10 minutes, activating the Execute CHOP node which launches the "API_Call" script. This sequence, shown in Figure 20, will now be explained in detail.

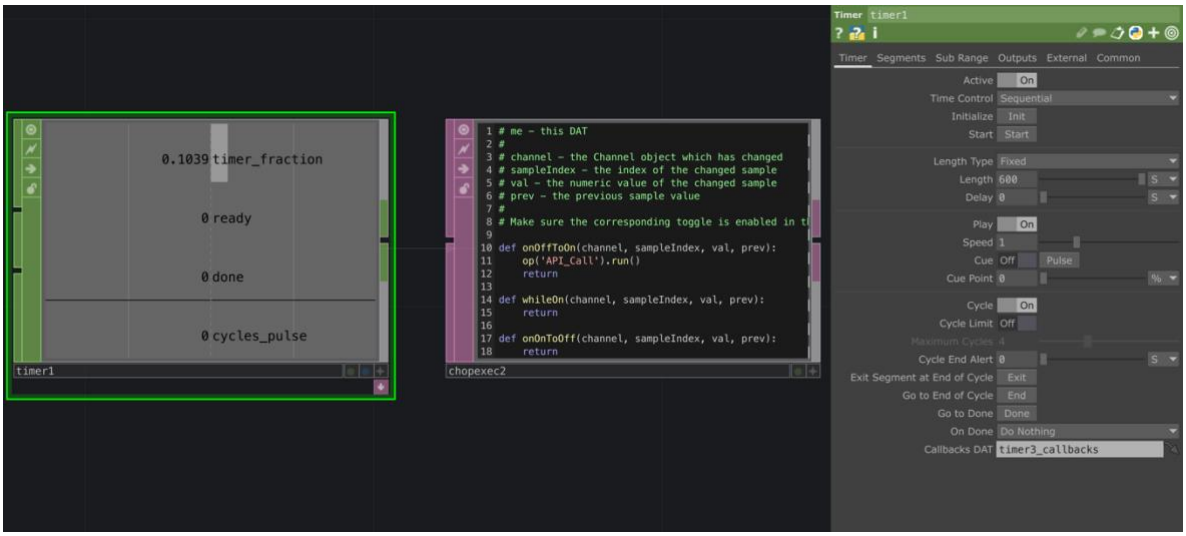


Figure 20 – Timer and Execute CHOP for API_Call

The timer, lasting 10 minutes (Length: 600 seconds), triggers the Execute CHOP which, as can be seen in the definition of the "onOfftoOn" method, calls the running of the "API_Call" operator, which contains the script including algorithms and API requests for the execution of the random location selection process.

Within the Python code in the “API_Call” file, an API Request to the U.S. Environmental Protection Agency (EPA) service described in chapter 3.2 is executed, in which all available survey stations on the planet are requested, with attached information on the AQI value at the time of the request.

The data received in JSON format are then cleaned and analysed, to perform the division into categories as shown in Figure 21, and inserted into several Python Dictionaries, one for each category according to the ranges shown in Figure 16.

```
for item in r.json()['data']:

    aqi = item.get('aqi')

    if aqi and aqi != '-' and 0 < int(aqi) < 500:

        aqi_value = int(item['aqi'])
        station_name = item['station']['name']

        if aqi_value in range_1:
            dict_cat1[station_name] = aqi_value
        elif aqi_value in range_2:
            dict_cat2[station_name] = aqi_value
        elif aqi_value in range_3:
            dict_cat3[station_name] = aqi_value
        elif aqi_value in range_4:
            dict_cat4[station_name] = aqi_value
        elif aqi_value in range_5:
            dict_cat5[station_name] = aqi_value
        elif aqi_value in range_6:
            dict_cat6[station_name] = aqi_value
```

Figure 21 – Data cleaning and categorization

These data are then sent to TouchDesigner, storing it in six different nodes of type Text DAT, which will then contain the dictionaries with the locations and AQI values of each station divided by category.
From the Text DAT nodes, it is necessary to switch to the JSON node type in TouchDesigner, in order to allow the exchange of optimised data using the JSON format. This data will in fact immediately be used for random place selection. The Text DAT and JSON nodes are shown in Figure 22; as it can be seen, there is one node per type for each category: the nodes in the left column are filled with data from the Python code, i.e., data received via API request; the nodes in the right column are the result of a type conversion from Python Dictionary to JSON.

Figure 22 –Text DAT and JSON nodes in TouchDesigner

At this point, another timer comes into play, lasting 20 seconds, which launches a script that performs the random choice of category and location. This operation is performed with the same nodes used previously and shown in Figure 20, but this time the Execute CHOP will run a different Python script, shown in Figure 23, which, through the random library, first extracts a category and then a place within it. The category, place and corresponding AQI are saved in three nodes of type Text DAT in TD, so they can be used to modify the graphics.

```
cat_selected = random.randint(1, 6)

op('actualCat').text = str(cat_selected)

if 1 <= cat_selected <= 6:
    dict_key = f'json_cat{cat_selected}'
    dictSelected = json.loads(json.dumps(op(dict_key).source))
    if len(dictSelected) > 0:
        key, value = random.choice(list(dictSelected.items()))

op('actualPlace').text = key
op('actualAQI').text = str(value)
```

Figure 23 – Random selection of category and place

3.3.3 Visual Effects Creation

Before showing how the data collected through the APIs and imported into TD are used to modify the final visual work, it is necessary to show how this graphic was created and what elements it is composed of.

The visualisation in this case is a simple succession of three Noise TOPs, as shown in Figure 24, particular components of the TouchDesigner software. They generate a noise pattern that can have different varieties and types: Perlin, Simplex, Sparse, Alligator and Random. Some patterns are calculated on the CPU, others like the one used in this project, are calculated on the GPU (Derivative, 2022b).

What happens within Noise TOPs is the random generation of a field of pixels, based on various patterns. It allows the creation of random and dynamic visual effects, which change over time by changing parameters and are never the same as before.

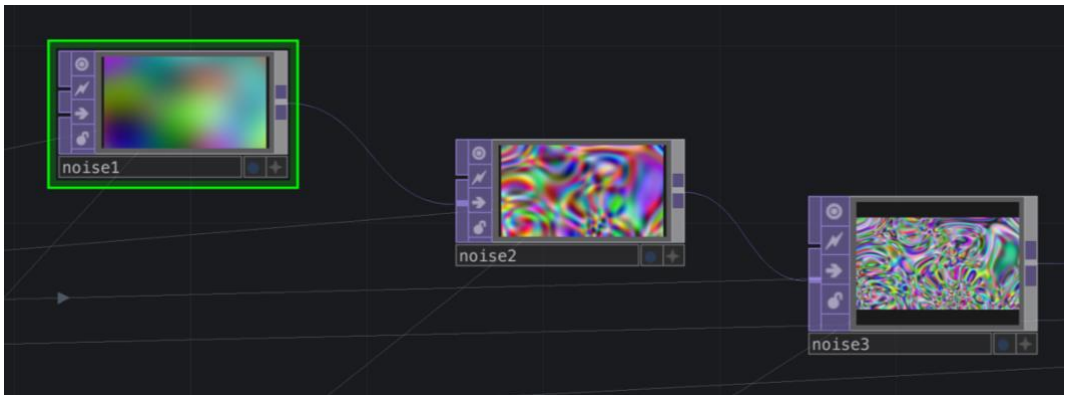


Figure 24 – Sequence of Noise TOPs

Noise Parameters

The Noise TOP parameters used in this project to achieve different and varied visual effects are:

- Seed: a number representing the start of random generation, according to which completely different patterns are generated;
- Period: the separation between peaks of a noise cycle. As the period increases, the pattern lengthens and expands.

The Seed parameter is randomly generated each time there is a change of location and thus a change in the pattern.
The Period parameter, on the other hand, increases and decreases along with the y- and z-axis translate values, which will be described in the following paragraphs.

This parameter creates a smoother, more pleasant effect when it is high, and a more vibrant, jerky, unsettling effect when it is lowered.

A study was then carried out comparing combinations of various Period, translate tx and translate tz values to arrive at a satisfactory final result, the values and parameters of which are shown in Figure 25.

Transform translate in y and z axis

It is also possible to play with the movement of the visual pattern by inserting a mathematical operation in the Translate fields of the Transform section inside the

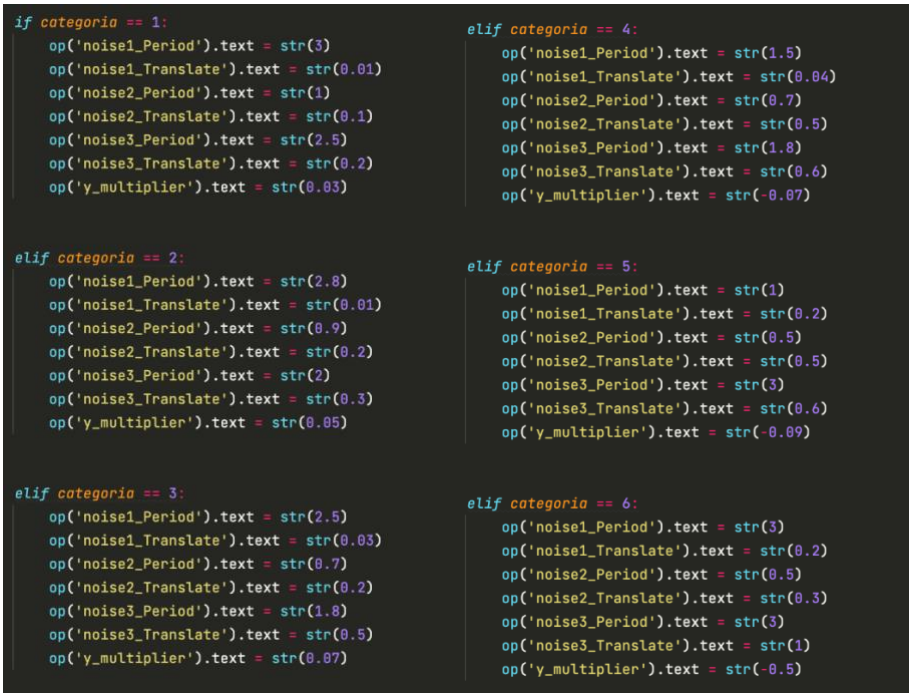
Noise TOPs settings. In particular, in this project, the ty and tz fields have been modified to create vertical dynamism and depth.

An operation was inserted into the Translate ty and tz fields of the Transform section, it plays with the absTime.seconds factor, which in TouchDesigner is a read only class that provides access to a continuously increasing value that stands for 'absolute time'. It starts counting seconds the moment the software is opened and only stops when it is closed. There is no way to access this value in modification, it is therefore a security of continuous and unstoppable dynamism.

To ensure different dynamicity according to the selected category, two different variables were created: "noise_translate" and "y_multiplier", both of which increase and decrease the speed of movement of the visual by acting as multipliers on the absTime.seconds value. By increasing the values of these variables, the visual will be faster and jerkier, while decreasing it will be slower and more sinuous.

Dynamicity on the z-axis is handled in all three Noise TOPs, so there are three different noise_translate variables, one for each TOP, which are modified in their values according to the selected category.

Dynamism on the y-axis, on the other hand, is only managed and modified in the first of the three Noise TOPs, to create a pattern that flows upwards or downwards, at different speeds, depending on the chosen category.



```
if categoria == 1:
    op('noise1_Period').text = str(3)
    op('noise1_Translate').text = str(0.01)
    op('noise2_Period').text = str(1)
    op('noise2_Translate').text = str(0.1)
    op('noise3_Period').text = str(2.5)
    op('noise3_Translate').text = str(0.2)
    op('y_multiplier').text = str(0.03)

elif categoria == 2:
    op('noise1_Period').text = str(2.8)
    op('noise1_Translate').text = str(0.01)
    op('noise2_Period').text = str(0.9)
    op('noise2_Translate').text = str(0.2)
    op('noise3_Period').text = str(2)
    op('noise3_Translate').text = str(0.3)
    op('y_multiplier').text = str(0.05)

elif categoria == 3:
    op('noise1_Period').text = str(2.5)
    op('noise1_Translate').text = str(0.03)
    op('noise2_Period').text = str(0.7)
    op('noise2_Translate').text = str(0.2)
    op('noise3_Period').text = str(1.8)
    op('noise3_Translate').text = str(0.5)
    op('y_multiplier').text = str(0.07)

elif categoria == 4:
    op('noise1_Period').text = str(1.5)
    op('noise1_Translate').text = str(0.04)
    op('noise2_Period').text = str(0.7)
    op('noise2_Translate').text = str(0.5)
    op('noise3_Period').text = str(1.8)
    op('noise3_Translate').text = str(0.6)
    op('y_multiplier').text = str(-0.07)

elif categoria == 5:
    op('noise1_Period').text = str(1)
    op('noise1_Translate').text = str(0.2)
    op('noise2_Period').text = str(0.5)
    op('noise2_Translate').text = str(0.5)
    op('noise3_Period').text = str(3)
    op('noise3_Translate').text = str(0.6)
    op('y_multiplier').text = str(-0.09)

elif categoria == 6:
    op('noise1_Period').text = str(3)
    op('noise1_Translate').text = str(0.2)
    op('noise2_Period').text = str(0.5)
    op('noise2_Translate').text = str(0.3)
    op('noise3_Period').text = str(3)
    op('noise3_Translate').text = str(1)
    op('y_multiplier').text = str(-0.5)
```

Figure 25 – Noise parameters setting

As shown in Figure 25, once the category is selected, the Python code takes care of saving the Period, Translate, y_multiplier and seed values in the appropriate Text DAT operators in TouchDesigner.

These are then automatically saved in a Constant CHOP operator called newConstants. This operator groups all the necessary parameter values and makes them available for use by the Noise TOPs as their parameter settings.
What has just been described is shown in Figure 26.

Figure 26 – newCostants CHOP filled with Text DAT values

3.3.4 Data-driven Noise Pattern Modelling

As anticipated, the values saved in the newConstants node are used as dynamic parameters in the three Noise TOPs described above as shown in Figure 27.

Respectively, the variable “noise1_Period” will assign its value to the Period parameter of the Noise TOP named "noise1", the variable “noise1_Translate” will assign its value to the Translate tz parameter of the Noise TOP just mentioned.

In the same way, the variables “noise2_period” and “noise 3_period” will set the Period values of the Noise TOPs “noise2” and “noise3”, and the same for the variables “noise2_Translate” and “noise3_Translate” which will set the Translate tz values of the Noise TOPs “noise2” and “noise3”.

Finally, the variable “y_multiplier” will modify the Translate ty parameter of the Noise TOP “noise1” and the variable “seed” will set a random value to the Seed parameter of the same Noise TOP.

This is the step that ensures that the graphics are dynamic and change according to the data received from the APIs. This step is making visible the work done through the Python code, the API requests, and the integration of all this into TD.

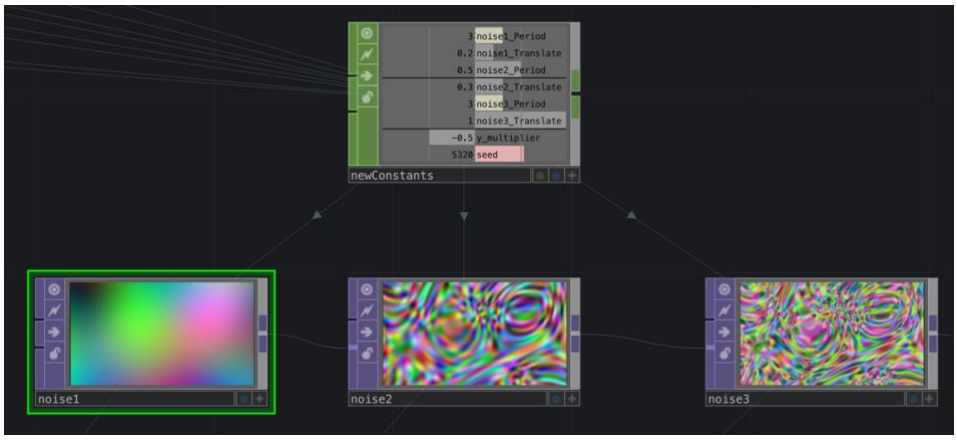


Figure 27 – Connection between newConstants CHOP and the Noise TOPs

The graphic pattern output from this series of Noise TOPs was inserted into a Monochrome TOP which is responsible for changing it to greyscale colours.

Following this, detailed work was also done on the colours, as explained in the following sections.

3.3.5 Colour adaptation based on Plutchik's Wheel

As mentioned in chapter two, to link air pollution values to human emotions, trying to create an impact on the viewer by making the experience immersive, it was decided to use Plutchik's wheel of emotions, a tool that identifies and classifies emotions by connecting them to various colours.

Six different colour palettes were therefore created, each with a predominant colour and shades of other colours to awaken different emotions in the viewer and make the work of stimulating sensory impact. In order to achieve this, it was

first necessary to transform the illustration of the wheel of emotions into a table format, connecting each colour macro-category to its three facets, both at the level of emotions and at the level of colour patterns.

Table 1 shows this transformation, the first column lists the colour macro-categories, the second column the emotions belonging to these categories, the third the RGB codes corresponding to every emotion, and the fourth the respective HEX codes.

Thanks to this table, it is possible to chromatically depict each emotion described by Plutchik, and then create colour palettes that join different emotions to form a combination to be linked to a range of AQI values.

Table 1 – Plutchik's wheel of emotions with colors, emotions, RGBs and HEXs

Color	Emotion	RGB	HEX
Orange	Vigilance	246,146,61	#f6923d
	Anticipation	248,174,101	#f8ae65
	Interest	249,198,135	#f9c687
Yellow	Ecstasy	249,203,8	#f9cb08
	Joy	251,221,122	#fbdd7a
	Serenity	252,240,161	#fcf0a1
Light Green	Admiration	139,199,80	#8bc750
	Trust	172,211,106	#acd36a
	Acceptance	202,224,140	#cae08c
Dark Green	Terror	49,166,80	#31a650
	Fear	56,183,116	#38b774
	Apprehension	122,199,153	#7ac799
Light Blue	Amazement	54,154,206	#369ace
	Surprise	61,175,217	#3dafd9
	Distraction	138,201,231	#8ac9e7
Dark Blue	Grief	48,132,198	#3084c6
	Sadness	116,168,219	#74a8db
	Pensiveness'	161,193,230	#a1c1e6
Violet	Loathing	138,115,179	#8a73b3
	Disgust	164,145,197	#a491c5
	Boredom	186,171,211	#baabd3

	Rage	240,90,97	#f05a61
Red	Anger	242,114,109	#f2726d
	Annoyance	230,230,230	#e6e6e6

From this table, the six different colour palettes were developed, one for each AQI category. They are meant to represent a transition from low AQI values, with therefore good air quality, to very high AQI values, with therefore bad air quality and health problems.

The first palette, mainly yellow, has the task of communicating positive emotions, as it is connected to an AQI of less than 50. Consequently, colours connected to serenity, ecstasy, joy, admiration and interest were selected.

In the second, on the other hand, the intention is to convey positive emotions with a hint of alertness, so colours related to alertness, expectation and trust were selected. This palette is predominantly orange in colour.

The third category, representing dangerous AQI values for sensitive groups, was represented by colours related to apprehension, fear and thoughtfulness. It therefore has a predominance of green and light blue.

The fourth category, which groups together air quality readings that are unhealthy for human beings, was represented by colours connected to the emotions of sadness, anguish and fear, and thus has a predominance of dark blue.

The fifth category, which groups AQI values with very unhealthy air, was connected with a colour palette intended to recall the emotions of repugnance, disgust, anger. It has a predominance of the colour purple.

The last category, the one with really dangerous AQI values for human health, obviously has a predominance of the colour red, which Plutchik links to the most negative emotions such as anger and rage.

In conclusion, there are six different palettes, each with a predominant colour but also secondary colours that provide the graphic pattern with dynamism and evolution.

These palettes were represented through the Ramp TOP operator in TouchDesigner, inserting the colours one by one and creating a mix that will then vary the graphic pattern.

Figure 28 shows the six different palettes just described, all connected to a Switch TOP operator, which takes care of the transition from one to another according to the connected category. This is done via a Text DAT which stores a value from 0 to 5, i.e. the current category number minus 1. Thus, when the index is 0, category 1 will be displayed, when the index is 1 category 2 will be displayed, and so on.

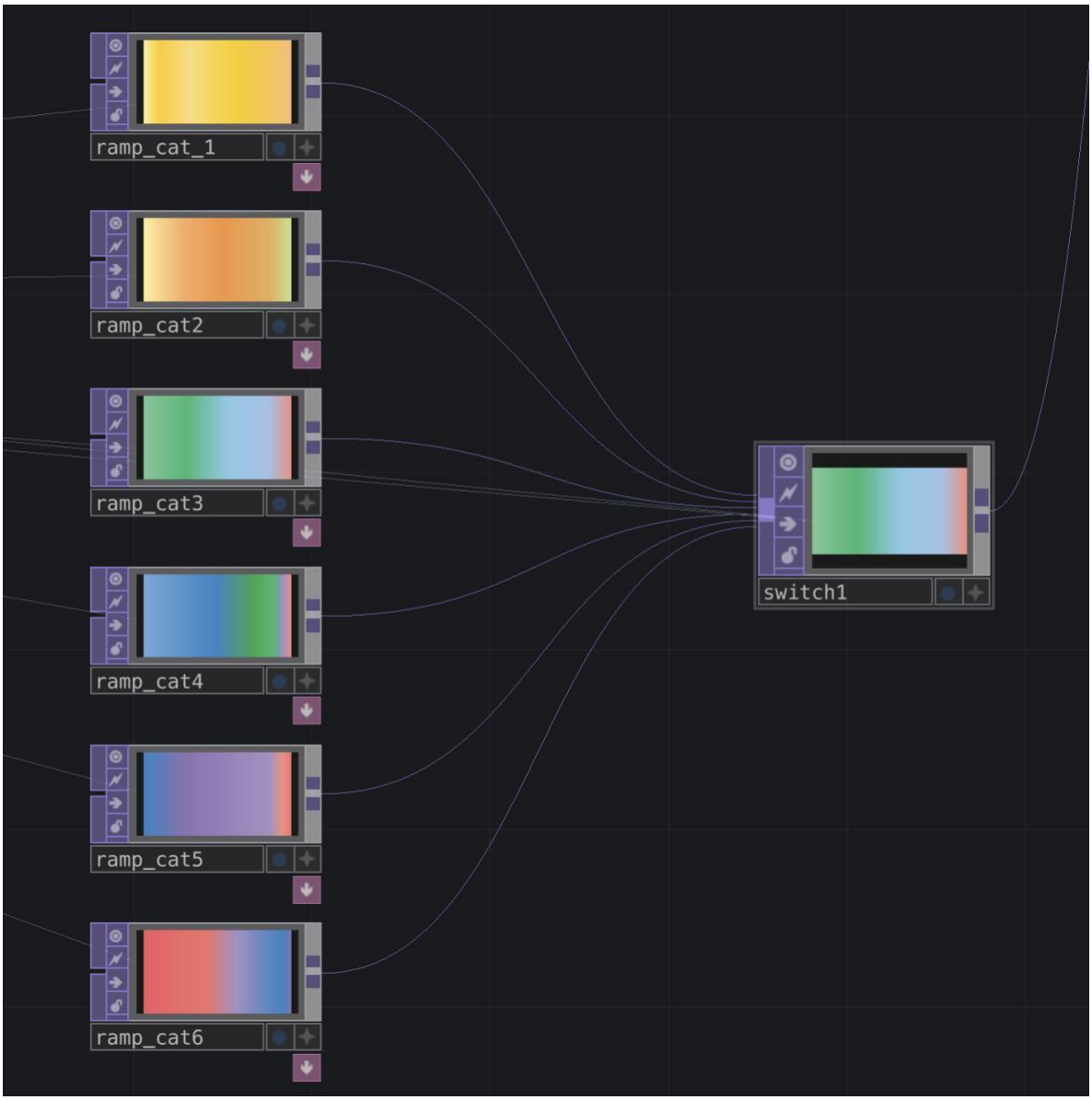


Figure 28 – The six palettes and the Switch TOP

The output from the Switch TOP is then inserted as the second operator within a Lookup TOP. The operator just mentioned replaces the colour values of the operator it receives as first input, with the values it receives as second input.

What happens, therefore, is that the graphic pattern produced by the Noise TOPs and rendered in greyscale by the Monochrome TOP, through the Lookup TOP is modified in colour by the Switch TOP which manages the six colour palettes. In

this way we will have as output of the Lookup TOP the graphic pattern produced previously with colours linked to the emotions we want to convey to the user.

A text overlay is then applied to this output, showing the place where the air quality survey was carried out and the corresponding AQI value.
The latter action is performed by two different Text TOPs that receive the string for the location and the AQI value from the previously mentioned Text DATs that store the data received from the Python code that performs the API requests.

These steps, shown in Figure 29, lead to the final result, a graphic pattern that changes in shape, colour, movement and overlay text, all based on the data received in real-time from around the world.

Figure 29 – Colour and text application

The final graphical result, in all its variations related to real-time data and emotion-related colours, will be shown in the next chapter related to the results.

4. Results

This chapter will present the results obtained, starting with the documentation and research process on the topic in question, and then moving to the collection and analysis of data. Finally, the results of the work done using TouchDesigner will be analysed, with the effects produced by the use of this software and its graphic

node interface for the development of the interactive and emotional graphic design. Consideration will also be given to the result obtained from the integration in this project of the theory relating to Plutchik's Wheel of emotions and thus the relationship that was attempted to create, through the use of colours, between visuals and emotions. In fact, as broadly anticipated in the previous chapters, one of the objectives of this project is the production of an artistic work that can have an awareness-raising impact on those who use it.
As a result, the practical experimentation, technical-artistic research, and digital development of an alternative channel of communication that can aspire to be a new method of mass involvement and empowerment is to be analysed.

Several factors were included in this project, starting with the environmental problem and the need to voice concern on this issue, this can be considered the fuse that triggered the start of this project. This first factor led to thinking about the effect that is sought in this work, namely awareness and impact on those who benefit from it. This is another fundamental element to take into account when reviewing the development process.
The second factor concerns the chosen media, namely the digital, including interactivity and immersiveness, combined with the emotional, through the use of Plutchik's Wheel of Emotions. These two elements merge into an artistic vision of the project, thus losing pragmatism in visualisation, but gaining expressive power from a conceptual point of view.

Indeed, this is the compromise that needs to be analysed: the scientific and technical approach in the development based on data collection and algorithms, combined with the expressive power that wants to use emotions as a driver for change.

4.1 Documentation and research

The first factor to be analysed when talking about results is the choice of data to be collected for analysis and their consequent visualisation in the project. As already mentioned, the environmental theme is what it was decided to deal with and, in detail, the problem of air quality in different places on the planet.

The topic of air quality was chosen because it is one of the major consequences of climate change on human beings and the quality of life. It is important because on the one hand it is the result of human activities such as the lack of sustainable development in transport or industry, and on the other hand it has a visible, undeniable, negative impact on the daily life of every citizen.

The latter is the element that makes the choice made satisfactory, in fact we wanted to search for a factor that would have an impact on the feelings of the population and awaken both negative feelings of concern and positive feelings of activation and proactivity.

This topic was chosen because on the one hand it touches each individual personally, making them reflect on their own health, on what they breathe every day and on the consequences this has on their future and that of their loved ones. On the other hand, it is hoped that this theme will awaken a critical sense, a willingness to change “every day” behaviour that can create an impact.
The keyword on which we have reflected is “every day”, both in the emotional impact we wanted to seek, found in the effect that the quality of the air we breathe has on each of us every day, and in the consequent activation of the informed and sensitised individual, who every day can create a change in the community by making a contribution with small and simple ethical choices in the field of personal mobility, for example.

Specifically, the Air Quality Index calculated by the U.S. Environmental Protection Agency has proved to be an excellent yardstick and method of communicating this factor. In fact, it has the great merit of making information that is otherwise difficult to understand 'easy' and usable even for non-experts.
The technical and complicated work is done beforehand, collecting the measurements of several pollutants and calculating the index. To the end user all this is hidden, the only value shown is a number ranging from 0 to 500; the higher it is, the higher the level of health concerns.

This allows for an immediate impact, an emotional reaction that needs no prerequisites to be experienced, it should be considered a starting point to inform, raise awareness and bring about a behavioural change in the public involved through the work.

4.2 Data collection, data cleaning and analysis

In this section, the results of the data collection via the Air Quality Programmatic APIs and the following processes initiated from these data are to be analysed.

It can be stated that the choice of Google Maps Geocoding APIs for extrapolating latitude and longitude coordinates from an address or a city name was a positive one. They turn out to be very efficient, fast in sending the response and easy to use.
In addition, they also allow different ways of requesting, so there are possibilities to modify and change the code in case one wants to make changes and future developments to the project. The only negative note, which applies to both the Google Maps Geocoding APIs and the Air Quality Programmatic APIs, is the fact that much more data are sent in response from a simple request than are used. A lot of information is not needed in this specific project, resulting in an extra step of cleaning such data and deleting all unnecessary data.
Although this step does not lead to a great use of resources, it is still important to specify this. It is also important to state that all data not considered in this first version of the project, could be used in future versions, as an interested user could be provided with additional information both on the various elements that led to the calculation of the AQI, and on the survey stations used to calculate this value.

The choice of using a minimum of two different sources of information for the calculation of the AQI average is also satisfactory. Indeed, it is important to consider that the survey stations may have been placed in locations that do not reflect the true air quality of a geographical area.

This method, which takes all sensing stations (at least two) at a distance of a certain radius from the selected location, is a simple mechanism that allows for a minimum of extra accuracy in the data.

4.3 Development of a data-reactive visual

In this section, the efficiency of TouchDesigner will be analysed and the choice of using this software in this project will be evaluated, based on the experience of using it. Both the positives that enabled the work to be completed and the

negatives, i.e. the difficulties encountered in using the interface and the problems faced in the various processes, will be taken into consideration.

In general, it can be said that the choice of TouchDesigner turned out to be extremely positive in terms of user experience. The node-based visualisation of the graphic interface proved to be very intuitive, easy to use and extremely customisable.

The software turns out to be very malleable, making it possible to find a compromise between technical expertise and the use of tools with which one is not fully familiar. In fact, it was possible to go deep when technical skills permitted, modifying codes, creating new ones, developing a series of automatic mechanisms through the use of Python functions and specific operators.

At the same time, the graphical interface of visual programming also makes it possible to use tools with which one is not fully familiar, such as Noise TOPs. They create interesting graphical patterns, which can be easily modified by means of the parameters described above but are the result of extremely complicated algorithms and procedures at a mathematical level. They are, however, hidden from the user, who, if he is not interested in delving into them, still has the possibility of using such a powerful tool with more than acceptable results.

Already from the first steps taken in TouchDesigner for the creation of the start value of all processes, i.e. the global parameter 'DECISION', and the subsequent mechanisms, the interoperability of the working environment can be appreciated.
In fact, this parameter is easily set from the graphical interface, by choosing the name and type, thus limiting the user's possibilities regarding the values to be entered. Moving on with the process, the necessary work shows the other functionalities of the software, namely the operators in the form of visual nodes that control the change of the parameter value and allow Python code to be inserted into them. This code allows other functionality to be started, in this case scripts in an additional node.
These scripts allow the value to be saved, operations to be performed and the results to be sent to multiple new operators in the project.

Already in these few steps, which are a very small part compared to the totality of the project, it can be seen that information flows from one operator to another, and the design of this movement was extremely developer friendly.

Also noteworthy is the easy handling of the operators that deal with the creation and manipulation of graphic patterns, such as the aforementioned Noise TOP, but also the nodes that allow the creation of colour palettes connected to Plutchik's Wheel of Emotions.
Each parameter is described in the online documentation, which is also carefully explained through examples on the manufacturer's official website.

Overall, the ease of interaction between code and interface elements proved optimal for the project to be developed.
In spite of this, the greatest difficulty encountered concerns the hardware requirements of such advanced software. If, in fact, the design via the graphical interface is fluid and fairly intuitive, this cannot be said completely with regard to the testing and visualisation of the result at a graphical level.
In order to correctly visualise, with good resolution, a dynamic design that modifies itself in real-time, it is necessary to have a machine with adequate technical specifications, i.e. a latest-generation multi-core processor, a high-performance dedicated graphics card and a RAM memory of at least 16GB.
In the absence of such specifications, it is necessary to test the project at lower resolutions, in order not to run into display problems, blocking and grainy effects.

The final graphic output is totally satisfactory because of its dynamicity and color variations. Screenshots of the six different graphic patterns will be shown below, these images do not do justice to the final result as the patterns are in constant motion and this dynamism plays a fundamental role in the work and perception of emotions that was sought.

Figure 30 shows a frame of the graphic pattern generated in relation to the best AQI values detected, those ranging from 0 to 50. As anticipated, it is predominantly yellow, the colour Plutchik links to the most positive emotions.

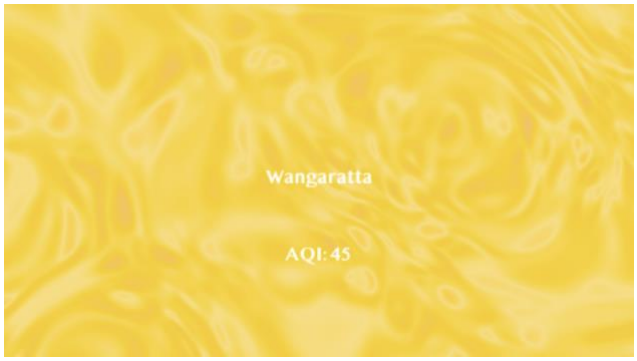


Figure 30 – Graphic pattern of the AQI's first category

Figure 31 shows a screenshot of the pattern generated in relation to AQI values ranging from 51 to 100, thus having an acceptable air quality. The colour orange predominates but inserts of yellow and green can be seen.

Figure 31 – Graphic pattern of the AQI's second category

Figure 32 shows a frame of the pattern related to the third category, the one with AQI values ranging from 101 to 150 and hazardous air quality for sensitive groups. The predominant colours chosen are green and light blue, with slight hints of red.

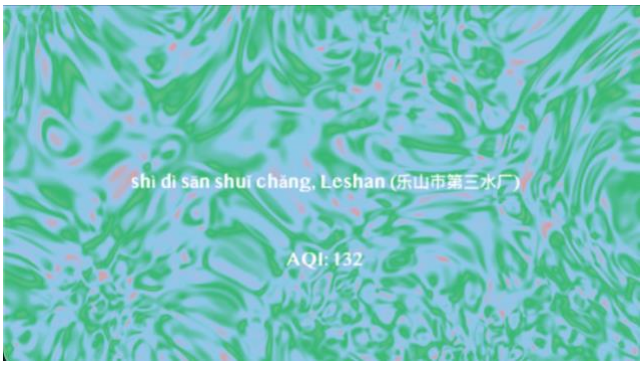


Figure 32 – Graphic pattern of the AQI's third category

Figure 33 shows the pattern for the fourth category, where the air quality is unhealthy and therefore the colours are close to dark blue with hints of green, and the movements are also jerky and annoying.

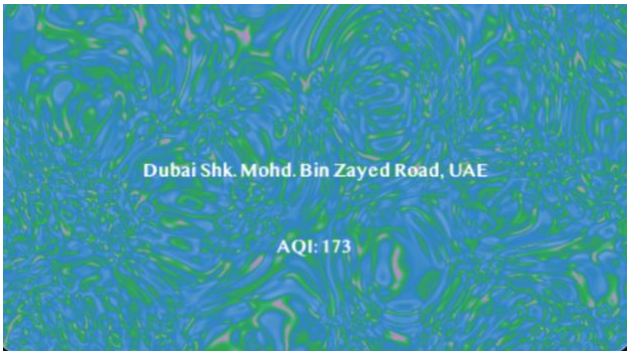


Figure 33 – Graphic pattern of the AQI's fourth category

Figure 34 shows the graphics for AQI values between 201 and 300, taken at locations worthy of health alert. The predominant colour is violet, and the movements are even faster and snappier.

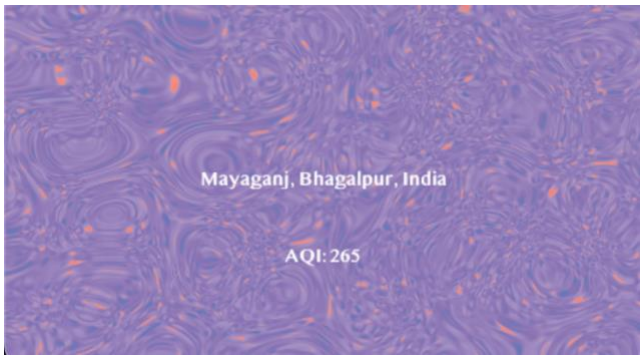


Figure 34 – Graphic pattern of the AQI's fifth category

Finally, Figure 35 shows the last category, the one that is extremely dangerous to human health, with AQI values ranging from 300 to 500. The predominant colour is red, with inserts of blue that make the graphics unattractive. The rapid and extremely jerky movements contribute to the goal of stimulating negative emotions.

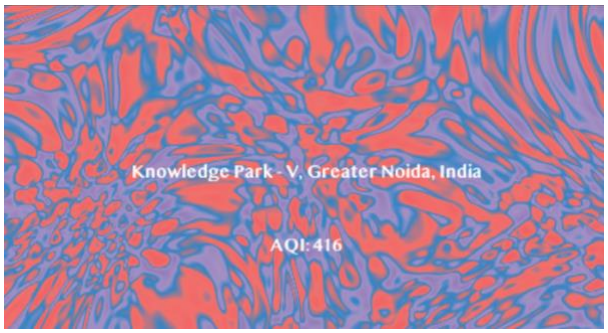


Figure 35 – Graphic pattern of the AQI's sixth category

5. Conclusions

The results obtained are fully satisfactory, considering that the work was carried out from scratch. In fact, the project was developed without any particular prior knowledge regarding most of the steps completed and the tools made freely available to the developers for collecting information on air quality were not known beforehand. Therefore, the first part of the research and collection of information was successful and led to the creation and real-time updating of a very interesting database, which in this case was used for an art project but which can also be applied to different areas.

The practical development steps are also to be considered satisfactory, starting with the development of Python scripts to make requests to the web services made available by Google and the EPA. The result obtained is an agile and streamlined code that, through just a few lines, provides a great deal of interesting data on air quality over a very wide geographical area.

The subsequent steps of processing the collected data, calculating averages, and dividing the information into categories allow the developer to have an ordered database: a very important starting point for the subsequent development of the graphic work.

The work done in Python for the categorisation of the AQI indices by means of a few simple scripts greatly streamlines and facilitates the process. It is therefore

considered efficient to alternate between visual tools and writing programming code, without which the project would have been much heavier, more complicated and probably difficult to realise.

The part concerning the use of the TouchDesigner software is certainly the most complicated one, which required more time to understand the various functionalities and the dialogue of them with the code. At the same time, however, once the initial difficulties due to the lack of expertise were overcome, the choice of such a complete software, full of functionalities suitable for interoperability, turned out to be a winning one.

In fact, the result appears streamlined and clean even in the graphic design, in which the flow of data is clear and fluid, such as the channelling of them to the graphic operators who conclude the project by displaying the final visual.

In conclusion, the theoretical integration of Plutchik's Wheel of Emotions proved to be an interesting tool, adding conceptual and emotional power to a work that up to that point had been mainly technical.

The limitations of this project are to be found in the lack of high-level hardware, as mentioned above. This could lead to a more detailed testing of the graphical results and a greater fluidity in the case of using a larger amount of data, adding information to extend the database created.

Another limitation is undoubtedly the partial knowledge of computer graphics, which did not allow a certain level of results to be exceeded with regard to the final video. With further study and acquisition of skills, it would be possible to create a more graphically elaborated work.

As far as the activities that could be started from the final result of this project are concerned, they can be divided between the integration of new functionalities and the accompanying presentation of the work.

In the first case, the project could be enriched with work on the collection, processing, and visualisation of data on topics closely related to air quality. An example could be mobility, as well as ocean pollution, waste management or industrial emissions. These data could be added to the database, combining them with those already present and creating a broader, cross-cutting narrative, to raise awareness among the population in a more comprehensive form.

Under a technical point of view, however, a sound part could be added to the project, making the work audio-visual. This would certainly make the work more immersive, creating greater participation and attractiveness.
This work on sound would be carried out following the same concepts and modus operandi, thus still using data as raw material, but modelling the sound through them. This could be done via TouchDesigner but would probably require the integration of a music production programme such as Ableton Live.

With regard to the accompaniment in the presentation and display of the project, the next steps could be providing engagement activities to explain the meaning of the data used and give information on how the air quality index was calculated. After that, experts in sustainable development could advise interested people on possible green alternatives in their personal daily behaviour, starting on the data collected and visualised.

Finally, an analysis of the appreciation and impact the work may have on the public would be essential.
In the case of an exhibition, a study of the participation, awareness and attractiveness of the work in public places would be important, aimed at collecting data and accompanying the population, for a behavioural change towards greater awareness of environmental problems and sustainable development.

Bibliography

AirNow.gov (no date) *AQI Basics*. AirNow.gov, U.S. EPA. Available at: https://www.airnow.gov/aqi/aqi-basics (Accessed: 22 August 2023).

Anadol, R. (2021) *Machine Hallucinations - Nature Dreams*. Available at: https://refikanadol.com/works/machine-hallucinations-nature-dreams/ (Accessed: 22 August 2023).

Anadol, R. (2023) *Artificial Realities: Coral*, *Refik Anadol*. Available at: https://refikanadol.com/works/artificial-realities-coral/ (Accessed: 22 August 2023).

aqicn.org (2022) *Real-time Air Quality data feed*. Available at: https://aqicn.org/json-api/doc/ (Accessed: 6 September 2023).

Berman, R. (2019) *Ryoji Ikeda: Artist and Data Scientist | SPIEGEL-WILKS SEMINAR: VENICE BIENNALE*. Available at: https://web.sas.upenn.edu/venicebiennale/ryoji-ikeda/ (Accessed: 22 August 2023).

Bridle, J. (2011) *The New Aesthetic*. Available at: https://jamesbridle.com/works/the-new-aesthetic (Accessed: 22 August 2023).

Derivative (2022a) *Operator Family*, *Derivative*. Available at: https://docs.derivative.ca/Operator_Family (Accessed: 14 September 2023).

Derivative (2022b) *TouchDesigner Documentation - Noise TOP*, *Derivative*. Available at: https://docs.derivative.ca/Noise_TOP (Accessed: 13 September 2023).

Fernandes-Marcos, A. (2007) 'Digital Art: When Artistic and Cultural Muse Merges with Computer Technology', *Computer Graphics and Applications, IEEE*, 27, pp. 98–103.

Finke, K. and Roosegaarde, D. (2013) *Interview to Daan Roosegaarde*, *Friends of Friends / Freunde von Freunden (FvF)*. Available at: https://www.friendsoffriends.com/workplaces/daan-roosegaarde/ (Accessed: 22 August 2023).

Galanter, P. (2003) *What is generative art? Complexity theory as a context for art theory*.

Google (no date) *Geocoding API overview*, *Google for Developers*. Available at: https://developers.google.com/maps/documentation/geocoding/overview (Accessed: 11 September 2023).

Hancox, S. (2013) 'The Performativity of Ice and Global Ecologies', *Performance Research*, 18(6), pp. 54–63. Available at: https://doi.org/10.1080/13528165.2013.908057.

Hornby, L. (2017) 'Appropriating the Weather: Olafur Eliasson and Climate Control', *Environmental Humanities*, 9(1), pp. 60–83. Available at: https://doi.org/10.1215/22011919-3829136.

Kanchan, K., Gorai, A. and Goyal, P. (2015) 'A Review on Air Quality Indexing System', *Asian Journal of Atmospheric Environment*, 9, pp. 101–113. Available at: https://doi.org/10.5572/ajae.2015.9.2.101.

Lakatos, M. (2020) 'Sights and Sounds of Big Data: Ryoji Ikeda's Immersive Installations', *Acta Universitatis Sapientiae, Film and Media Studies*, 18, pp. 109–129. Available at: https://doi.org/10.2478/ausfm-2020-0006.

Lineberry, H.S. and Wiek, A. (2016) 'Art and Sustainability', in H. Heinrichs et al. (eds). Dordrecht: Springer Netherlands, pp. 311–324. Available at: https://doi.org/10.1007/978-94-017-7242-6_26.

Melina, F. (2023) 'Prospettive teoriche: le opere di Olafur Eliasson per un'arte ecologica', *Itinera* [Preprint]. Available at: https://doi.org/10.54103/2039-9251/20843.

Mohsin, M.A. and Beltiukov, A. (2019) 'Summarizing Emotions from Text Using Plutchik's Wheel of Emotions', in. *7th Scientific Conference on Information Technologies for Intelligent Decision Making Support (ITIDS 2019)*, Atlantis Press, pp. 291–294. Available at: https://doi.org/10.2991/itids-19.2019.52.

Nake, F. (2018) 'The Pioneer of Generative Art: Georg Nees', *Leonardo*, 51(03), pp. 277–279. Available at: https://doi.org/10.1162/leon_a_01325.

Paul, C. and Arnold, D. (2016) *A Companion to Digital Art*. Hoboken, UNITED STATES: John Wiley & Sons, Incorporated. Available at:

http://ebookcentral.proquest.com/lib/polito-ebooks/detail.action?docID=4443200 (Accessed: 22 August 2023).

Roosen, L., Klöckner, C. and Swim, J. (2017) 'Visual art as a way to communicate climate change: a psychological perspective on climate change–related art', *World Art*, pp. 1–26. Available at: https://doi.org/10.1080/21500894.2017.1375002.

Ruiz, M. and Pérez, R. (2018) 'Arte, Tecnología y Humanismo. El laboratorio de diseño social Studio Roosegaarde como ecosistema creativo tecnopoético', *Artnodes* [Preprint]. Available at: https://doi.org/10.7238/a.v0i21.2968.

Shanken, E.A. (2002) 'Art in the Information Age: Technology and Conceptual Art', *Leonardo*, 35(4), pp. 433–438.

Shanken, E.A. (2016) 'Contemporary Art and New Media', in *A Companion to Digital Art*. John Wiley & Sons, Ltd, pp. 461–481. Available at: https://doi.org/10.1002/9781118475249.ch21.

Studio Roosegaarde (2013) *Smart Highway*. Available at: https://www.studioroosegaarde.net/project/smart-highway (Accessed: 22 August 2023).

Studio Roosegaarde (2019) *Smog Free Tower*. Available at: https://www.studioroosegaarde.net/project/smog-free-tower (Accessed: 22 August 2023).

Tempel, M. (2017) 'Generative art for all', *Journal of Innovation and Entrepreneurship*, 6. Available at: https://doi.org/10.1186/s13731-017-0072-1.

The World Air Quality Index (no date) *World's Air Pollution: Real-time Air Quality Index*, *waqi.info*. Available at: https://waqi.info/ (Accessed: 22 August 2023).

TouchDesigner Software (2017) *Derivative*. Available at: https://derivative.ca/feature/application-building (Accessed: 13 November 2023).

Transforming our world: the 2030 Agenda for Sustainable Development | Department of Economic and Social Affairs (no date). Available at: https://sdgs.un.org/2030agenda (Accessed: 22 August 2023).

U.S. Environmental Protection Agency (2023) *Air Quality Index - A Guide to Air Quality and Your Health | AirNow.gov*. Available at:

https://www.airnow.gov/publications/air-quality-index/air-quality-index-a-guide-to-air-quality-and-your-health/ (Accessed: 6 September 2023).

US EPA, O. (2016a) *Basic Information about NO2*. Available at: https://www.epa.gov/no2-pollution/basic-information-about-no2 (Accessed: 22 August 2023).

US EPA, O. (2016b) *Particulate Matter (PM) Basics*. Available at: https://www.epa.gov/pm-pollution/particulate-matter-pm-basics (Accessed: 22 August 2023).

US EPA, O. (2016c) *Sulfur Dioxide Basics*. Available at: https://www.epa.gov/so2-pollution/sulfur-dioxide-basics (Accessed: 22 August 2023).

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