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Space, human, data: A lighting design framework

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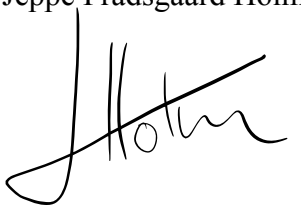

Abstract:

In 1960, Jane Jacobs and William W. Whyte came up with a concept they called placemaking. This offered a practical approach for neighborhoods and cities to reinvent public spaces with a focus on community. Now, the rise of digital cities and other emerging technologies adds new tools to the toolbox of urban planners. This is encapsulated in the concept called "Digital Placemaking", where digital media is utilized to make better community-based designs for the urban space.

This report combines the idea of human-centered urban design with technology and lighting design, by mapping and evaluating the notion of digital placemaking and bringing it into contact with the theory of its actors: place, human, and data. By investigating how today's technology is used in urban planning and how this can be used in the future.

This information will then be applied to develop a design framework that would equip designers with a toolkit for working with site-specific lighting. An iterative design process was used to conceive an end-to-end framework by working with a set of case studies on the side. The examples of how to work with the design framework are shown in three separate locations in Copenhagen, Denmark.

Aalborg Universitet

SPACE, HUMAN, DATA

a lighting design framework

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AALBORG UNIVERSITET

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chapter 1

introduction and methods

BACKGROUND

Cities all throughout the world have grown in population during the last few decades. Since 1995, the population of Copenhagen has increased by 35%, and this trend is predicted to continue until 2031 (Status på København 2021). This has necessitated the rapid development of infrastructure and new homes. Though much effort has been put into making newly constructed neighborhoods coherent and livable, this has sometimes failed. This has resulted in some new developments lacking spatial identity and a lot of areas failing to encompass the local community into architecture and urban planning.

Older districts have also been affected by population growth and an increase in traffic in recent decades. With a few new buildings appearing between old buildings and a diverse population, a fragmented identity might emerge from incoherent architecture. On the other hand, this has the potential to be the very catalyst for a vibrant and colorful urban environment, but only if the communities have a channel through which to express themselves.

For the past 50 years or so, urban development has been rooted in theories and ideologies, but the cities are often envisioned as machines where functionality is the most important element, and city planners have designed cities to provide the best conditions for cars - not humans (Gehl, 2014).

In 1960, Jane Jacobs and William W. Whyte came up with a concept they called placemaking (What is Placemaking?, 2022). This offered a practical approach for neighborhoods and cities to reinvent public spaces with a focus on community. Later on, digital placemaking was suggested to include media architecture as a tool to visualize and enhance the identity of public spaces.

> *"Cities have the capability of providing something for everybody, only because, and only when, they are created by everybody"* (Jacobs, 1961)

Furthermore, the rise of digital cities, also known as smart cities and other emerging technologies, adds a new tool to the toolbox of urban planners. Most major cities have established or are in the process of developing a city-wide digital infrastructure that can collect data throughout the city. Despite a lot of uncertainty and technological and privacy obstacles that prevent us from fully using the capability of smart cities, there are many possibilities to design for a more human scale urban space by focusing on interactivity and playfulness.

Digital placemaking is still a relatively new concept with few practical applications. In the book "Media Architecture Compendium" (Hespanhol et al., 2017) a definition of digital placemaking is investigated. However, it also underlines that a framework is missing:

"We have come a good way in terms of developing the technical foundations for making media architecture work, but we lack tools and approaches to address how media architecture can successfully contribute to placemaking" (Hespanhol et al., 2017)

"Ideas on how space, people and things articulate were usefully framed to help designers being more aware of the potential consequences of their own moves. It is time now to refresh those efforts at the light of the emergence of new variables and extended

INTENTION

relationships and possibilities" (Aurigi in Hespanhol et al., 2017)

This report hopes to introduce a fresh approach to how to design with light for public spaces and inhabitants by including the local community as a central element in the design in order to make more relevant and long-lasting public light installations.

The aim is to combine the idea of human-centered urban design with technology and lighting design. We will look into the idea of digital placemaking and urban data aggregation in order to come up with an end-to-end design framework that municipalities, urban designers, lighting designers, and local communities may use to construct human-scale urban lighting landmarks.

The design framework will be deduced through a study of scientific articles and by boiling down the diverse sectorial methods into one single toolbox. Then, in order to demonstrate and test the framework and reiterate it into a widely applicable tool, three examples of urban spaces with different characteristics have been analyzed following the newly built framework.

The aim is not to make an advanced technological piece, but to create the best possible design for a specific place, where technology is the tool to support the design. When working with lighting, designers should not be limited to formulating a design according to the standards, but should instead strive to provide the best possible illumination for the space and its users, based on playfulness and with the help of data.

Problem statement

How can a new structured framework developed for public lighting support the design of public space based on digital placemaking, data and human interaction to create the best possible site-specific lighting?

methods

THE DESIGN EXPERIMENT MODEL

This report is based on the Design Experiment Model (Hansen et al., 2014), which provides a method for structuring the process of designing and researching within a project. It is based on a problem based learning approach (PBL). A PBL perspective focuses on applying knowledge to real-world issues. This means that problems are constructed and reconstructed repeatedly during the learning process. The interplay between theory and practice, combining the abstract and the contextual, is a basic value of the PBL (E. Holgaard & Kolmos, 2021).

The Design Experiment Model is composed of the following steps: design vision, design intentions, design proposal, design evaluation, and design solution. It is suggested to approach these steps from three distinct disciplines: natural science, social science, and humanities/art.

AGILE MANAGEMENT

Throughout the whole report, agile management is applied. This method encourages detailed project management grounded in strong communication within the team and with external partners. It suggests breaking the project into smaller components and dividing them between teams. It recommends holding daily meetings to ensure that everyone is on the same page. It also introduces the use of an iterative design method where a project goes through multiple iterations of planning, designing, testing, and evaluating before realizing the final project.

This method has inspired this project to divide the initial vision into smaller components, which could then be investigated separately before being assessed and evaluated and finally merged together into a summarized theory. The iterative design process was also utilized when working with design cases and prototyping.

chapter 2
theory

This chapter introduces the theoretical background for digital placemaking, to then break down its actors in order to find accurate tools for a design framework. It will focus on the intersections between these actors and analyze the theories around these: community, playfulness, and technology.

digital placemaking

This section will examine the evolution of modern cities and outline the history of human-centric urban planning. The underlying theory of urban design will be examined, and the future direction of urban design will also be explored.

BIRTH OF PLACE-MAKING

Since the beginning of the 20th century, transportation has been one of the most important aspects of urban planning. Transportation is the lifeline of the city, connecting the people and buildings. With an efficient transport system, a city can expand the creative and productive power of human beings. However, it also has the possibility of being a stressful, polluting, and space consuming crawler. With cars as a central element of the city, roads take up a substantial amount of the overall space. (Gössling et al., 2016). As a consequence, in the 1960s, critical voices began to emerge. Cities have been repressed by vehicles, rational planning, and specialized processes (Gehl & Svarre, 2014).

In 1961, Jane Jacobs published her book on urban design called "The Death and Life of Great American Cities". She claimed that urban regeneration and slum clearing were not always beneficial to citizens. She addressed the city's social capital, launching a movement in which people were prioritized over cars and buildings in urban design (Jacobs, 1961). At the same time, William H. Whyte started studying and observing public spaces in New York, focusing on the people. He would observe the activities of people and meticulously count the number of people using the space. He would record time-lapses, make interviews, and produce diagrams and films (Elsheshtawy, 2015). Together with Jane Jacobs, he came up with the concept of placemaking in the early 1960s, where the core principle was to make urban design about people, citizens, and community (Hespanhol et al., 2017).

In the last 20 years, media architecture has become an increasingly bigger part of urban design. With LEDs and other technologies becoming more developed, it is now possible to make big media facades and light sculptures that are the defining elements of urban spaces.

It might be quite useful to integrate thoughts about placemaking in this context to ensure that the new media designers meet the demands of the citizens. This new movement is known as "digital placemaking", whose goal is to employ digital technology to support citizen-centered placemaking (Hespanhol et al., 2017).

DEFINING DIGITAL PLACE-MAKING

The purpose of digital placemaking is to provide a notion that can be referenced and studied while dealing with digital media in the public space. The goal of digital placemaking is to include the context for a light installation as opposed to creating a piece of media art without regard to its surroundings.

Using digital media may also contribute to the creation of a sense of place, as it allows one to create emotional attachments to a location. However, digital media can also cause a space to lose its coherence. Therefore, it is essential to approach a new design carefully in order to ensure that the design incorporates the space and its users; it is important to integrate the communities to develop more relevant and connected environments through digital activities that help people to place themselves and others. It is also crucial to make the design inclusive for all the users of the space and to make sure it does not expose or amplify pre-existing inequities, exclusions, or erasures in the ways that certain populations experience digital media in place and placemaking.

In "Media Architecture Compendium," a definition of digital placemaking is examined through a compilation of essays authored by architects, media designers, urban planners, and computer scientists. According to the book, digital placemaking is the use of digital media to create a sense of place for oneself and/or others, and it may be used to shape meaningful public spaces. It is also referred to as a sort of digital storytelling, and it can strengthen local ties to shared culture and create a unified sense of place. Additionally, it is described as community-based and participatory design, a collaborative process through which the public environment can be modified and optimized. However, the book also states that we lack the necessary skills and strategies to address how media architecture might effectively contribute to placemaking.

Martin Tomitsch, Professor in Design and Planning, talks about two design approaches when working with digital placemaking: the interactive and the ubiquitous approaches.
The first approach is to turn an urban space into a stage, resulting in passers-by choosing to actively engage, becoming performers, or to stand back and be observers (Hespanhol et al., 2017). The ubiquitous interaction approach, instead, "shifts awareness towards the broader work as part of the surrounding environment, enhancing the interplay between people and place and diluting the role of the performer across the whole audience" (Hespanhol et al., 2017).

In the essay "Embracing Place: Grounding Technology Back into Context", Alessandro Aurigi argues that placemaking is a "holistic and context-embedded endeavor". He further explains: "Thinking and designing holistically implies articulating intentions which take into account not just technology and its users, but the fact that physical space and urban form, history, memory, culture, socio-economic conditions, and more, are actors too, and actively make place" (Hespanhol et al., 2017).

PLACE-KEEPING

Media art in cities for the purpose of civic participation often follows the model of an arts festival (Hespanhol et al., 2017). Installations are temporary and are only given 'permission to play' in a very specific and predetermined way and with a limited duration: "Placemaking often detracts from longer-term aspects such as adaptability and maintenance of the solutions initially proposed" (Hespanhol et al., 2017).

Large amounts of capital continue to be spent on creating spaces without appropriate consideration for long-term maintenance and administration of public spaces, referred to as placekeeping. The importance of placekeeping is rarely put into practice, even when public spaces are regarded as important for contributing to health, wellbeing, biodiversity, and also their economic value (Dempsey and Burton, 2012).

Consequently, it is essential to consider the long-term effects of a reconfigured urban space. This applies to the physical aspects of the installation (the lifespan of the luminaires, the durability of the materials, and the risk of vandalism) and the fact that digital placemaking has the potential to develop an element that is more adaptive within the urban environment. With light or media as a central element in sculpting the installation, it is possible to transform the sculpture's expression continuously into something that keeps resonating with the local community.

"Like clay for artisan, swift malleability of precisely the core strength offered by media architecture as prototyping raw material to digital placemaking, and an enabler to its smooth transition to placemaking" (Hespanhol et al., 2017).
Placekeeping is more than just the physical environment, its design and maintenance, however. It is also about the non-physical dimensions of partnerships, governance, funding, policy, and evaluation (Dempsey and Burton, 2012).

THE TERNARY PLOT

For a deeper understanding of how digital placemaking works, it is fundamental to thoroughly analyze its three coexisting main actors: space, humans, and data (see fig. 1).

In this context, the term "human" refers to the socio-cultural context and a human-centric design approach. "Data" is the collection of the technological side of the project, including collecting, processing, and representing data, and "space" is the physical setting.
It is, however, in the interconnection between these actors that the most relevant matters emerge: the combination of people and space spawns community, people and data generates playfulness and space and data create the technology.

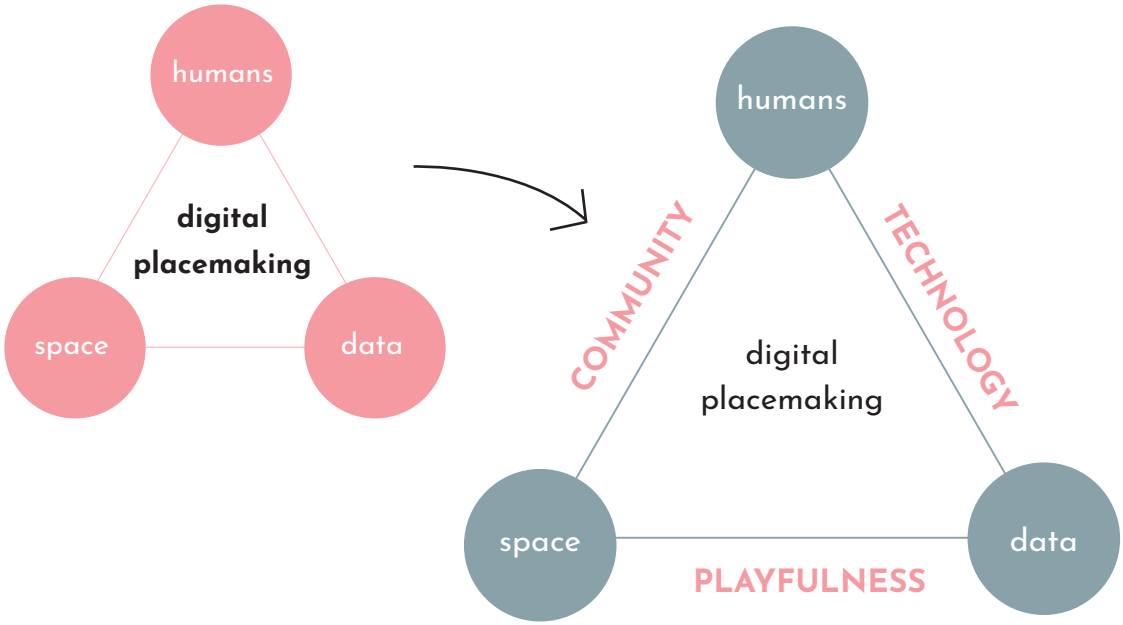


Fig. 1 – The ternary plot

SUMMARY

Digital placemaking can be seen as the marriage between 60 years of work with studying public life and the emerging of digital architecture in urban space. It includes techniques and tools on how to observe and form the public domain in a way that puts the people and communities at the center and that includes participatory designs. At the same time, digital placemaking tries to absorb the rapidly evolving technology into the terminology in order to give a toolset for planners and designers to use when working with digital art and architecture. However, this is still a rather new approach and it still needs refinement: most observers professionally working in this field, agree that a set of tools still needs to be defined in order to include the digital realm into the original terminology of placemaking that has been confirmed through many years of practice.

community

The following section aims to clarify the difference between a space and a place, starting from Lefebvre's revolutionary concept of "The Other", followed by Soja's Thirdspace. Then more methodological tools are presented for the analysis and comprehension of a place, such as Lynch's and Gehl's analytical methods and user's observation, in order to set the basis for the spatial and human analysis in the framework. A method for creating inclusive designs is also being investigated.

THIRD-SPACE

First of all, it is important to clarify the concept of "place", in contrast to the definition of "space".
While "space" is a geographical location, a physical measurable space, "place" has a meaning, an identity, a cultural, emotional, and historical aspect to it. It is a geographical zone to which a personal or collective memory gives meaning (Saar et al., 2009).

Historically, the abovementioned binary dialectic was what geography was founded on; a space was considered to be divided into physical space and conceived space.
In 1991, Lefebvre introduced "The Other" to widen and expand the traditional arbitrary approach. He speaks of a "space triad" consisting of spatial practice, representations of space, and representational space; the three coexist in the space, they are created by the space and they create the space at the same time, "space is at once result and cause, product and producer" (Hardt et al., 2000). Space is therefore ever-evolving and constantly changing, "the production of space is a continual process, and that space is always changing as conceptions, perceptions, and lived experiences change" (Goonewardena et al., 2008).

E. W. Soja in his book "Thirdspace, the trialectics of being" (1996), further develops Lefebvre's concept of "representations of space": he introduces the Thirdspace as the third element of the concept of spatiality, together with the First- and Secondspace.
Firstspace is conceived space: the physical dimension of a space, objective, measurable, and concrete. It is the traditional way of analyzing space.
Secondspace is the perceived environment; it is the elaborated image of a space processed by people's minds. It encloses the historical dimension of the space, its conceptuality and the subjective vision, but also the architects' and designers' conceptions. "Secondspace is the interpretive locale of the creative artist and artful architect, visually or literally re-presenting the world in the image of their subjective imaginaries; the utopian urbanist seeking social and spatial justice through the application of better ideas, good intentions, and improved social

learning" (Soja, 1996).
The lived space, or Thirdspace, is the social space. It is both "real and imagined, concrete and abstract" (Soja), it differs from First- and Secondspace, yet it also encloses them. It is linked to social life and to the experience within a space. It is the "space" where everything merges: "everything comes together in Thirdspace: subjectivity and objectivity, the abstract and the concrete, the real and the imagined, the knowable and the unimaginable, the repetitive and the differential, structure and agency, mind and body, consciousness and the unconscious, the disciplined and the transdisciplinary, everyday life and unending story" (Soja, 1996).

LYNCH'S ANALYSIS

Kevin Lynch, in his book "The image of the city" sets the basis for an objective analysis of physical space. According to him, a city, a neighborhood or a smaller area can be analyzed by recognizing five main elements in it: districts, paths, edges, nodes, and landmarks.

He defines paths as the "channels along which the observer cusomaily, occasionaly, or potentially moves" (Lynch, 1960). It includes every kind of street, be it for pedestrians, cyclists, trains, or cars. It is the perspective from which users perceive the environment around them and the city; what connects the city and what, at least partially, determines the experience of a city.
Edges, according to Lynch's theory, are "bounderies between two phases, linear breaks in continuity" (Lynch, 1960). They are walls and barriers that create confined spaces within the city. They organize and define the city's different areas, the so-called districts.
Districts are the city's sections with a shared identity. People are able to move within the district, through paths, and experience its characteristics. They can be defined as a neighborhood or a section of a smaller city, depending on the scale of the analysis.
Nodes are junctions or places of interest, and they often naturally occur at the paths' convergences. They are the district's focus points, and people can enter or find themselves within these points and use them freely.
Landmarks are a recognizable element in a district, a reference point. They can either be seeablefrom a distance or be locally recognizable. They help with orienteering within a district or a city and they contribute to defining the identity of a district.

All of the elements are interconnected and overlapping, and what is a path for a person using, for example, a train or driving a car, is an edge for a pedestrian or a cyclist. This space analysis is an important first step in the investigation of a concrete place because it allows for a deeper understanding of how the space is used and what the points of interest are. It also exposes the design failures in urban development, allowing for the creation of potential alternatives.

HUMAN SCALE DESIGN

The long and ongoing process of gentrification, together with the drastic increase of the global population, has influenced the urban development of cities by shifting "focus from the interrelations and common spaces of the city to individual buildings" (Gehl, 2010). The city's suburbs have become denser residential areas and, in some cases, actual cities within the bigger city. In some ways, the cities are conglomerates of smaller local communities spread out in the city area. However, the needs of the population have not been a priority, leaving little space for the community and social activities in the areas.

On top of that, the cities have quickly shifted to a car-centric design, prioritizing larger car roads in spite of sidewalks, parks, and also pedestrian safety. This trend has changed with the realization of the importance of a space where people can meet, socialize, and be physically present in the city. Because of the high density of modern cities, every open, public space becomes an important opportunity for the locals to create the "social place" they need. This means that when designing for a public space, a designer is actually planning a place for the people and therefore has to consider their needs as a priority.

As well as we are shaping the city, the city is shaping us. Design choices have major consequences for the people using a space. It frames their daily life by influencing the way they live, how they experience the city and the way they navigate it. A design choice that gives more space to pedestrians and bikes can positively influence the entire neighborhood: cyclists and pedestrians are more likely to stop and shop in the local boutiques and cafes; fewer cars means noise and pollution reduction; better biking infrastructure lures people into using it as biking results in being faster than cars (Gehl, 2010).

By designing more human-friendly spaces, we create places for the community to meet, places where to be and to flourish and where to grow socially and culturally: the better a public space is designed, the more it will be used for optional activities, as a contrast to a poorly designed one, mainly used for necessary activities. By increasing the general activity level, the space will eventually be used more for social activities too, as "social activities [...] require the presence of other people. If there is life and activity in urban space, there are also many social exchanges. If city space is desolate and empty, nothing happens" (Gehl, 2010).

If the design aims to create a place where people stop and hang out, it needs to provide comfort for all of the different users: safe walking paths, sitting possibilities, and comfortable standing opportunities. It needs to be multifunctional to support all needs: a place for playing, chatting, and seeing.
More specifically, an optimal design contributes to creating protection, comfort, and delight for people: it aims to protect them from car traffic, crime and violence, and weather conditions (like wind, pollution, and noise); it should provide comfort for people walking, standing, and sitting and to support playful

activities as well as activities like talking and socializing; also, it needs to take into consideration the scale and the possibility to enjoy the place, like natural elements and direct sunlight (Gehl, 2010).

INCLUSIVE/ UNIVERSAL DESIGN

In order to design an inclusive urban space, Gehl underlines that it is important to consider edges, accessibility, and perceived safety, and to analyze the target people the design is for: "If that target is the pedestrians and cyclists, the speed and the sight are the core elements" (Gehl, 2010), creating a slower dynamic that invites social activities, as social activities increase the perceived safety of a place. Inclusive design may address a variety of topics, including accessibility, age, culture, economic situation, education, gender, geographic location, language, or race (Inclusive Design, 2022).

Universal design is a design approach with the intent of preventing the dividing of individuals into different groups by creating designs that include people with disabilities as well as people of all ages and groups in society. To put it another way, universal design aspires to be usable by everyone to the maximum possible extent without needing specialized design.

Human rights researchers have recently begun to re-conceptualize universal design in order to place it in the context of social equality and non-discrimination. Universal design focuses on the social disadvantages that a person faces as a result of their social identities and power and privilege structures.
In particular, "artificial intelligence, wireless technologies, and the Internet of things generate a pressing need for more socially integrated projects with operational consequences on individuals in the built environment and at all levels of design and society" (Langdon et al., 2020).

USERS' OBSERVATION METHODS

For designing the best possible community and user-based urban environment, it is important to gain an understanding of how people interact with a space. This can be achieved through the ethnographic analysis method, which includes participant observation, field notes, and traditional interviews, among others. Here, an insight into an environment can be gained from observing and actively participating. Participatory observation can, however, be both active and passive and can be used to investigate practices that otherwise would be difficult to cover through interviews (Horton, 2001).

Observing people's behavior in public spaces is an ancient discipline, but it was not put into a system before the mid-1960s, when people started observing life in cities methodically. In the mid-1980s, this changed from being primarily

observation-based research done in academia to being more focused on creating tools that could be directly part of urban planning (Gehl, 2013). Since then, it has become increasingly common to engage with the life of a place while designing an architectural or urban area, and various techniques for analyzing space have been developed:

"In city life studies, human behavior is documented, analyzed and interpreted. This does not happen with the use of a microscope, but with the naked eye and sometimes with help of other utilities that can zoom in on situations and freeze moments to better analyze situations more closely. It is all about sharpening your gaze" (Gehl, 2013).

In his book "How to study public life" from 2013, Jan Gehl presents a set of both qualitative and quantitative tools for the analysis of human's relation to a space, such as counting, mapping, tracing, tracking, looking for traces, photographing, keeping a diary, and test walks.

- **Counting** is a tool used to register the number of people doing specific activities (walking, standing, or sitting) within a set space; it provides objective data from the users.
- **Mapping** is used to understand the areas of interest in a space, especially focusing on people standing and sitting, to gain knowledge about the activities held in the place. Mapping integrates the counting method with the qualitative side of the data.
- **Tracing** is the registration of people's flow within a space. This is used to map the dynamic usage of a space, the users' choice of direction, and their pace.
- **Tracking**, also called shadowing, is a method used to observe in a more detailed way how people move within a space: not only for analyzing speed and unexpected turns, but also to notice if people look in a specific direction or if they stop.
- **Looking for traces** is a tool to analyze people's usage of the space in a different way: it can help detect extra details that would not be considered otherwise.
- **Photographs** can document and communicate the mood of a place, the activity happening within it or the absence of it. They help integrate with more objective data the rest of the analysis, as it is possible to re-analyze and re-interpret a picture or a film.
- **Keeping a diary**. This method requires an observer to note real-time data. It is useful to comprehend the "lived space" in an analytical way, as it helps explain complex settings and situations. This can be used as a stand-alone method or it can be used in parallel to the other methods to complement and add details and meaning to them.
- **Testing walks** gives the ability of gaining a more subjective view on the space: the observer can impersonate a user and can experience delays, barriers and practicalities.

The aforementioned are in-depth tools for the analysis of a place and the users' relationship to it. It invites the designers to focus on the details, "details can be vital additions to our understanding of how life in public space develops as sequences and processes" (Gehl, 2013).

SUMMARY

Space and place refer to different things: space is purely physical, while place also includes the perceived and memory-related side of it.

Lefebvre and Gehl add a third dimension to the understanding of space: "The Other" and "Thirdspace", or lived space.

Because the lived space exists only via the interaction of users with it, it is critical to incorporate Gehl's "human scale" into the design process in order to create a place for people: by dedicating more space to pedestrians and cyclists, by creating a safer and more intriguing space for the users, and by building a multipurpose space to support all needs and desires.

The analysis of the space and of the people allows for a deeper understanding of how the space is used and what the points of interest are, as well as architectural flaws in urban development. For the analysis of physical space, Lynch's classification of elements in the city is a good tool to use, while Gehl's toolbox sets the basis for the analysis of human's relation to a space.

playfulness

This section introduces the concept of playfulness in relation to public spaces. Playful design will be explained as an important element for the general well-being of a local population and for the development of a community. The concept of "Homo Ludens" is unraveled and the tools for designing a playful urban design are presented. Finally, this section will be concluded with how interactivity can support this design.

PLAY-FULNESS IN URBAN SPACES

Humans are, by nature, playful creatures. As recently shown and accepted, playing performs an important role throughout an individual's life, from infancy to old age (Donoff & al, 2017). Toddlers and young adults learn the basic social rules and how to interact with others through play, but play is just as important in adults' lives. It helps humans improve physical and mental health in three ways: it allows for taking a break from a stressful work life, thus decreasing depression and anxiety; it encourages physical activity, which improves heart health; and it fosters community relationships. Furthermore, it also promotes creativity and new learning approaches. (Donoff & al, 2017).

According to Huzinga, play creates an imaginary world next to the real one, which is a necessary factor for culture to thrive. In fact, play exists before culture, as culture is a product of human interaction and coexistence. When defining play, Huzinga underlines the importance of it being free, extraordinary and not connected to materialistic aspects.
Play has the ability to create the settings for meeting people and to generate shared memories. It can create a feeling of belonging, and therefore community: "A play-community generally tends to become permanent even after the game is over. The feeling of being "apart together" in an exceptional situation, of sharing something important, of mutually withdrawing from the rest of the world and rejecting the usual norms, retains its magic beyond the duration of the individual game" (Huzinga, 1949).
Urban ludic interventions and the integration of playful elements into city design can improve the general well-being of users, help integrate unused sides of a city and solve safety issues. "Playful urban design answers our innate need to explore, discover, experiment, and even test our mental and physical boundaries. The urban environment as "play space" can offer ample opportunities for nurturing adults' innate playfulness" (Donoff, 2017).

The ludic intervention should aim to spark creativity and spontaneous behavior in the users by focusing on the bodily experience of the participants rather than a materialistic goal. There are different types of ludic urban intervention, depending on the area and the aim: the playful design can either be incorporated

into the urban infrastructure in order to change the everyday experience of the users of the space, or it can be placed in unused areas to revitalize them and arouse people's interest in discovering and using new spaces. Also, it can be intended for solely fun purposes, or it can require participants to actively play to create something. It can be individual or it can require cooperation.
A playful city has a major effect on the population's happiness and feeling of belonging, both because it helps people connect to a place and create positive memories within the space, and because it encourages social encounters; "happiness arises from feeling connected to and supported by our physical and social surroundings" (Donoff, 2017).

DESIGN PLAY-FULNESS

When designing for a community, it is important to use a subjective personal approach to complement the scientific one. Not only by focusing on the designer's personal experience, but also by deepening the understanding of the people and the community the design is made for. This can be done by analyzing the people's needs and desires, by meeting the local community, and by generating a feedback system (Gaver, 2014).
The design needs to leave space for personal interpretation. William W. Gaver in his paper "Designing for Homo Ludens" (2014) states that the design needs "to create 'suggestive media' - suggestive in that they are designed to encourage or impel ludic activity, and media in that they are tools through which people experience, create, or communicate freely" (Gaver, 2014). Also, he states that it is important to aim for an ambiguous design, as it leaves space for personal interpretation and impersonification, and more complex and interesting iterations. "Designers should be provocateurs, seeking out new possibilities for play and crafting technologies that entice people to explore them" (Gaver, 2014).

INTER-ACTIVITY

Usman Haque, in his "Architecture, interaction, systems" (2006), underlines how interaction happens when a circular transaction occurs between two parts. It is human-human, human-machine, or machine-machine. For this reason, when there is no iteration or change in one of the two parts, it is considered merely a reaction.
Haque then distinguishes between two types of interactions: one-loop and multi-loop interactions. The first is an interaction that completes a circle; a simple interaction with an expected set of responses. When talking about one-loop interaction with a machine, it is important to underline the fact that the machine, with its preprogrammed set of interactions, is limiting the interaction's possibilities and therefore it doesn't allow for creativity and constructive interaction. This type of interaction is mainly useful for uncomplicated, functional settings.

Multi-loop interactions, instead, are continuous and highly iterative: "A provokes B, but B affected A in the first place, in an ever-continuing loop" (Haque, 2006). For a multi-loop interaction to happen, it is fundamental for the responses to be open and continuous, and for the parts to be able to modify each other. When designing for architecture and public spaces, this type is the most stimulating and effective because it is "a system in which people build up their spaces through "conversations" with the environment, where the history of interactions builds new possibilities for sharing goals and sharing outcomes" (Haque). This indicates that the system allows users to shape the environment with which they engage on a continuous basis.

The cybernetician Gordon Pask published in 1976 "Conversation Theory", where he theorized a framework that sets the rules for the design of the aforementioned multi-loop interaction system: a system where the parts can exchange information in an iterative way without the need for flawless communication.

This could be implemented with a system where the set of sensors regulating the response to the human is open-ended, and where the system itself is able to determine what data are relevant for the response.

This would create unlimited and unpredictable responses from the machine, which would intrigue the users to interact with it in a more direct way and to shape it by doing so. This integrates the local community directly into the development of their surroundings (Haque, 2006).

SUMMARY

The urban environment as a "play space" can offer ample opportunities for nurturing adults' innate playfulness. Playful urban design answers our need to explore, discover, experiment, and test our mental and physical boundaries. The ludic intervention is intended to spark creativity and spontaneous user behaviors by focusing on the participant's bodily experience rather than a materialistic aim. It might be just for recreation, or it can require users to actively participate in order to create or alter anything in their environment.

Interaction happens when a circular information transaction occurs between two parts, be it human-human, human-machine, or machine-machine. There are two types of interaction: one-loop and multi-loop interactions; the second one being the most stimulating because of its continuous and highly iterative character.

technology

This chapter will explore how the relationship between humans and machines has evolved, as well as how digitalization has affected us and our cities. What are the benefits of using data in urban planning and what are the drawbacks?

HISTORY

In late 1800, a group of people were working on making self-operating mechanisms that moved and acted like animals and humans. This was called automata and was the beginning of the idea that humans could build advanced mechanical instruments that would one day be able to work just as well as humans (Automata: Mechanical Wonders of the Nineteenth Century | SFO Museum, 2022).

The birth of the combustion engine in the 1870s transformed the human world and allowed humans to make machines do the hard work and do many times heavier work than before. This was the start of the first machine age (Brynjolfsson & McAfee, 2014).

This had a significant impact on the cities as well. With the invention of the elevator, it was possible to build much taller buildings. And, with the rise of the automobile, bigger roads were required. Furthermore, with people being able to travel longer distances in cars and the cities being more densely built-up, an entirely new urban typology has become conceivable.

When the world wide web was invented in 1989, a new era began, where machines were not only able to automate physical work, but now also mental work. Eventually, with the invention of smartphones, the true significance of the second machine age was encapsulated: a variety of technologies were connected and made available everywhere (Hespanhol et al., 2017).

CYBERNETICS

As with the smartphone, our cities are becoming an interconnected digitized network that collects a variety of data from different inputs and processes it into meaningful information. This can automate tasks, connect people and predict trends to make cities more efficient.

Smart cities have the potential to connect utilities, buildings, and humans in cities in a way that opens the doors for another redesign of our cities, as the first machine age did in the 20th century. Parking and transportation can be managed on a grand scale to avoid unnecessary traffic, thus giving the opportunity to make cities more sustainable and environmentally friendly on a human scale again. Also, people can connect to each other in new and creative ways without having to move through traffic.

However, the concept of smart cities has significant privacy issues. The government and large corporations may abuse data collected on residents

moving throughout the city. It is therefore necessary to find a way to make our cities more sustainable and livable without jeopardizing our societies' core ideals: "It seems only to be logical that we will need both, new technologies as well as socio-cultural developments, in order to take advantage of smart technologies while at the same time taming their impact on daily life and privacy" (Hespanhol et al., 2017).
Smart technology is not an aim in itself, but rather a means for creating a future that is both for humans and nature. The rapid progression of human society is accompanied by several serious consequences for both humans and nature, all of which are ironically produced by technological advancements. Worse yet, as indicated by different short-sighted practices, smart technologies have been exploited and abused as tools to worsen social disparities and environmental degradation (Zhang & He, 2020).

URBAN OPERATING SYSTEM

In 'Media Architecture Compendium', M. Hank Haeusler introduces the idea of an urban operation system. An operating system is a program that controls how a computer works and allows users to use its hardware resources. "Consequently, an urban operating system is needed for architecture in the second machine age to connect all devices in the city" (Hespanhol et al., 2017). But, rather than a central operating system connecting all the technological gadgets of the city, perhaps an operating system that, through technology, serves the inhabitants and users of the city is needed. Actually, the major focus should be on developing an efficient system to connect citizens to city services and institutions, allowing local communities to thrive, rather than on connecting technology for the sake of technology.

INTRO TO AI

A 2016 Stanford University study investigates the impact of artificial intelligence (AI) on city life. It is expected that by 2030, AI will have a profound impact on urban planning. The assumption is that AI can help manage our cities (Hespanhol et al., 2017).
AI can help shape sensor networks, information processing, and communication technologies. In the sensing and device layer, an AI can take advantage of recently developed edge computing architectures and machine-learning approaches, such as active learning, transfer learning, and federated learning (Seng, Ang and Ngharamike, 2022).

AGILE WORKFLOW

Agile project management is a valuable tool for software development, but it can be applied to nearly any project. The technique is based on twelve principles, which can be summarized as follows:

- Individuals and interactions over processes and tools
- Working software over comprehensive documentation
- Customer collaboration over contract negotiation
- Responding to change over following a plan
  (Manifesto for Agile Software Development, 2022)

The Agile methodology advocates the use of collaboration with a team and clients. It also encourages frequent and early prototyping, as well as learning and relearning throughout the process. The more complex the project, the more important agile management becomes.

In "The Agile Pocket Guide" by Peter Saddington, the significance of team and customer communication is emphasized. It is essential to clearly define what the end product should accomplish. This may be achieved with a set of design criteria. This should be developed in close collaboration with the client and interested parties. Even after the initial design requirements have been agreed upon, it is essential to maintain close contact with interested parties and to provide regular feedback and updates.

It is advised to create a detailed project plan that breaks all subtasks into teams and to create a timetable. Here, it is essential to identify task dependencies, so it is clear which tasks must be completed before others can begin. A Gantt chart is a handy tool in this situation, in order to prevent projects or teams from coming to a halt. A Daily Stand-Up is a key part of the Agile concept. This can assist the team to have better shared accountability and it helps members to be in tune with the challenges of the project at all times.

Iterative development is a significant component of the agile workflow. This approach incorporates a cyclical process of ideation, prototyping, testing, and evaluating a product. The cycle should then be restarted once each round is completed until the desired conditions are reached.

It allows for continually learning, adapting, and collecting indications about how the design should look and operate through feedback and trial-and-error. It will not be the most direct path to the finish line, but it will make sure the project is not heading in the wrong direction. Design iteration gives the design process more time, insights, and long-term stability (An Introduction to the Design Iteration Process, 2022).

DATA FUSION

In order to get a more practical method of working with data, it might be useful to look into data science and data fusion. Data fusion is the science of combining data logically from a number of different sources or sensors to provide a robust and complete description of an environment, process, or object of interest (Raol, 2015). In data fusion, there are some common approaches to how to transform collected data into a meaningful output. This process can be divided into four steps: (1) Acquire and store, (2) process and analyze, (3) identify relationships and (4) interactive and visual representations. This can further be fractalized into the categories described in figure 2:

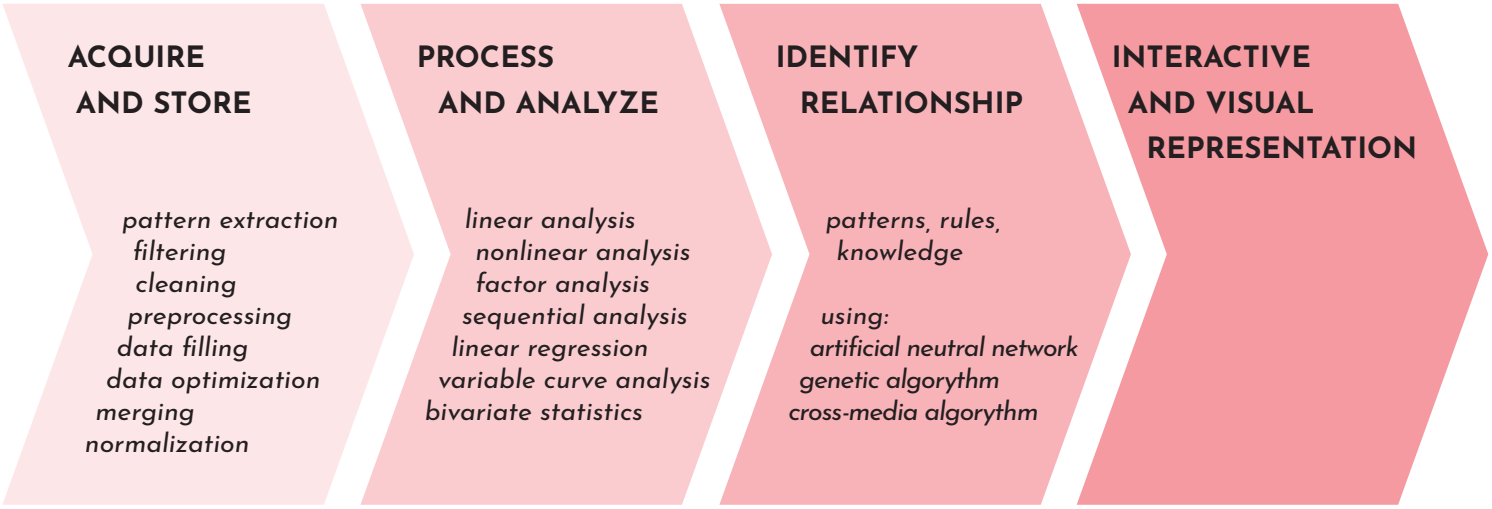


Fig. 2 – Data fusion process

SUMMARY

Today, data is an integrated part of the world we live in. However, it is now driven mostly by data provided by our online presence. With the growth of the Internet of Things and smart cities, this might change. This results in an increase in the number of data points created by sensors that detect pollution, free parking spaces, patterns and preferences of customers, among many other factors. If this data is gathered, preserved, and used properly, it may result in a wealth of knowledge for both practical and aesthetic urban development.

In any case, it is essential to follow a structured project plan while developing complex technological systems. The agile workflow offers a collection of tools that ensure the project remains on track and is finished to the customer's and users' satisfaction. Additionally, an iterative design approach will ensure that the product's full potential is realized.

chapter 3

design framework

The design framework is a visual way of structuring the elements needed to make a good design that includes space, human society, and data to make a light installation. The aim of the design framework is to give designers a general and linear regression model that they can utilize to make sure that they include all the important steps.
A design framework is a visual method of organizing the components required to create a successful design. The goal of the design framework is to give designers a broad, linear model that they can use to make sure that all of the important processes are included.

This chapter will go through each of the actors: space, humans, and data, and it breaks them down into smaller factors. It will then provide some tools to analyze each factor and explain how to use them. This is an end-to-end framework that will start by analyzing the site, then create a vision and design criteria, before finally providing some tools on how to design the product.

This framework assumes that a specific space has already been chosen. This is a general list of common factors in public spaces, but they should be adapted to each space specifically. This framework assumes the designer can approach the design from a clear canvas, even though in real life, a project often comes with a set of predetermined requirements. However, the design framework should be robust enough for most special cases since it can be used mostly as a guideline and checklist from which the recipient can pick or choose the individual elements as she/he pleases.

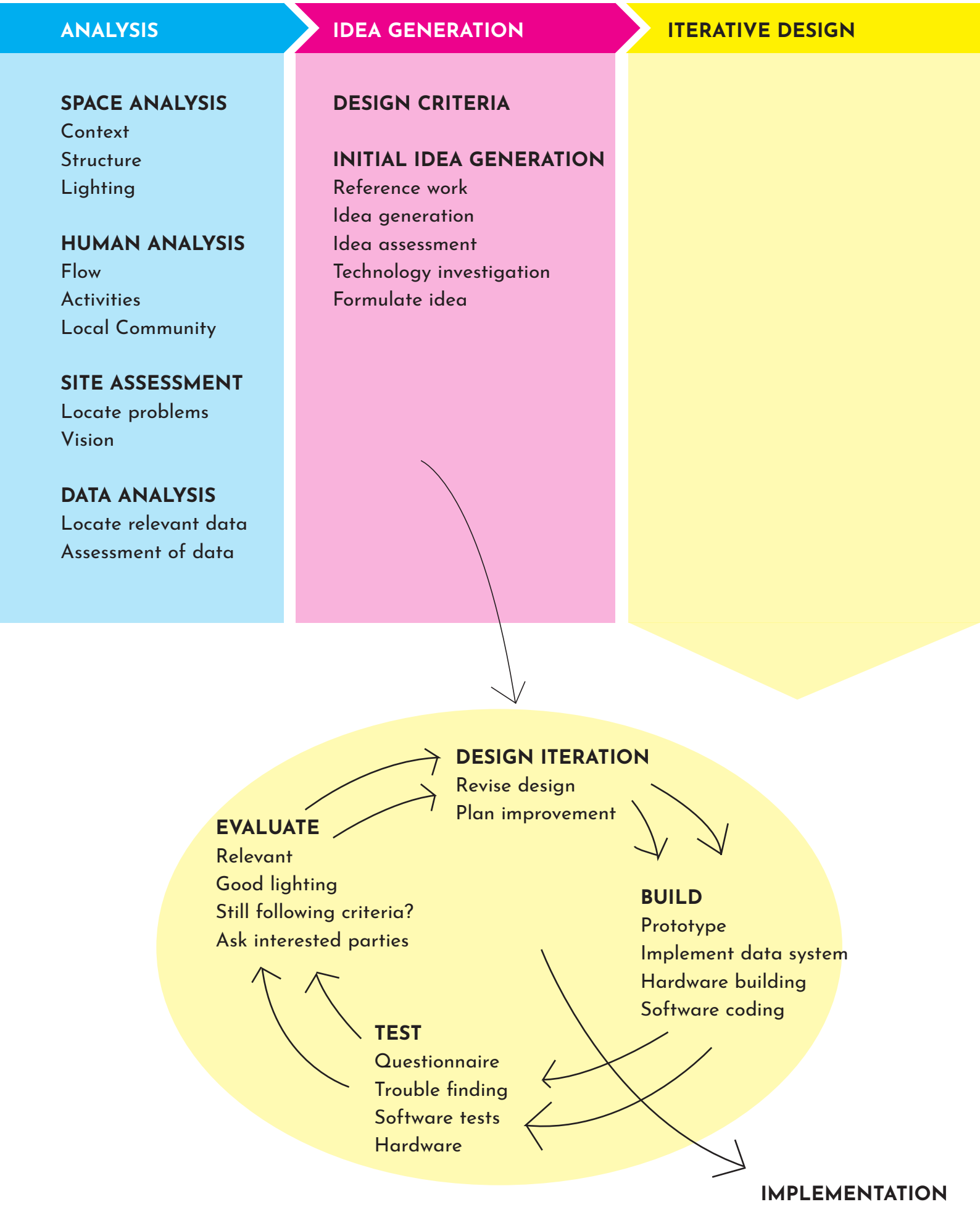


Fig. 3 – Design Framework

SPACE ANALYSIS
Context
- City and neighborhood
- Historical context

Structure
- Architectural elements
- Dimensions

Lighting
- Describe lighting
- Measure lighting
- Daylight
- Visibility and lighting
- Lighting masterplan

HUMAN ANALYSIS
Flow
- Amount and density of users
- Direction and speed

Activities
- Usage of the space
- Necessary, optional and social

Local community
- Target group
- Needs and desires

SITE ASSESSMENT
Locate problems
Vision

DATA ANALYSIS
Locate relevant data
Assessment of data
- Vision
- Complexity
- Privacy

Reference work
- Literature
- Lighting standards
- State of the art

Idea generation
- Brainstorming, sketches

Idea assessment
- Does it address the design criteria?
- Is it following the lighting requirements and ma
- Inclusivity
- Environment / Sustainability
- Placekeeping

Technology investigation
- Software
- Hardware
- Luminaires
- Interactivity

Formulate idea

- Design iteration
  - Revise design
  - Plan improvement
- Build
  - Prototype
  - Implement data system
    - input (sensors, AI, API)
    - output (light)
  - Hardware building
  - Software coding
- Test
  - Questionnaire
  - Trouble finding
  - Software tests
  - Hardware
- Evaluate
  - Relevant
  - Good lighting
  - Still following criteria?
  - Ask Customer or interested parties

ANALYSIS

Context

Knowledge of the city and the neighborhood can be obtained through a variety of techniques. That being through a web search, visiting the neighborhood, talking with the locals, and reading about local evaluation reports.

For what concerns the historical context, visiting local libraries is the first step to finding relevant literature and documentation (history books about the neighborhood, archival pictures, newspapers, etc.). If relevant, the next step would be to talk with the local authorities to acquire more specific documents.

Structure

Next, a structural analysis of the space is conducted by first looking at the greater surroundings and then zooming closer into the space. An outline of the district can be developed by using the 5 element approach by Lynch:

- Pathways
- Districts
- Edges
- Landmarks
- Nodes

To understand the structural form of the immediate space, look at the dimensions of the space and the buildings and elements surrounding it. It can be helpful to measure the dimensions of the space, the height of the building, and to map the different structural zones of the space.

Lighting

In order to map the lighting a mixture of qualitative observations and quantitative measurements can be used. A list of the most common factors of light is provided, which can be used as a checklist that can help define the features of the light in the space.

Describe light:

- Luminance
- Correlated color temperature
- Color
- Light sources

Measure light:

- Illuminance
- Reflectance

Daylight:

- Sunpath
- Shadows

Visibility and light:

- Contrast
- Glare
- Uniformity
-

Lighting Masterplan:

Check if there is a local master plan that dictates any specific standards to use in lighting or if there is a defined focus area for lighting in the place.

ANALYSIS

HUMAN ANALYSIS

Flow
- Amount and density of users
- Direction and speed

Activities
- Usage of the space
- Necessary, optional and social

Local community
- Target group
- Needs and desires

Flow

Jan Gehl's toolbox is a very detailed and complete toolbox that can be used for analyzing flow and activity of humans in a place.
To investigate the amount and density of the users, tools like counting and mapping are to be used, while for the direction and speed, tracing and tracking are more appropriate.
A more methodological explanation follows:

Counting

The count of the people in the space should be done for ten minutes every an hour in order to have a more clear overview of the whole day. Generally, the choice of the day does not influence the results. However when designing for places with a large thermal difference between months and weather scenarios, it could be relevant to repeat the analysis on days with different conditions.

Mapping

For a more relevant set of data, it is important to repeat the method several times, preferably at different times of the day and week, to be able to notice if the set of activities and focus points change throughout the day and week.

Tracing

This is done by drawing the people's movement from A to B in a space throughout a specific amount of time. For bigger or more complex places, it is possible to execute this digitally. This will visually show the most used paths and the "exceptions" to them.

Tracking

This method involves "following" an unaware person in order to gain a better understanding of how they use space and the smaller details of their flow. When analyzing the speed, it is recommended to conduct the research from a more distant point of view, by timing the people.

Activity

The usage of the space and the type of activities can be observed by looking for traces, photography, keeping a diary and testing walks (see Gehl's toolbox):

Looking for traces

The aim here is to examine the space with "detective eyes" (Gehl, 2013) and to look for elements of interest: for example a worn-out bench in the space, a track out of the sidewalks in the grass, etc.

Photography

The emphasis should be on the people and the situation rather than on the aesthetics, and the point of view is at eye-level, on top of that the lenses used to capture should recall the human vision. It is also an option to make a time-lapse, to be able to compare and confront different settings over time.

Keeping a diary

This can be done by keeping an updated written observation of the habits and the dynamics of a place. This can also be a more detailed analytic addition to the other quantitative methods.

Test walks

This is done by choosing specific routes (a very trafficked one or an odd one) and walking through it while paying attention to waiting times, barriers and obstacles.

Necessary, optional and social activities can be mapped using a cross-tool approach: evaluating the participatory observation done with the previously mentioned tools, together with a more focused analysis of a case study of a group of people. This can help quantify the different types of activities held in a space.

Local Community

Involving the local community, either directly or indirectly, can help you make a design that fits their needs and wants.

First of all, it is important to assess the target group, not only by considering the types of actors that frequent the space but especially by researching what institutions and facilities are nearby.

There are different ways of directly integrating the local community, for example, by making questionnaires and interviews to gather both quantitative and qualitative data on the preferences and needs of the users of the space.

ANALYSIS

SITE ASSESSMENT
Locate problems
Vision

Once a full understanding of the space and its users has been obtained, the strengths and disadvantages of the space can be evaluated. This will be used to determine where a design may improve the space. Make use of this knowledge to approach an area of interest. The space may contain more than one problem, but it is acceptable to focus on a limited number of problems. Create a vision for the design by asking yourself: "Imagine what it…?". Typically, vision is focused on what the design can achieve for the space with the local community in mind. Only later in the process can a specific notion be articulated as design criteria.

ANALYSIS

DATA ANALYSIS
Locate relevant data
Assessment of data
- Vision
- Complexity
- Privacy

Next, it is time to look into the data. With the knowledge of the space and the users at hand, along with a vision, the data that could help address the problem can be located. Keep an open mind and do not focus too much on the vision to begin with. We want to be creative about the use of data and we want to include data as a central element in the design.
Then do a quick analysis to find out if the proposed method is feasible in regards to the vision, level of complexity, and if it violates any laws of privacy. Always aim for the simplest solution and try to cut complexity as much as possible throughout the process.

Working with data

Define the relevant data that can be collected in the space and can be used for the design; which information can be acquired through internet services (APIs) and which information may be collected in-situ from sensors.

It is necessary to consider privacy and inclusivity. Is the data person-specific and can it be used to break privacy laws? Can it be used to find a specific person or a mass trend that can be used for targeted advertising, politics, or ethics suppression?

IDEA GENERATION

DESIGN CRITERIA

Write down a set of design criteria based on your vision. The design criteria are explicit goals that are formulated in a precise and simple language. Design criteria can be divided into primary and secondary criteria. The primary criteria are those that constitute a successful project. Secondary criteria are highly desirable but not absolutely essential. Design criteria are often best presented as listed in bullet points with a short title followed by an elaboration text (Design and Decision Criteria, 2022).

INITIAL IDEA GENERATION

Initial idea generation is the process where all the information gathered up until this point is transformed into a specific design idea. The aim is to formulate a precise description of a design concept. In order to come up with the best possible concept, it is first important to make sure that all the relevant information for the space is acquired.

Reference work
- Literature
- Lighting standards
- State of the art

Idea generation
- Brainstorming, sketches

Idea assessment
- Does it address the design criteria?
- Is it following the lighting requirements and masterplan?
- Inclusivity
- Environment / Sustainability
- Placekeeping

Technology investigation
- Software
- Hardware
- Luminaires
- Interactivity

Formulate idea

Reference work

Explore the available literature: this will offer an updated perspective on the research in the specific areas of interest and will help build the foundation for a design that meets the vision. When the project requires it, it is also relevant to look into lighting standards in order to make sure the design follows the lighting rules and recommendations.

The state of the art can be used to get ideas for both aesthetic and technological approaches to design. It can also help designers figure out how to solve specific problems.

Idea generation

The idea generation process comes with a wide variety of methods. The best method can vary a lot according to a person's modus operandi and preferences. For this reason, it is ideal to try different methods to find the ones that work best for the designer for specific cases.

The paper "Idea Generation Techniques among Creative Professionals" (2009) presents several techniques that can help to unravel the process and to find suited solutions to the site assessment, as follows:

- Brainstorm
- Storyboards
- Sketching and documenting
- Active Search
- Encompass
- Role Playing
- Concrete Stimuli

Idea assessment

Assess each of the ideas to make sure they meet the criteria. Test it against each of the design criteria to make sure it can solve the problems.

Check also if it follows the masterplan and that it does not conflict with any lighting requirements or standards for that region.

Consider edges, accessibility, and perceived safety, and analyze the target people for the design. Ensure that the design concept is accessible to the target audience and that it does not exclude any group of people for being exclusionary or too complex to interact with—unless this is a defined goal for the project. Consider whether it improves the feeling of safety, for example, by encouraging social participation.

Consider how the concept would affect the local environment—will it cause excessive unwanted noise or light pollution? It is also a good idea to look over the Sustainable Development Goals and figure out which ones can be implemented in your project.

Think about the future of the installation depending on the scope of the project. What is the durability of the materials and what are the risks of vandalism? What is the lifespan of the luminaires? What happens if they stop working? Also, consider how to keep the installation relevant to the community. Can the content be adapted? Also contemplate the non-physical elements of the project: partnerships, governance, funding, policy, and evaluation.

Technology Investigation

Here, it is advised to focus on the technical aspects of the project.

Software

If the project requires programming, choose the programming language and consider how to access the data and control the luminaires in that environment. Consider utilizing some artificial intelligence tools for some or all of the software.

Determine precisely which APIs you want to employ and how to access the data. If relevant, identify the appropriate sensors for the projects. Decide on messaging protocols and be thoughtful about encryption and security. It is preferable to keep data as local as possible.

Hardware

Decide on the hardware with which you want to operate. Is it a microcontroller, a computer, or perhaps something analog?

Luminaires

Find the appropriate luminaires for the project. Look into the data sheet and consider CRI, CCT, power consumption, efficiency, and light distribution. Think about how to control and power them.

Interactivity

Consider how the design interplays with machines or humans and, if it is relevant, think about whether the design should follow an ubiquitous or interactive model.

Formulate idea

With all things considered, it is now time to formulate an idea. Make sure to make it descriptive and to include all the main goals and tools that are important for the installation. It is also a good idea to make sketches and renderings, which will help convince interested parties.

Try to break the idea into smaller components. This will often make the project more manageable and will also help to identify design flaws sooner rather than later. An Agile workflow can be utilized for this.

ITERATIVE DESIGN

Now it is time to start the iterative design process. Go through the following steps repeatedly until the product meets the design criteria and the designers and partners are happy with the product.

Design iteration

Revise design
Plan improvement

Build

Prototype
Implement data system
    input (sensors, AI, API)
    output (light)
Hardware building
Software coding

Test

Questionnaire
Trouble finding
Software tests
Hardware

Evaluate

Relevant
Good lighting
Still following criteria?
Ask Customer or interested parties

chapter 4

case studies

The following chapter presents a series of concrete examples of how to apply the design framework in a space. The examples are diverse types of public spaces: a square, a park, and a tunnel. The spaces are found throughout Copenhagen, Denmark.

SANKT HANS SQUARE

SPACE

CONTEXT

Sankt Hans Torv is a square in Nørrebro neighborhood in the heart of Copenhagen, 300m away from one of Copenhagen's main shopping streets, Nørrebrogade and 500m from the main hospital, Rigshospitalet.
In the past, this area of Copenhagen was called "Blegdam Kommune" and Sankt Hanks Torv was a meeting point for milking cows ("København, Sankt Hans Torv", 2022). The square was historically and continues to be a junction point for several major streets.

It was renewed in 1993 by City Architect Otto Käszner as part of an urbanistic renovation plan, after which several bars started to pop up in the adjacent buildings. In the same year, the sculpture that is placed in the square was made by the Danish sculptor Jørgen Haugen Sørensen. The sculpture is called "Huset, der regner" which means "the house that rains" and it is made out of granite, the same material as the pavement of the square. Several granite blocks are leaning into each other, creating a solid yet seemingly light structure. Seven water jets wet the structure and fall back into the square, giving the monument a vibrant, ever-moving appearance ("Huset, der Regner - Monumenter i København", 2022).

STRUCTURE

The square is surrounded on three sides by busy roads and on the north side by a building block. It is, according to Lynch's space analysis, a node defined by paths all around it. Moreover, it works as a sort of continuation of Elmegade, a cozy small shopping street that defines the square as the crows fly

on its northern edge.
From the pedestrians' perspective, the automobile paths are viewed as edges since they enclose the square and limit the pathways that walking users can utilize.

The only side of the square that is not facing buildings is the eastern part, where Nørrebro's oldest church is located, which has a green park area in front of it. The buildings on the other three sides are classic Copenhagen's 4-6-storey apartment buildings, and some of those date back to 1851.

The monumental fountain sculpture is placed almost in the middle of the square, and it is visible from every side, creating different suggestive points of view as one moves within the square. The sculpture is a clear landmark for the whole neighborhood. When you're walking to the square from most directions, it's in the middle of your view and helps you find your way.

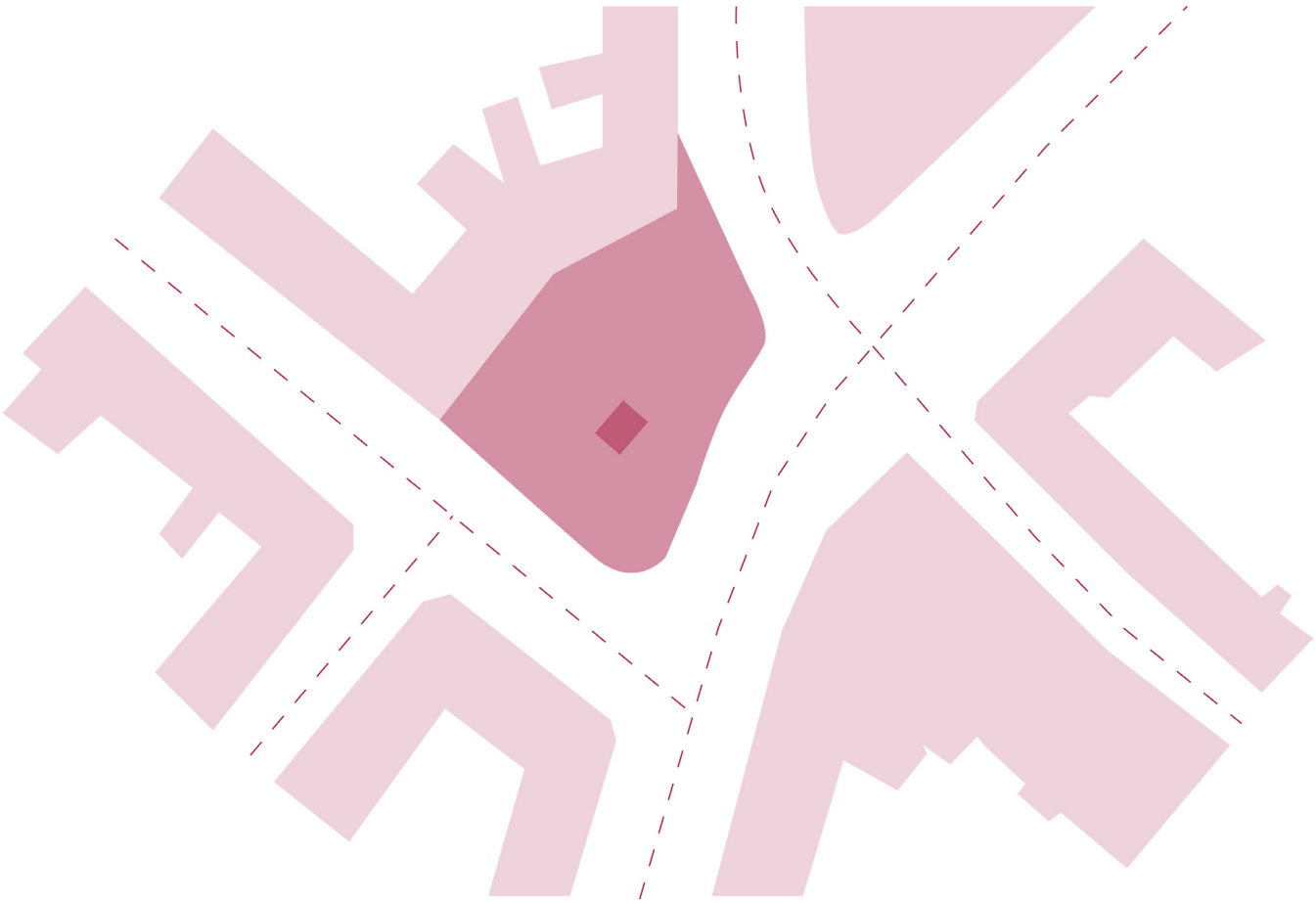


Fig. 4 - Sankt Hans square's abstract map

LIGHTING

The square is a rather open space because the buildings are only directly adjacent on the north side. During the summer, most of the square is exposed to sunlight for most hours of the day; in the winter, however, it benefits from direct sunlight only for a few hours and only in some parts of the square.

In the figures below (5, 6), the sun trajectory in winter and summer solstice are compared: the first figure represents the sun's trajectory on the 21st of December at 12am, and the second is at exactly the same time, but on the 21st of June.

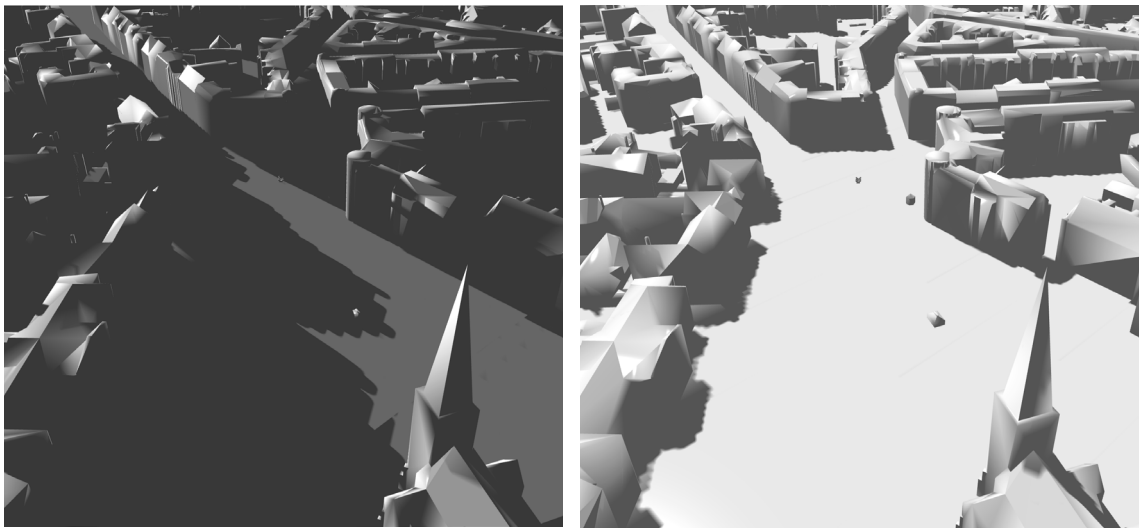


Fig. 5, 6 – Winter solstice midday vs summer solstice middaymap

The figures 7 and 8 represent the sun's trajectory on the same day, the 21st of June, in the morning and in the afternoon. The sun is present, especially in the morning, and as it approaches the sunset time, it begins to cast shadows from the building placed on the northwestern side of the square.
In winter, there are only a few hours of direct sunlight, which makes the square dark and uninviting in the daytime.

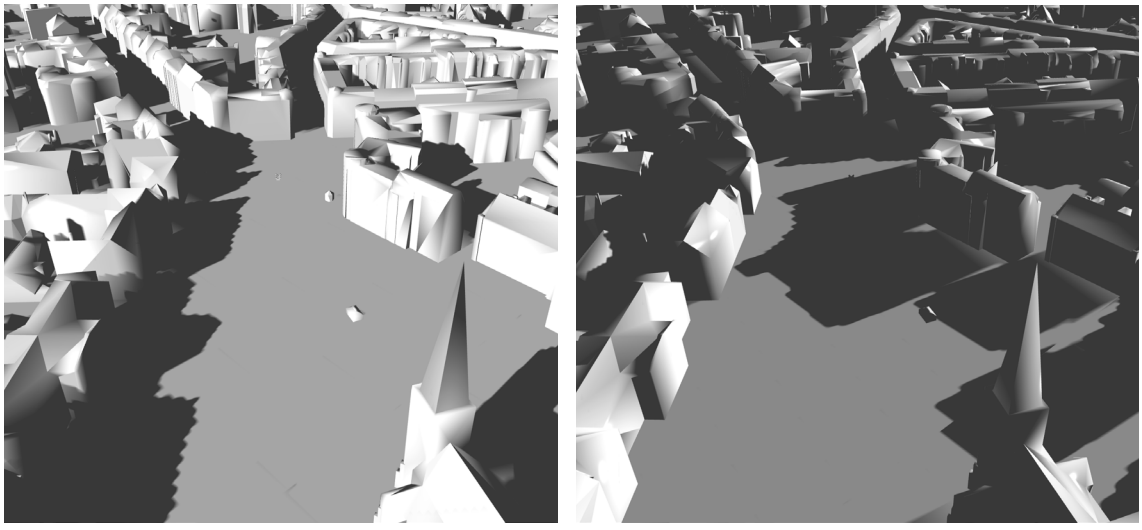


Fig. 7, 8 – Summer solstice morning (6.30am) vs evening (5.30pm)

Artificial light and masterplan

The only artificial light illuminating the square comes from the road lights hanging above the roads around the square and also a light pole on the square holding 12 spot lights. Also, some warm lights spill out from the cafes on the square. This leaves the square with a very dynamic lighting scenario. While the part around the light pole is well lit, there are a lot of long shadows further back on the square, resulting in some rather uninviting spots.

The lighting masterplan for Copenhagen Kommune cites Sankt Hans Torv as a lively and safe part of the city, where the lights from the bars around it give a cozy atmosphere to the square (Københavns Kommune & Citelum, 2014).

Fig. 9, 10, 11
The luminaries of the square at night. There are some dark spots around the edges of the space.

HUMANS

FLUXUS

Most people use the square mainly to cross from one side to the other, using it as a shortcut between the different streets. Most people walk through the square alone or in small groups of 2-3 people, rarely in bigger groups. Some users walk from every direction towards the bars and the few benches present in the square.
The car and bike flux around the square is very dynamic and a critical element of the space. This creates a hectic atmosphere in the space, interspersing periods of noise with moments of stillness, following the pace of the traffic lights.

A tracing observation has been conducted to get a more precise view on how many people use the square. This was done on the 25th of May, from 15 to 15.10. The temperature was around 17°C, there was no rain, and the wind was medium to strong.

Fig. 12 - Tracing of cars (purple) and bikes (blue)
Fig. 13 - Pedestrians' tracing

Most of the traffic comes from cars, especially in the streets Fælledvej and Blegdamsvej. Cyclists are distributed in the space, coming and going in every direction, especially from and towards Nørrebrogade.

Pedestrians' movements in the space are dynamic and the pace differs greatly from user to user; most of them walk through the square to get somewhere else.

ACTIVITIES

This mapping method was conducted on a sunny and warm Sunday, the 5th of June 2022, at 12am. This allowed for a greater understanding of the activities held in the space, because of the large number of people in the square. However, a further investigation of the activities in the space in winter and in bad weather conditions has to be conducted, to differentiate between the different data sets.

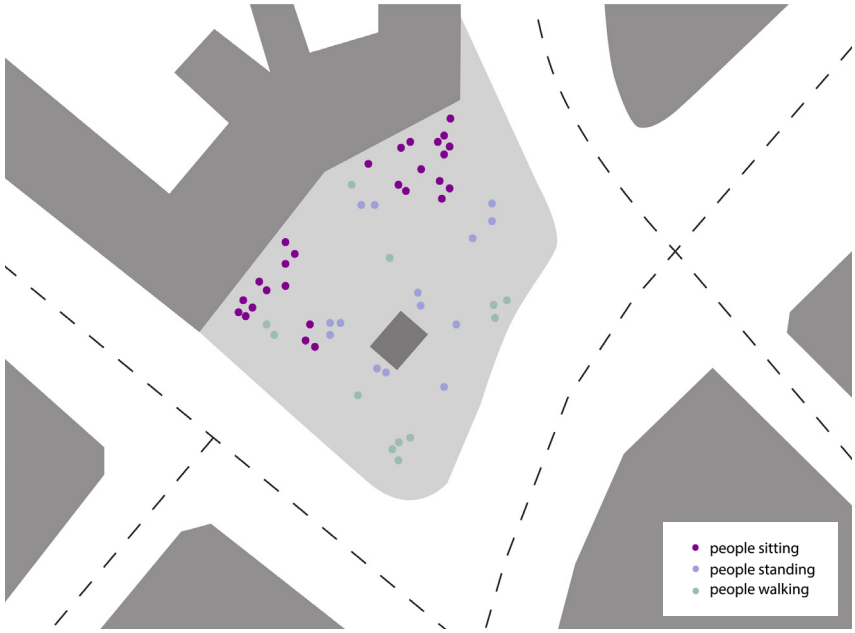


Fig. 14 - Mapping of people's activities

From the analysis, it is possible to see that the people sitting are mainly using the bar's outdoor facilities and the few benches present in the space.

Some of the passers-by, especially people with dogs and toddlers, tend to spend some time in the square, especially in the area around the monument and under the trees. The people walking are mainly following the paths shown in "Fluxes".

Mainly, the users' activities are optional and social, except for the people purely walking or biking through the space, which is a rather small percentage of the total number of users. However, this could change in bad weather conditions and on colder days, so further investigation needs to be undertaken.

LOCAL COMMUNITY

It is a central element in the neighborhood of Nørrebro, and is used by different people, both from the neighborhood and passers-by. The shopping streets close to the square and the many restaurants, bars, and cafes attract visitors from all over Copenhagen.

For the sake of the project, several people have been interviewed informally to get a deeper understanding of how they relate to it and what their needs and desires are.

The majority of the interviewed, with the exception of one person, stated that they rarely feel unsafe in the square, but they simply do not use it because they find it boring: “I rarely come to the square at night. There are no sitting possibilities other than in the bars and cafes and it does not have a cozy atmosphere” (female, 31 years old). Others interviewed stated that the square does not provide adequate lighting at night, and so they would rather go to other, more interesting places with fewer cars. Everybody agreed that the car traffic takes over the whole space with the noise and the carlights.

SITE ASSESSMENT

The square is very spacious and creates a breathing space in the crowded neighborhood. However, it is surrounded by highly trafficked streets, generating a very hectic and dynamic atmosphere, with significant car noise. Moreover, it is often very windy because of how it is structured and the streets around it that create air flows.
It also lacks a centrality, a gathering place for people to congregate: around the central fountain there is no facility for sitting and it feels rather dispersive and not very intimate.

The vision with the space is to create a comfortable and attractive place where people would feel invited to meet and to hangout while removing the distractions from the traffic.

DATA

RELEVANT DATA

The major data aspects worth investigating for the design include noise detection to address the space’s frantic nature; wind direction to tackle the issue; pollution level; and weather conditions to produce a site-specific design. It is also relevant to examine people’s movements in the space, and so PIR sensor and traffic API data should be investigated..

DESIGN CRITERIA

The set of rules for the design proposal of this space, it is as follows:

- limit the visual and auditory noise factor
- create intimacy in an open space
- enhance engagement

IDEA GENERATION

REFERENCE WORKS

The installation alters the passers-by's images by recreating a pixelated digital version of their silhouettes and mirroring their movements on a large-pixel LED screen. This creates great engagement and inspires playfulness in the people that walk by, making them become active or passive participants in the installation.

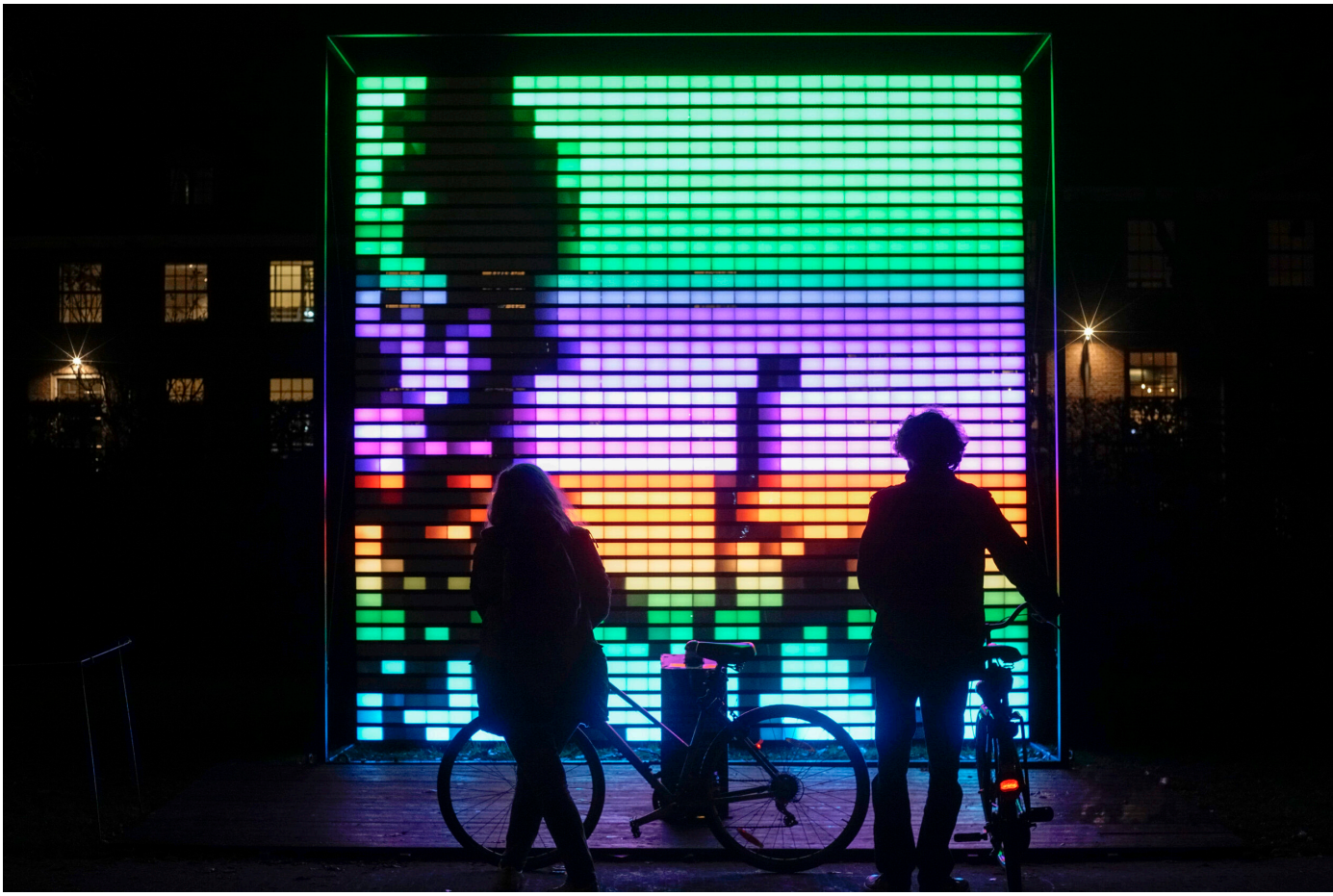


Fig. 15 - Felipe Prado - PICTO SENDER MACHINE

"Mirror Mirror" is a public temporary installation exhibited in 2019 in Alexandria, Virginia. It is a semi-circular shape that people can interact with by walking around it or entering it through the opening. It is made of fresnel lenses in honor of the lenses historically used in the city's lighthouse. The outer surfaces are all coated with a one-way mirror foil, while the inner surfaces are coated with a semi-transparent colored foil. The lights in the installation are sound-responsive and invite the participants to interact with them: when the lights turn on, the apparent mirrors of the outer layer become bright, dynamic fixtures. The installation creates a place within a space. It alternately takes in and reflects the surroundings, and it changes them with light and color.

Fig. 16 – SOFTlab – Mirror Mirror

INITIAL IDEA

The idea generation process in this case started with a brainstorm of ideas on how to address the hecticity issue and lack of centrality. These are the main points boiled down from the brainstorm:

- Create a shield from the traffic, the wind and the noise
- Having an interactive installation people would be invited to engage with
- Generate sitting/standing comfortable possibilities
- Create a cozy atmosphere
- Installation reacting to the traffic and pedestrians' movement
- Design also with a focus on daylight

IDEA ASSESSMENT

The design criteria, the lighting requirements, and the masterplan are used to evaluate the initial concepts, to reiterate them. The concept gets shaped as the elements come together to better tackle the issues of the space: creating a physical semi-transparent barrier that can create a place for people to feel secure and intrigued. At the bottom of the barrier are strips of LED lights that light up the whole structure in a soft, natural way.

Because the square is highly exposed to daylight in the warmer months, the aesthetics and relevance of the installation should follow the sunlight.

TECH INVESTIGATION

An IR array sensor will be used to detect cars, cyclists, and pedestrians' movement. Multiple sensors would be implemented into the different pieces in order to cover the whole area. The sensors' values would then be interpreted by the LED strips at the bottom of the engraved plexiglass structure, where the sum of the values on the X axis would be translated into intensity: the installation would be more transparent when there is less movement or it is further away, while it would become more illuminated, hence less transparent, when the detected movement is intensified.

Also, the LED controller would collect data from weather APIs and would influence the LEDs color palette based on the time of day and the weather condition, so as to create the perfect lighting setting according to the atmospheric light. During the daytime, the lights will be very dim or turned completely off to allow for the daylight to create the play of light.

The prototype will consist of several units that each take care of a unique part of the system:

- Central unit: A master controller that communicates with sensor units and online services.
- Sensor units: Several controllers that each contain a set of sensors.
- LED-driver: power and wiring for LEDs.
- LED strips

The central unit is a Raspberry Pi Zero W with a WiFI connection. This receives data from the sensor units over WiFi using the MQTT messaging protocol.

The sensor units are based on an ESP32-C3 microcontroller. As mentioned, this unit will communicate over WiFi with the central unit. The sensor units will have low power consumption and will be powered by a battery, making them completely wireless, which makes them easy to move around. The following sensors will be used for the prototype:

- An ultrasonic distance sensor
- An ambient light sensor
- A PIR sensor

Moreover for getting weather data OpenWeatherMap API (https://openweathermap.org/api) I was used. To get the time of day the API Network Time Protocol (http://www.ntp.org/).
The light output consists of 6 meters of WS2812 LED strips. This is individual addressable LED strips, making it possible to do animated light output.

Before working with the materials of the installation, the hardware, software, and luminaires wanted to be tested in a prototype. The purpose of this prototype is to create a test environment for collecting various data from sensors and APIs and to create a setup for testing light output. The work with this prototype will follow the iterative design process.

IDEA FORMULATION

This square is located in the heart of Copenhagen's most vibrant neighborhood, but it does not represent the cohesive local community of Nørrebro. Sankt Hans Square, with its heavy traffic and chilly gusts of wind, is in need of a social hub. This, however, can be rectified with a simple fix. The concept is to place a number of "Light Hedges" along the square's perimeter to protect it from traffic and wind. The hedges are made of clear acrylic, keeping the space open and welcoming. The hedges will be able to regulate their transparency with colorful light. This will be used to block the view of the roads when traffic is heavy. Furthermore, it will work as an interactive element, producing an animated play of light when bicycles pass by or people approach, inviting them to sit on the bases of the hedges.

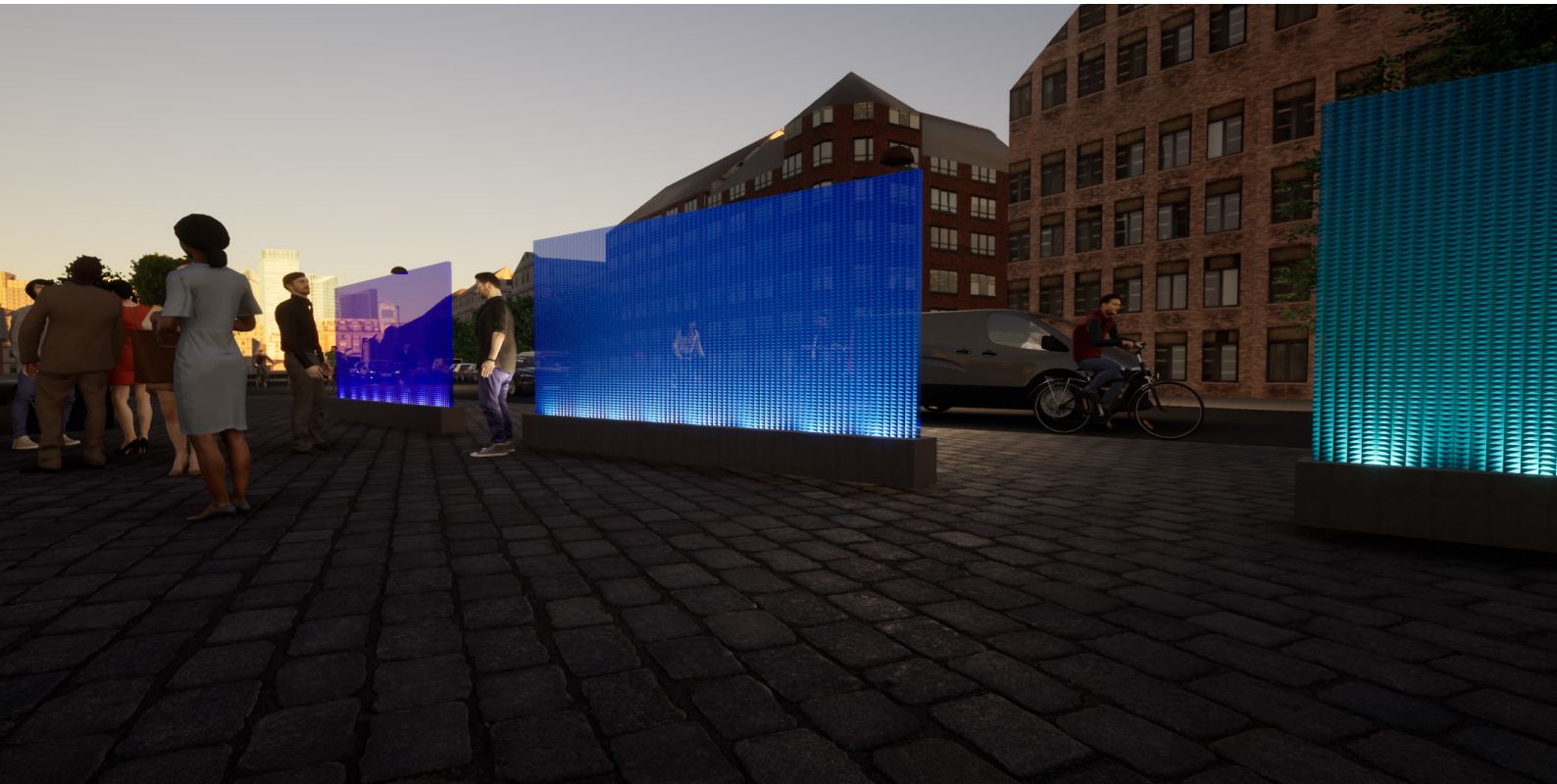


Fig. 17, 18
Cutting out morning rush hour while opening up to the more silent road

Cozy meeting area in the evenings - with animated light and in shelter from the wind (fig. 19)

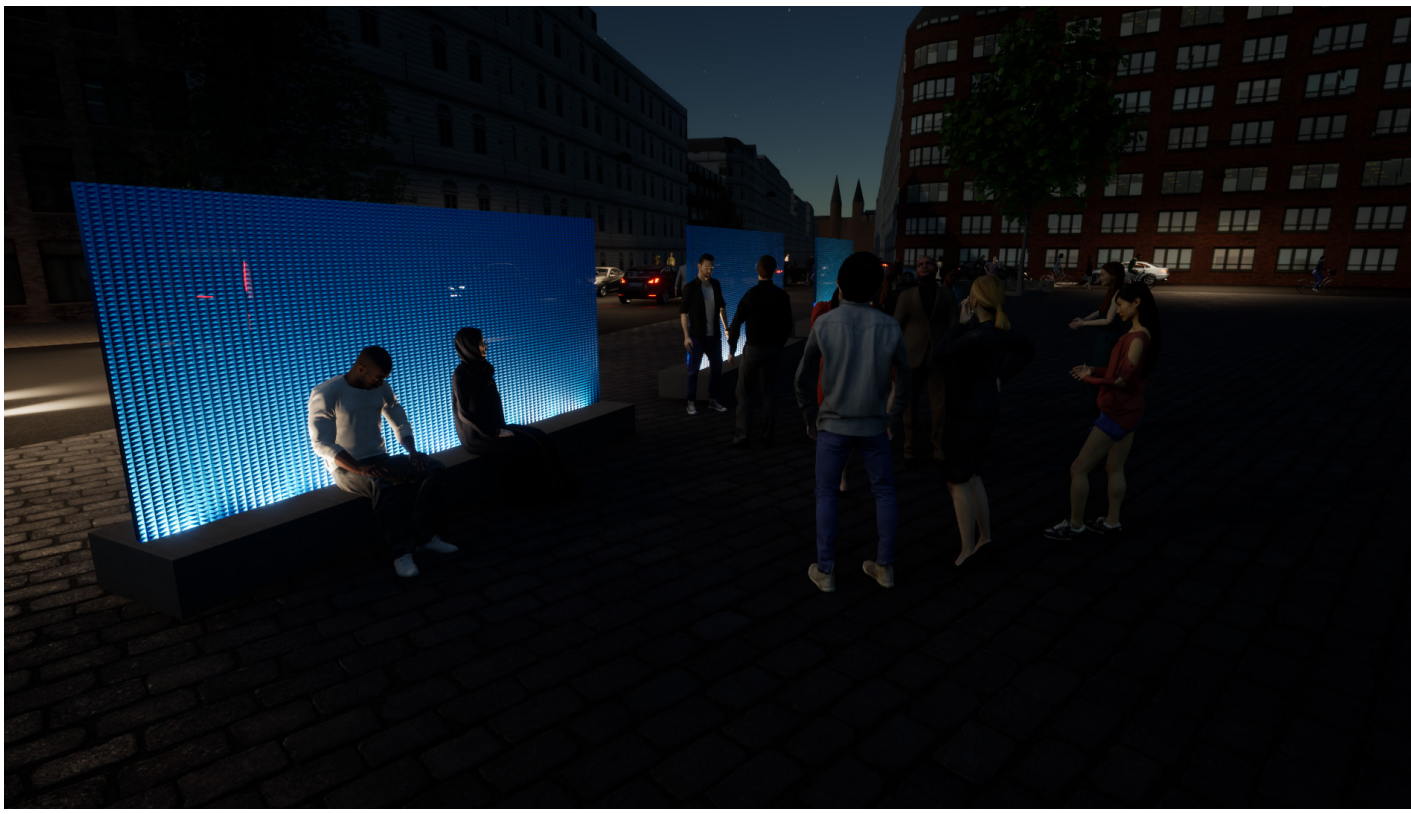


Fig. 19 - Render by night

The monumental size of the design makes the hedges feel more incorporated into the space.

Fig. 20 - Edges in the afternoon

During the afternoon, a weak play of color based on the weather is shown.

Fig. 21 - Closer pic of edges in the afternoon

In the evenings, the hedges will be more illuminated with warmer colors to make the square feel more cozy and inviting for stays.

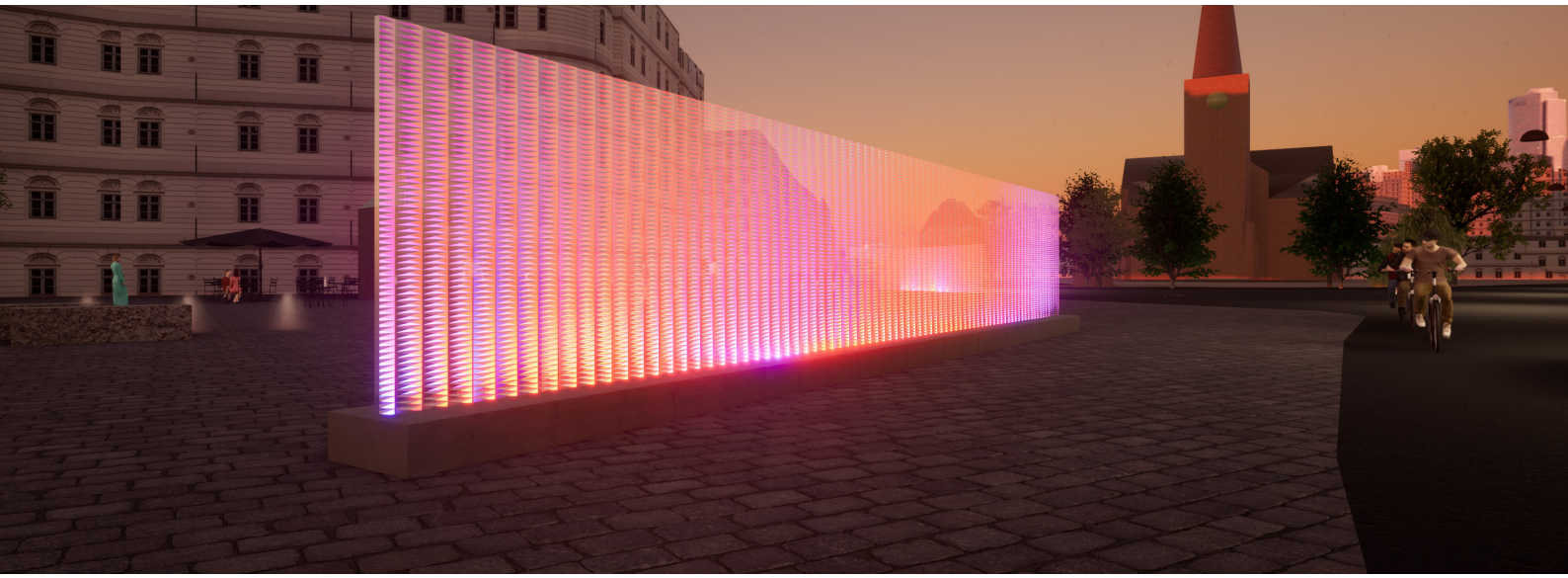


Fig. 22, 23, 24 - Edges at sunset

PROTOTYPE

DESIGN ITERATION

Now the design process can begin. First, some of the core technical features of the project will be tested on a prototype. A sensor network will be set up that can collect weather data, time of day, and detect movement.
The light output will be controlled by a chaotic wave equation (figure 25).

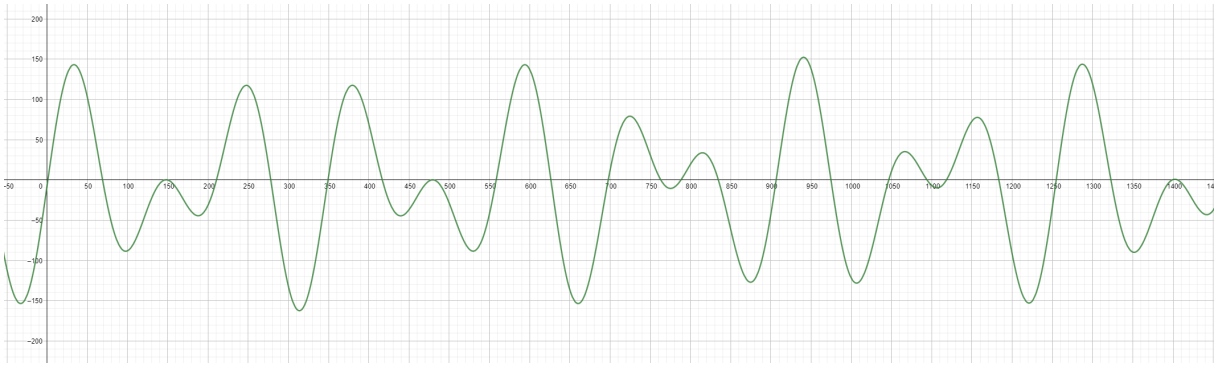


Fig. 25
Graph showing the non-repeditative wave used to map the individual LEDs

The data inputs will be mapped to the light in the following way:

- Humidity will control the green color of the light and is mapped to the values of the value equation below 0. This way an altering part of the light strip will be more green the higher the humidity.
- Temperature controls red color and is mapped to the positive wave numbers. The intensity of the red will be higher the higher the temperature.
- Time of day controls the blue value. It will follow the time of day in the way that it will be most intense at noon and be off at nighttime.

Also, the ambient light sensor will be used to measure the surrounding light level, which will then control the light output of the installation. Furthermore, the PIR sensor, along with the ultrasonic sensor, will create the interactive element, increasing the pace of the animation when people are getting closer to the installation.

BUILD

First, the NeoPixel library from Adafruit is installed on the Raspberry Pi. This will enable us to control the addressable LEDs from the Raspberry Pi. We will now turn to the ESP32, where the Arduino bootloader is installed. This way, we can use the Arduino IDE to program the microcontroller. The PIR sensor, ultrasonic sensor, and ambient light sensor are implemented. Now we can add an MQTT environment to the Raspberry Pi and the ESP32. Finally, a connection is established to the weather and time API.

TEST

The prototype is tested through a series of experiments. Here the resulting light is shown in different scenarios. This test is conducted in a controlled environment where the different scenarios are simulated in order to assess all the various scenarios.

Fig. 26

Light scenario on a cold day (0°C) with high humidity at noon.

Fig. 27

The light output on a warm day with high humidity at noon.

Fig. 28

The light output on a warm day with high humidity late in the day.

EVALUATE

This first iteration of the design gives some good indications of the hardware, software, and interactive elements. The hardware used provides a simple but functional environment—the nodes are working as intended—picking up data continuously and relaying it to the central node successfully. However, there was a problem with using the Raspberry Pi directly to control the LEDs. The multi-purpose OS of the Raspberry Pi resulted in a slow and lackey animation of the LED strip. A dedicated real-time system is needed in this case. APIs and sensors were used to control the different light scenes as planned.

DRONNING LOUISES BRO UNDERPASS

SPACE

CONTEXT

Dronning Louises bridge in Copenhagen spans the lakes between the inner city and the district of Nørrebro. On the side of Nørrebro, the bridge is crossed by a bicycle and pedestrian underpass. The space of interest for this project is the bicycle and pedestrian underpass.
The peaceful lakes, the busy bridge, and the intense cityscape of Nørrebrogade are all present in the district surrounding the underpass. Dronning Louises bridge is the most busy biking path in Copenhagen (København Cyklernes by, 2019). Nørrebrogade is famous for its shops and bars, and there are numerous eateries hidden under the trees along the lakeside path.

STRUCTURE

The bridge was completed in 1887 and is made of granite. The characteristic 5 storey buildings with shops on the ground floor can be found around the bridge along Nørrebrogade. On each side of Nørrebrogade there are two small areas of grass just above the bridge.

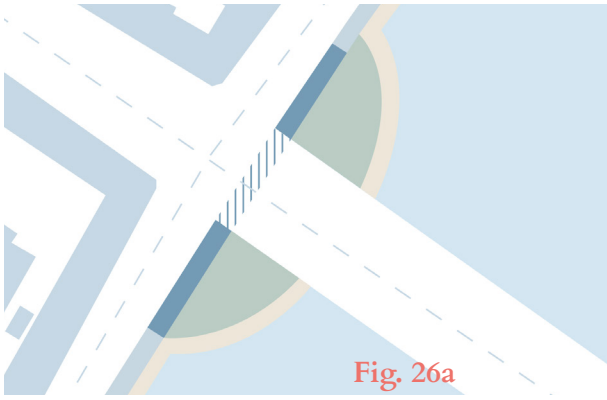


Fig. 26a

The underpass is made from concrete, and metal plates cover one side of the underpass on the inside. The opposite side is made up of quadratic bricks. The underpass is 30 meters long and 5 meters wide, with a two-way bicycle lane taking up half of it and a walking path taking up the remainder. For two bikes traveling in opposite directions, this is a rather tight space.

Daylight And Existing Lighting

The area surrounding the underpass is partly shaded by the tall buildings and huge trees, but it is also open to the lake to the east. The inside of the underpass is illuminated by 12 ceiling luminaires that operate 24 hours a day. There are a few luminaires on each side of the outside of the tunnel as well. However, there is a noticeable variation in light intensity outside and inside the tunnel, particularly during the day. As a result, visibility into the underpass may be restricted.

The bridge is highlighted in Copenhagen's lighting master plan as a spot where historic luminaires are installed to create a romantic and harmonic atmosphere. It also mentions that tunnels in general should have a focus on security. Furthermore, it says that "a network of luminous connections gives life to pedestrian tunnels, bridges, and paths in the city center. Warm colors and luminous installations invite one to stop and sense the city spaces" (Belysningsmasterplan for København, 2014).

Measurements

The amount of daylight was measured around the underpass at 16:00 on a bright sunny day. This was assessed to be when the problem with poor vision was most severe. The measurements show that the brightness was measured at 75000 lux outside the underpass - in daylight - and 150 lux inside the underpass, even if the lights were turned on.

Fig. 26b - Contrast between inside and outside

PEOPLE

FLUXES

The area surrounding the underpass is quite crowded, with a significant amount of traffic traveling from the city center to Nørrebro. Numerous cars and buses pass over the bridge over the underpass. The underpass itself carries a fair amount of traffic, as there are many cyclists and pedestrians along the lakeside. The majority of bicycles traverse the tunnel, whereas just a minority of walkers do so. The majority of them prefer to cross Nørrebrogade at the pedestrian crossing above the underpass.

ACTIVITIES

A lot of people are enjoying the car-free path along the lakes. Here they are walking slowly while enjoying the view or are going for a run. Some are also sitting on the slopes or the benches along the lake. The bicycles, on the other hand, are moving quite fast since it is a long stretch with no intersections, giving them an efficient highway between different areas of the city. This can be dangerous for both people on foot and people on bikes, especially since they share a narrow path with no dividers.

Fig. 27 - Underpass and sourroundings

SITE ASSESSMENT

The underpass provides bicycles and pedestrians with a quick and easy alternative to crossing the busy Nørrebrogade. However, from the observations, it is clear that there are some issues. First of all, in the daytime, the difference in light intensity between outside and inside the tunnel can result in poor vision when entering the underpass. It is especially problematic for cyclists, as they are going relatively fast through the tunnel because of the slope down towards the underpass. Furthermore, the underpass is also very narrow, which forces the cyclists to pass the other cyclists going in the opposite direction very close by. Thus, optimal visibility is required.

Darkness is a classic problem with tunnels, especially for car tunnels where the speed of the cars makes it impossible for the driver's eye to adapt to the sudden darkness, which will cause a momentary reduction of vision.
Even though the underpass is placed in a highly central location, no aesthetic consideration has been given to its design. The underpass is located beside the scenic lakefront and is actively used, mainly by cyclists. Therefore, it is essential to give the site a more aesthetically appealing appearance.

This can be concluded in the following vision:

> *Imagine if the underpass would always provide good visibility for cyclists and pedestrians at all times while at the same time enhancing the identity of the space?*

DATA

RELEVANT DATA

To locate the relevant data for this scenario, we can look at the area around the tunnel and the problems related to it. The area is shaped by the heavy traffic on Nørrebrogade, the busy shopping and nightlife street, and the lakeside. Here it could be relevant to measure traffic noise and pollution. We could also measure the light level to make sure the lighting level in the underpass is providing good visibility at all times. Furthermore, we could use the time of day to create different lighting scenes throughout the day.

A few things could be done in order to make a stronger connection of identity between the underpass and the area. For example, social media posts that mention "Dronning Louises" could be collected in order to use the images to control the lighting's colors. A camera could also be installed pointing towards the lake in order to capture the lights and colors of the area and digitally reproduce it.

DATA ASSESSMENT

At this point, it is relevant to assess which of the above mentioned data matches the design vision. In order to always have good visibility in the underpass, a way of measuring the surrounding light level will have to be in place. This can be done with a simple light sensor placed right outside the underpass, which would allow control of the lighting inside the underpass to complement the outside lighting and, in that way, enhance visibility in the underpass.

To create a stronger identity for the underpass, a connection between the lighting in the tunnel and the surrounding atmosphere is wanted. The idea of using social media is discarded as it would add complexity to the project without providing proper benefits to it, since social media posts from the area will not be consistent and will not give clear feedback for the system to work with. On the other hand, if we put up a camera in order to capture the light and colors of the

surroundings, there is a risk of violating privacy. However, the images could be used to create a color scene in the tunnel that brings the characteristics of the outside into the tunnel. To avoid conflicts with any privacy law, it will be ensured not to capture and store any person-specific information.

DESIGN CRITERIA

With all the preliminary analysis and research done, we can now start the design process. First, another look at the space, the problems, and the relevant data is needed. With all of this in mind, some specific design criteria can be conceived. The design criteria should aim to create a clear set of rules for the design to follow that solves the main problems of the space while not introducing new lighting issues and being inclusive.

The primary design criteria:

- Create an environment where everybody will feel secure
- Create appropriate visibility conditions for cyclists and pedestrians in all daylight scenarios

The secondary design criteria:

- Create a lighting scenario that will encourage pedestrians to take the way under the underpass instead of the Nørrebrogade road crossing

IDEA GENERATION

REFERENCE WORKS

Literature

Lights in tunnels are normally divided into two categories:

- an entrance zone (also called a reinforcement zone) where the lighting level is reinforced at the tunnel entrance and gradually decreases further along the tunnel.
- an interior zone that corresponds to the rest of the tunnel. In this area, the lighting level is constant and much lower than in the entrance zone. (Tunnel lighting system | Road Tunnels Manual - World Road Association (PIARC), 2022)

In the reinforcement zone, there is often a risk of what is called the black hole effect. This is caused by the much lower light levels inside the tunnel compared to outside on a bright day. This can be solved by installing a luminaire with high light intensity by the entrance. From here, the light level can be gradually reduced in the interior zone. However, at the exit, the opposite effect to the

black hole effect can occur. Here, users can be exposed to glare when moving from the darkness of the tunnel to the brightness of the daylight. Therefore, it is often necessary to gradually increase the lighting levels again towards the exit.

This is relevant to this tunnel, where the black hole effect can be experienced during the daytime. Since the tunnel is very short in length, the entire underpass could be treated as a reinforcement zone.

State of the art

Examples of how to achieve good lighting for tunnels and underpasses are now being explored. Also, other projects utilizing data to create an underpass that feels safe to use and that invites people to use it are included.

In Larissa Park in Maroondah, Australia, an underpass created an unsafe environment in the otherwise family-friendly area. The lighting company, Webb Melbourne, was hired to do something about this problem. They came up with a colorful solution, as seen in figure 28. They installed two rows of LED bars throughout the tunnel, displaying a color gradient. In the middle are placed a few bars with white LEDs to make sure the lighting levels meet the requirements for underpass lighting.

Fig. 28 – Webb Melbourne's underpass

A lot of tunnels meet the problem of tunnel glare by gradually cutting out some of the daylight outside the tunnel with the use of gitter. One very artistic example of that is the highway tunnel by Nordhavn, Copenhagen as seen in figure 29.

Fig. 29 - Nordhavn's tunnel. Photographer Astrid Maria B. Rasmussen

City underpasses are infamous for framing an unsafe environment in cities. A space can feel more safe with more activity. A way to do that is to create an aesthetically pleasing environment; a perfect example is a mall underpass in Kolding, Denmark. Here, the lighting company Kollision created an interactive lighting system in the tunnel. This installation, called "Interference", reacts to the direction and speed of people using the tunnel.

Fig. 30 - Interference by Kollision

IDEA GENERATION

Here are some ideas generated from a brainstorm in how to improve the space:

- Use colored light to create a safer feeling
- Lights reacting to movement and outside light level
- Light should create a double dynamic with the time of day
- The design includes a representation of outside color with camera

IDEA ASSESSMENT

Now all the ideas are assessed in accordance with the design criteria to make sure the best possible solution is implemented. The criteria dictates to create a secure area with good visibility and aesthetically interesting lighting. As a consequence, the lighting should not create a fast-paced animation, as this could be confusing for the traffic. Instead, working with daylight would create optimal visibility inside the underpass; the design should therefore be reactive to outside lighting levels. A set of color schemes will be generated based on the input from a camera; this will create an interesting lighting experience. Two different sets of luminaires will be implemented—one set for functional lighting to provide optimal visibility and another set of RGB luminaires to reproduce the colors captured by the camera.

TECH INVESTI-GATION

A light sensor and a camera will be connected to a central processing unit, which will also be connected to the luminaires. The camera will be transmitting data wirelessly to the central unit, in order to make it easy to place it at a distance from the underpass.

FORMULATE IDEA

Two rows of RGB luminaires will be placed along the sides of the underpass ceiling. In the center, another row of white luminaires will be placed. The intensity of all the lights will be decided by the ambient lighting levels, and the colors of the RGB luminaires will be based on a color scheme derived from a camera facing the rivers and city skyline.

DESIGN ITERATION

ON-SITE TESTING

Fig. 31, 32, 33 – Testing at the underpass

VIRTUAL EXPERIMENTS

Fig. 34, 35, 36– Renders of virual testing

The test was done with preset color schemes
Making color scenes based on selected scene from location

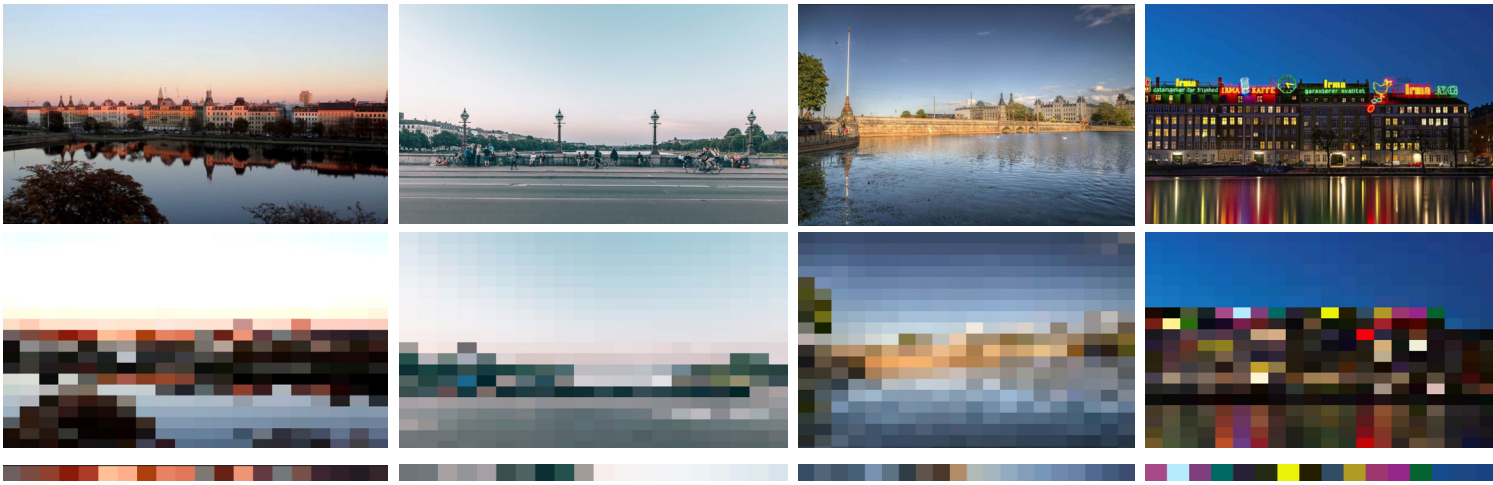


Fig. 37, 38, 38, 39 – Respectively dawn, noon, afternoon, night

Fig. 40, 41, 42, 43 – Representation of light settings at dawn, noon, afternoon and night

HANS TAVSENS PARK

SPACE

STRUCTURE

The park is a rectangular 300x100m area, outlined on the northern side by a cemetery and on the southern one by apartment blocks. At the western end of the park, there are sports facilities, while in the southern part, there is a playground.

The central part of the park is a green lawn, divided by gravel paths that connect the southern side of the park to the cemetery. The park has a concrete square placed in its central part. At the corner of this square there is a bronze statue. The northern path follows the edge of the park that divides Hans Tavsens Park from the cemetery, along which two additional statues are located.

Along the paths, the edges, and around the concrete square, there are many benches and trees all around the park, especially along the northern edge.

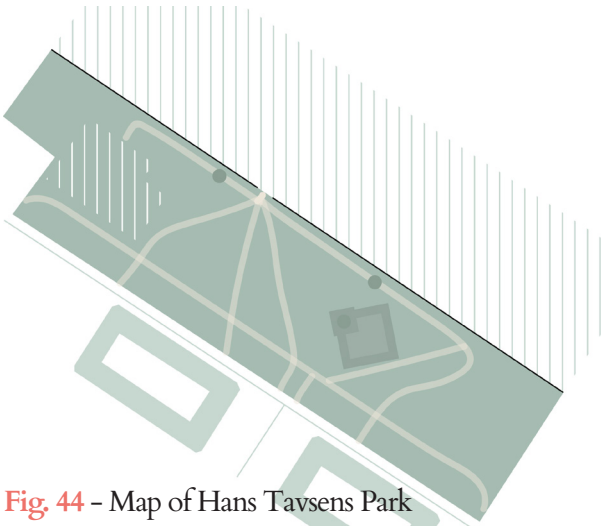


Fig. 44 - Map of Hans Tavsens Park

CONTEXT

Hans Tavsens Park is in Nørrebro's neighborhood, more specifically adjoining one of the city's main cemeteries, Assistens Kirkegård. Originally it was part of the cemetery: it has been used to bury the corpses of the people that could not afford to be buried inside of the cemetery, the so-called "free-cemetery", and to bury the victims of the cholera epidemic. It was only in 1909 that it was requalified and turned into a park ("Hans Tavsens Park – KEND KØBENHAVN", 2022).

In the park are placed three sculptures: one from 1934 by Johanne Bjerg and Poul Holsøes representing Artemis, the Greek goddess, riding a deer; another represents Laocoon and his sons, a casting from the Roman version of the classic Greek statue; and the last is a bronze version of Michelangelo Buonarroti's Moses (Monumenter i København, 2022).

LIGHTING

Daylight and light analysis

During the daytime, the whole park is exposed to daylight, as there are no imminent obstructions except for the trees. In the dark hours, the park is poorly illuminated: the pathways are dark, as is the central concrete square and the statues around the park.

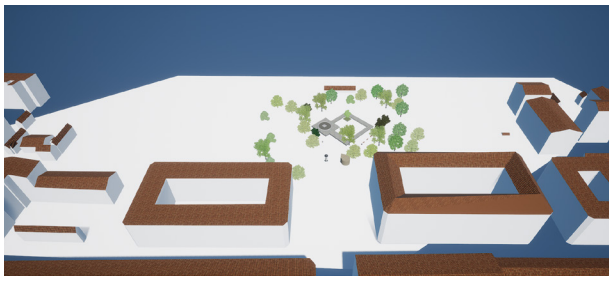


Fig. 45, 46
The sun and shadows in the park at winter solstice and summer solstice at noon

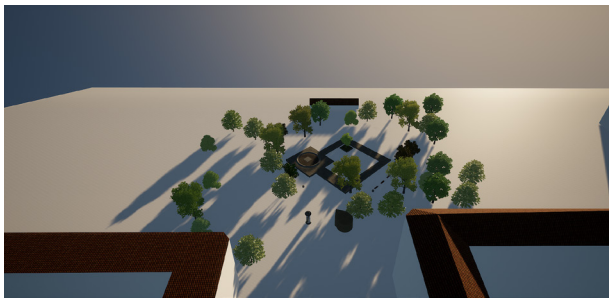


Fig. 47, 48
The sun in the morning and in the evening

Copenhagen Masterplan

According to the Copenhagen Lighting Masterplan (Belysningsmasterplan for København, 2014), Hans Tavsens Park is marked as a dark area ("Udvalgte Mørke Parker"), along with a series of dedicated parts of the city that have been chosen to support animals' well-being and limit light pollution. However, the same park is used as an example of an area perceived as unsafe and in need of a better lighting plan in order to make it a more inviting park and, consequently, a safer place.

HUMANS

FLUXUS

Many people walk or bike through it to reach the cemetery, the sports facilities, or the kindergarten's open playground. Some people are jogging in or through the park and doing sports. Most people, however, walk around the park and stop to sit or play.Although the park is highly used, the pace is slow and relaxed.

ACTIVITIES

Most people use the space for recreational purposes. Most people sit, both on the benches and on the grass, in small groups or alone, reading, sunbathing, socializing, or doing activities such as crocheting and knitting. In the park, there are also bigger groups of people playing games or sitting and hanging out. The flow of people passing through the park to get to the cemetery does not interfere with the calm atmosphere of the park.

LOCAL COMMUNITY

The neighborhood is a tranquil yet lively part of Nørrebro, Copenhagen's most young and multicultural district. In the immediate vicinity of the park, there are mainly living small families with young kids.

The age groups of the users of the park differ greatly; there are many young people because of the proximity to a kindergarten and sports facilities hosting teenagers and children. Young adults and adults are both enjoying the park, walking through it, or accompanying children to school or sports practice. Older people also sit in the park and walk through it to approach the cemetery. It is important to mention that the park has had a bad reputation and is still perceived as unsafe. From the masterplan's analysis, it is possible to read a few comments made by the local community: most of the people's comments address the fact that the park is dark ('mørkt' in Danish), scary ('uhyggeligt') and that it could use more light.

SITE ASSESSMENT

The park is very spacious and offers a lot of possibilities for activity. However, in the nighttime, there is no dedicated light along the pathways and around the meeting areas. This enhances the unsafety attributed to the space, and it does not invite social activities during the nighttime. On top of that, because of the oblong dimensions, it results in being very dispersive, and the central concrete square is unused and unlit. Also, the statues around the park are not lit and are almost invisible in the dark hours.

DATA

RELEVANT DATA

When addressing the problems of Hans Tavsens, the pertinent data to analyze are the weather conditions, the time of the day and the season in order to be able to provide dedicated relevant lighting and to limit unneeded energy consumption. Moreover, tracking the amount of people and their movement in the space can support a playful design, fostering people's creativity and well-being.
This data set allows for a change in scenery according to how the park is used and what the atmospheric conditions require.

DESIGN CRITERIA

Based on the analysis made and on the problems and affordances of the space, the design needs to meet the following design criteria:

- Create a dedicated central space for people to gather
- Address the safety issue related to lack of illumination, both in perceived safety and visibility issues

IDEA GENERATION

REFERENCE WORKS

TeamLab's immersive installation focuses on the bodily experience of the participants and the connections they create through play and movement, supported by an interactive projection that reacts to the participant's direction and speed of movement. The projection and the installation cease to exist if there is no participant or movement. This setting encourages people to participate by taking an active role in making the installation happen and freely shaping it by being present and moving within the space. It also calls for cooperative play and encounters because of the possibilities of scenarios and because, as the particles

Fig. 49
TeamLab, Moving Creates Vortices and Vortices Create Movement

move, they produce sounds, so the more particles, the more complex the sound becomes and it eventually creates music.

Fig. 50 - Kollision, Urban Platform

Kollision, a Danish media company based in Aarhus, created a playful platform where people can interact with light and with each other. It is a very simple setup where three moving heads are controlled by a motion sensor, but it has infinite possibilities: from collaborative or competitive games to dynamic lighting for illumination purposes and the possibility of developing new setups. The installation is programmed to change settings based on the hour and the time of the year, so when it gets dark at night, the installation becomes an ambient light provider rather than a playful platform.

IDEA GENERATION

The idea generation process starts with the brainstorm of possible lighting solutions for the space. These are the main concepts:

- design a community-based spaced
- create a central meeting point
- design a playful interactive environment
- tackle the safety issue
- non-invasive design to respect the neighbors
- dedicated light for the pathways and statues for wayfinding and safety

IDEA ASSESSMENT

First of all, because the square is widely used by many individuals and small groups, it is relevant to design a community-based space, focusing on the creation of a central meeting point where users can feel safe to meet other people.

Because the park is mainly used to relax or for social reasons, it is relevant to design a playful, cozy environment. The park is situated in the proximity of a residential area, so the design should not be invasive or create a high level of noise, but it should also lure people in during the darker hours, so as to address the perceived safety issues.

The pathways, now completely dark, need dedicated lighting to ensure wayfinding and safety. Also, the statues, public art pieces of the space, require a lighting design that can both enhance them as well as provide ambient lighting for the park.

TECH INVESTI-GATION

The interactive display would utilize four towers, each containing two projectors. The entire surface would be projection mapped. Two towers would be placed on either side of the square, and as a pair they would map the entire surface. The opposite towers would also map the exact same surface from the other side, thus eliminating shadows. Multiple tracking sensors would be placed around the square to track the movements and positions of the people inhabiting the square. Interpretations of this data can be projected onto the surface in different configurations.

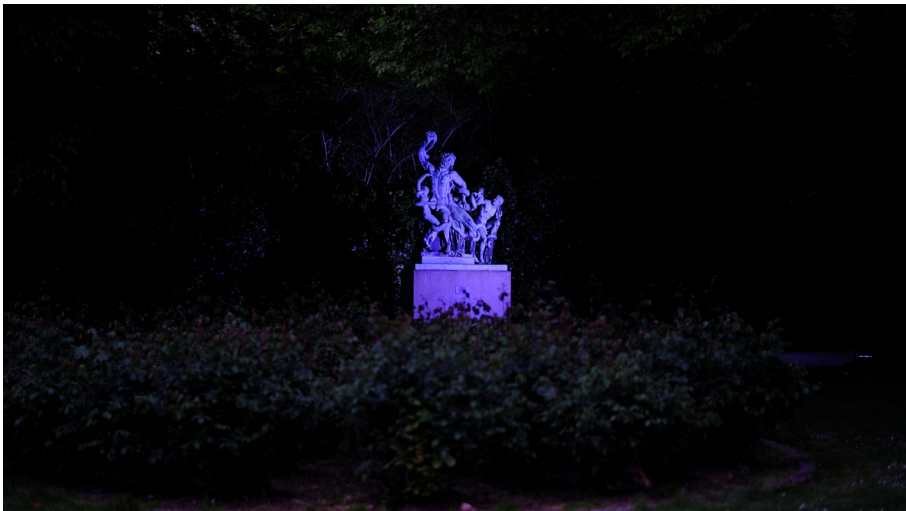
The tracking sensor would make use of object recognition to detect individual people from each other and to detect the people from animals. A program based on machine learning will be implemented to choose between various states. This will be based on the weather and the number of people in the square and the way they move. For instance, when two people are walking slowly on the square on a fall evening, the program will present a drawing game. If six people run around on the square on a summer night, the program will start a particle shooting game. When there are no participants, the program will decide whether to light up the statue or to light up the square with appropriate colors.

FORMULATE IDEA

The central concrete square is the main focus of this design proposal: from being an underused space and almost unusable at night because of the lack of illumination, it will become a playful square where light projected from projectors all around the square follows the users' movements by tracking them and shaping the projections around them.
The floor can be used as a canvas that people could paint on, and it can become a game for people to play. It can also create atmospheric light with slow-moving colored animations.
At nighttime, the system is set to turn into spotlights, illuminating the central statue and the square lightly to provide ambient lighting, so as to keep an overall secure feeling of the park without disturbing the people living in the apartment facing the park.
For the rest of the park, lights along the main pathways are to be placed in order to provide safety all-over the park and for cyclists' and pedestrians' way-finding. Also, the other two statues should be illuminated with dedicated light, to provide diffused atmospheric lighting and to illuminate the northern edge, which is perceived as the most unsafe area.

ON-SITE TESTING

Test showing the effect of lighting up the statue. It is shown how the edge of the park and the statue are left in complete darkness as it is now and how an illuminated statue will provide a focal point for the path.



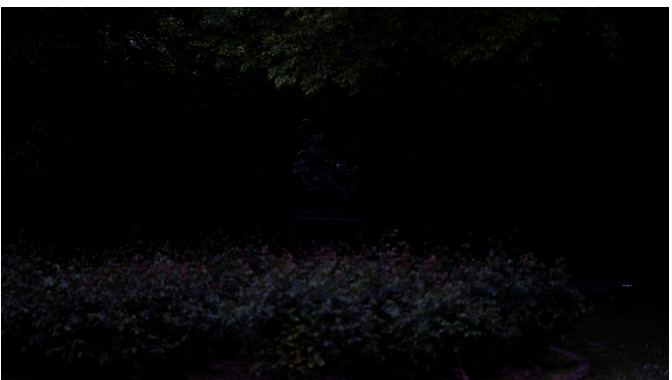


Fig. 51, 52, 53
Testing LED light on the statue at the edge and the difference when there is no illumination

Some experiments showing different lighting and color scenarios on the square. It is shown how it is possible to light up the square alone, without spilling light outside the square, causing unwanted light pollution. The experiments also test the illumination of the central statue. This will help preserve the statue as a landmark even after dark.

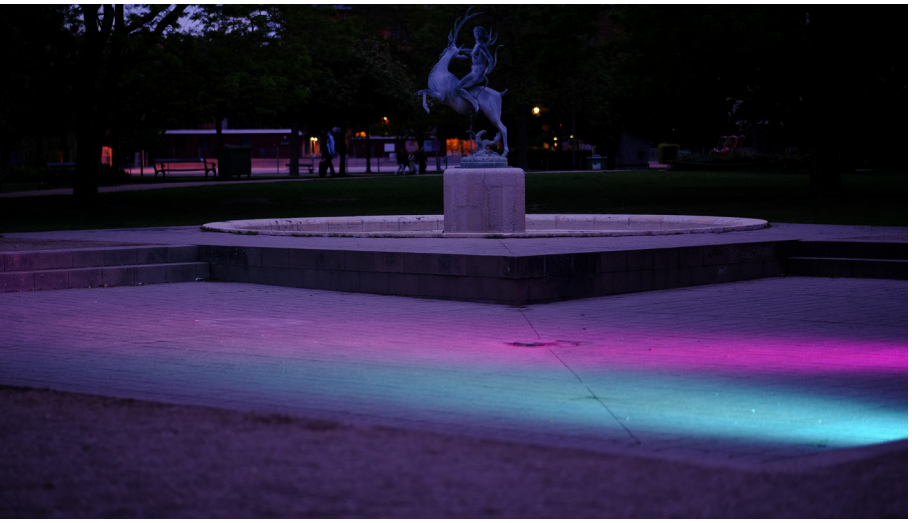
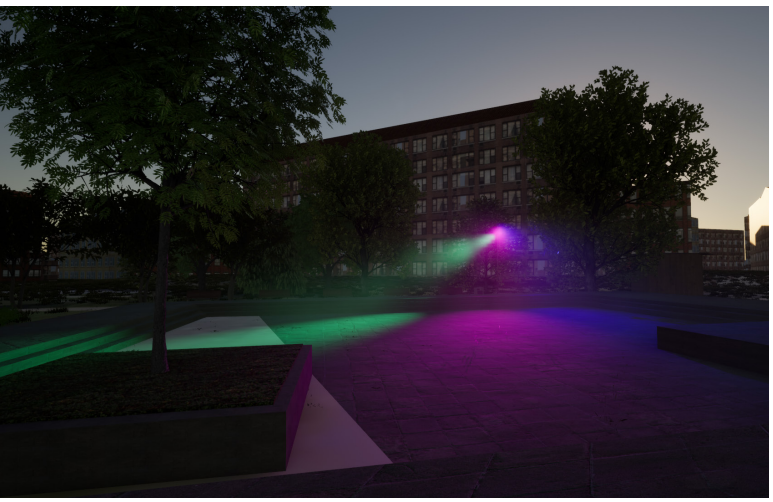


Fig. 54, 55, 56, 57
Testing LED light on the main square and statue

VIRTUAL TESTING

Virtual experiments showing how a light pole equipped with three spotlights could add a colorful element to the park after dark.



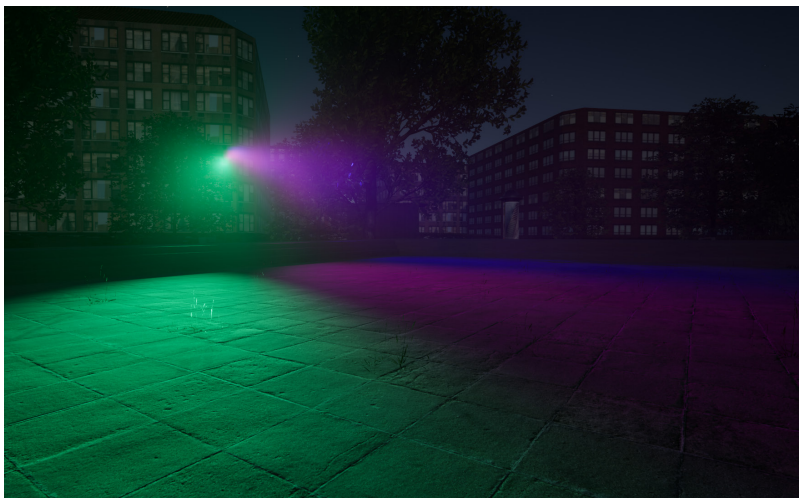
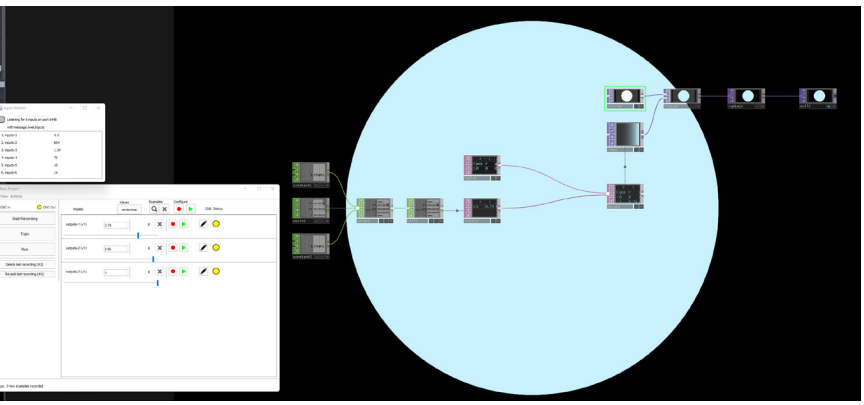


Fig. 58, 59
Testing LED light on the main square and statue

A state machine based on AI (machine learning) was tested to explore if this could be used for deciding the different light scenes. A python script fetches weather data, which is then fed into a machine learning software called Wekinator (http://www.wekinator.org/). From here, the data is passed to a visual programming environment where it is translated into graphics. This means that it is possible to train an algorithm to show specific content in certain weather situations. The advantage of using machine learning in this case is to avoid writing a program that takes every possible weather situation into account.

Here are some examples of the output shown. First, the cloud cover, wind speed and direction, temperature, and time of day data were simply mapped to a single color.



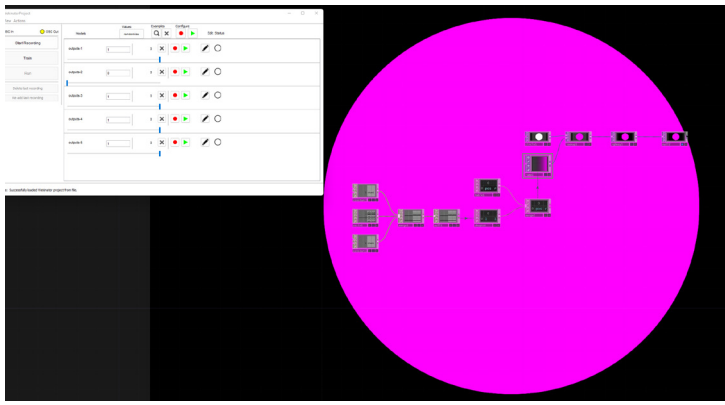


Fig. 60, 61
Touchdesigner's sketches

Later, the weather data was mapped to a detailed representation of the weather.

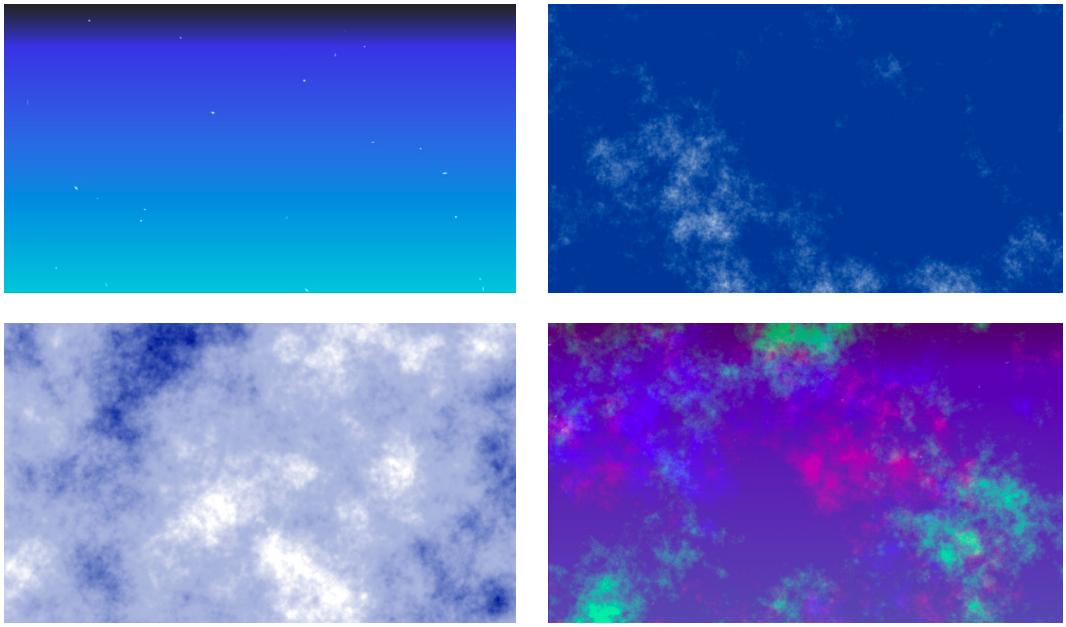


Fig. 62, 63, 64, 65 - Weather representation

DESIGN PROPOSAL

Here are some examples of how the square would look with a video mapped particle system. The first two images show the square when no people are present in the square, while the next two images display the interplay between a person and the particles.

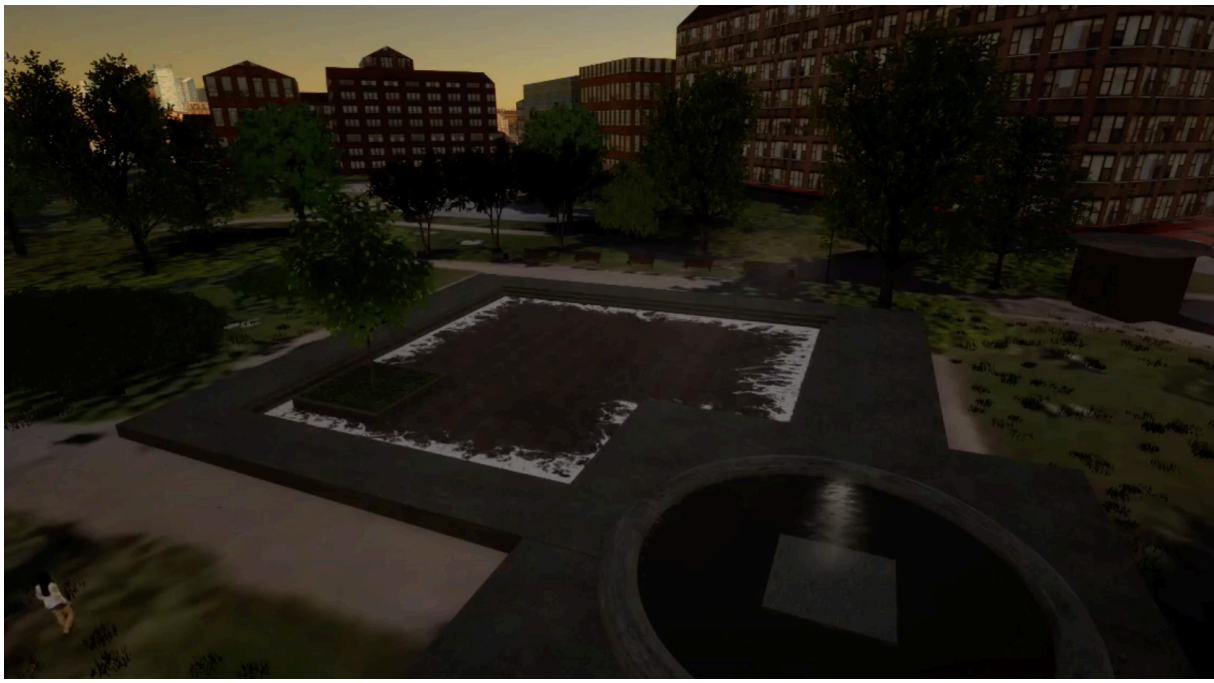
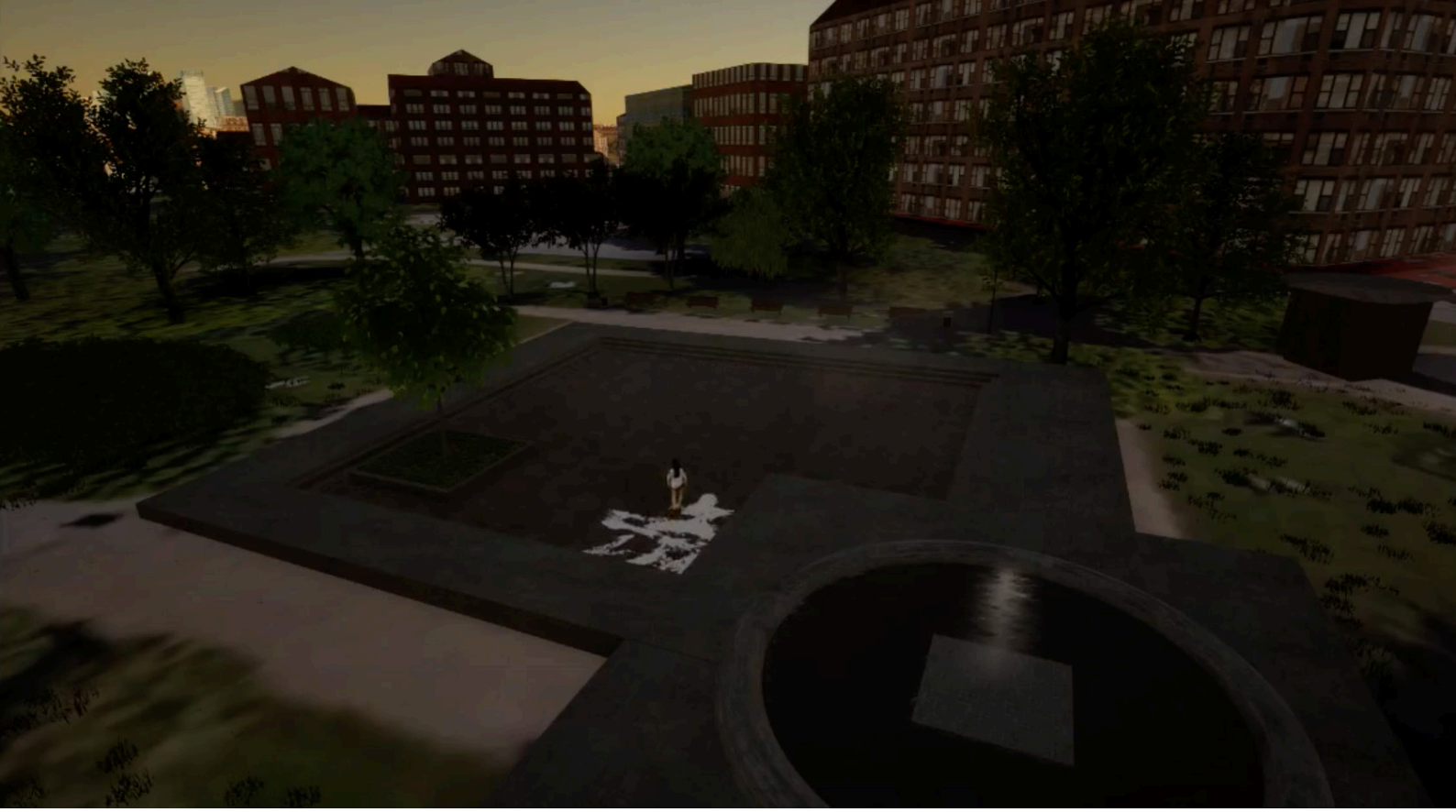


Fig. 66 - Render of design proposal



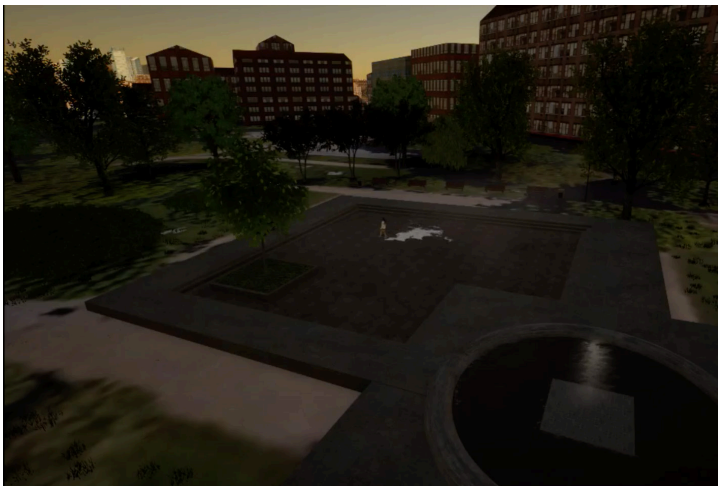


Fig. 67, 68, 69 - Renders of design proposal

chapter 4

discussion and conclusion

The purpose of this report was threefold: first, to map and evaluate the notion of digital placemaking; and then to bring it into contact with the theory of its actors. The second goal was to apply this information to develop a design framework that would equip designers with a toolkit for working with site-specific lighting. The final purpose was to use the design framework in a series of case studies to put it to the test and showcase to readers how to work with the framework.

The literature was effectively applied in the "Theory" chapter to deconstruct the meaning of digital placemaking and divide it into its main actors, who were then analyzed. With the emphasis on establishing a design framework, a number of peripheral theories, like universal design, human-computer interaction, and AI, were investigated, which contributed to the creation of a comprehensive toolkit.

Throughout the "Design Framework" chapter, the theory was applied to produce a set of steps that may be used as a universal recipe to aid designers in approaching a design in a way that incorporates the space and its users through data. It also includes some methods in project management, which will assist in the creation of the best possible design. An iterative design process was used to conceive an end-to-end framework by working with a set of case studies on the side. This helped to develop the framework not only from the literature but also from a practical approach. We believe this was the appropriate method to achieve the most universal and constructive product. We have made a clear and intuitive graphical representation of the design frameworks, which makes it independent of this report and therefore more approachable. It also makes it possible to apply it to many different kinds of projects.

Finally, examples of how to work with the design framework are shown in the chapter "Case Studies". Here are three separate examples based on locations in Copenhagen, Denmark. The examples depict several user cases and provide three distinct design concepts. Through the three different case studies, we show examples of how to utilize the design framework. This will give users of the framework a reference on how to work with the individual steps in the protocol while also showcasing some of the different ways the framework can be used for inspiration.

We realize that the framework is not completely universal. The entire approach is built on the assumption that a specific process is present for the project. We realize that in many real-world cases, the outline of a design is already dictated when first given the task of making a design. In the aim of making a universal framework, we risk identifying many steps that are irrelevant to the unique design scenario as well as leaving out other steps.

In summary, this project was successful in creating a new structured framework for developing public lighting, as specified in the problem statement. It also offers an effective tool that will assist designers in incorporating digital placemaking, data, and human interaction, which may lead to the creation of the best possible site-specific lighting.

references

An Introduction to the Design Iteration Process. (2022, April 19). Studio by UXPin; www.uxpin.com. https://www.uxpin.com/studio/blog/design-iteration-process/

Artemisspringvandet - Monumenter i København. (2022). Retrieved 11 June 2022, from https://kk.sites.itera.dk/apps/kk_monuments/index.php?id=106#

Brynjolfsson, E. and McAfee, A., 2014. The second machine age

Dempsey, N. and Burton, M., 2012. Defining place-keeping: The long-term management of public spaces. Urban Forestry & Urban Greening

E. Holgaard, J., & Kolmos, A. (2021). Framing the Introduction to Problem-based Learning. Aalborg Centre for Problem Based Learning in Engineering Science and Sustainability.

Elsheshtawy, Y. (2015). Observing the Public Realm: William Whyte's "The Social Life of Small Urban Spaces"

Gehl, J. (2014). Cities for people. Burnaby, B.C.: University of Simon Fraser Library.

Gehl, J., & Svarre, B. (2014). How to study public life. MTM.

Goonewardena, K., Kipfer, S., Milgrom, R. & Schmid, C. (2008) Space, Difference, Everyday Life; Reading Henri Lefebvre. Routledge

Gössling, S., Schröder, M., Späth, P. and Freytag, T. (2016). Urban Space Distribution and Sustainable Transport. Transport Reviews

Herring, S., Jones, B., & Bailey, B. (2009). Idea Generation Techniques among Creative Professionals

Hardt, M., Negri, T. (2000) Empire. Cambridge, MA: Harvard University Press

Hespanhol, L., Haeusler, M., Tomitsch, M. and Tscherteu, G. (2017). Media architecture compendium. avedition

Horton, D., 2001. Reflexive Ethnography: A Guide to Researching Selves and Others, Charlotte Aull Davies, London: Routledge

Huset, der Regner - Monumenter i København. (2022). Retrieved 11 June 2022, from https://kk.sites.itera.dk/apps/kk_monuments/index.php?id=106#

Huset der regner, Sankt Hans Torv. (2022). Retrieved 11 June 2022, from http://www.haugensorensen.com/huset-der-regner-sankt-hans-torv11

Huizinga, J., 1949. Homo ludens. A study of the Play-Element in Culture. London: Routledge. Taylor & Francis Group

Hans Tavsens Park – KEND KØBENHAVN. (2022). Retrieved 11 June 2022, from http://www.hovedstadshistorie.dk/noerrebro-2/hans-tavsens-park/

København Cyklernes by (2019). Copenhagen: Teknik- og Miljøforvaltningen

København, Sankt Hans Torv. (2022). Retrieved 11 June 2022, from https://web.archive.org/web/20160426134345/http://www.arkark.dk/building.aspx?buildingid=2673

Københavns Kommune & Citelum. (2014). Belysningsmasterplan for København.

Langdon, P., Lazar, J., Heylighen, A. and Dong, H., 2020. Designing for Inclusion. Springer

Laokoon - Monumenter i København. (2022). Retrieved 11 June 2022, from https://kk.sites.itera.dk/apps/kk_monuments/index.php?id=106#

Lefebvre, H (1991) The production of space

Lynch, K. (1960). The Image of the city. Cambridge: Technol. Pr. & Harvard Univ. Pr.

Manifesto for Agile Software Development. Retrieved 10 June 2022, from https://agilemanifesto.org

Medium. 2022. How to Maintain Effective and Efficient Street Lighting. Retrieved 11 June 2022, from: https://medium.com/@projectlinkaus/how-to-maintain-effective-and-efficient-street-lighting-ec9cdb92e03e

Mirror Mirror – SOFTlab. (2022). Retrieved 11 June 2022, from https://softlabnyc.com/project/mirror-mirror/

Monumenter i København. (2022). Retrieved 11 June 2022, from https://kk.sites.itera.dk/apps/kk_monuments/index.php?id=106#

Moses - Monumenter i København. (2022). Retrieved 11 June 2022, from https://kk.sites.itera.dk/apps/kk_monuments/index.php?id=106#

Moving Creates Vortices and Vortices Create Movement | teamLab. (2022). Retrieved 15 June 2022, from https://www.teamlab.art/w/vortices/ngv-triennial/

Nielsen Norman Group. 2022. Inclusive Design. Retrieved 11 June 2022, from: https://www.nngroup.com/articles/inclusive-design

Pictro Sender Machine - Amsterdam— PRADO.WS. (2022). Retrieved 12 June 2022, from https://www.prado.ws/picto-sender-machine

Pask, G. (1976). Conversation theory. Amsterdam: Elsevier

Pps.org. (2022). What is Placemaking?. [online] Retrieved 9 June 2022, from: https://www.pps.org/article/what-is-placemaking

Raol, J. R. (2015). Data Fusion Mathematics. CRC Press.

Saar, M., & Palang, H. (2009). The Dimensions of Place Meanings. Living Reviews In Landscape Research

Seng, K., Ang, L. and Ngharamike, E., 2022. Artificial intelligence Internet of Things: A new paradigm of distributed sensor networks. International Journal of Distributed Sensor Networks

Soja, E. (1996). Thirdspace. Oxford: John Wiley and Sons.

Status på København 2021. Copenhagen: Den Tværgående Analyseenhed

Tunnelsmanual.piarc.org. 2022. Tunnel lighting system. Retrieved 10 June 2022, from: https://tunnelsmanual.piarc.org/en/equipment-systems-general-support/tunnel-lighting-system

Web.mit.edu. (2022). Design and Decision Criteria. Retrieved 9 June, from: https://web.mit.edu/course/21/21.guide/designcr.htm

Zhang, J., & He, S. (2020). Smart technologies and urban life: A behavioral and social perspective. Sustainable Cities And Society

figures references

Interference, Kollision. Retrieved 4 June 2022, from: https://kollision.dk/en/interference
Larissa Underpass. Retrieved 10 June 2022, from: https://www.coolon.com.au/architectural-led-lighting/project-gallery/larissa-underpass

TeamLab, Moving Creates Vortices and Vortices Create Movement. Retrieved 11 June 2022, from: https://www.teamlab.art/w/vortices/

Traffic on Dronning Louises Bro. Retrieved 6 June 2022, from: https://billeder.velostrada.dk/wp-content/uploads/2015/12/Dronning-Louises-bro-med-cykler.jpg

Underpass in Copenhagen, Astrid Maria B. Rasmussen

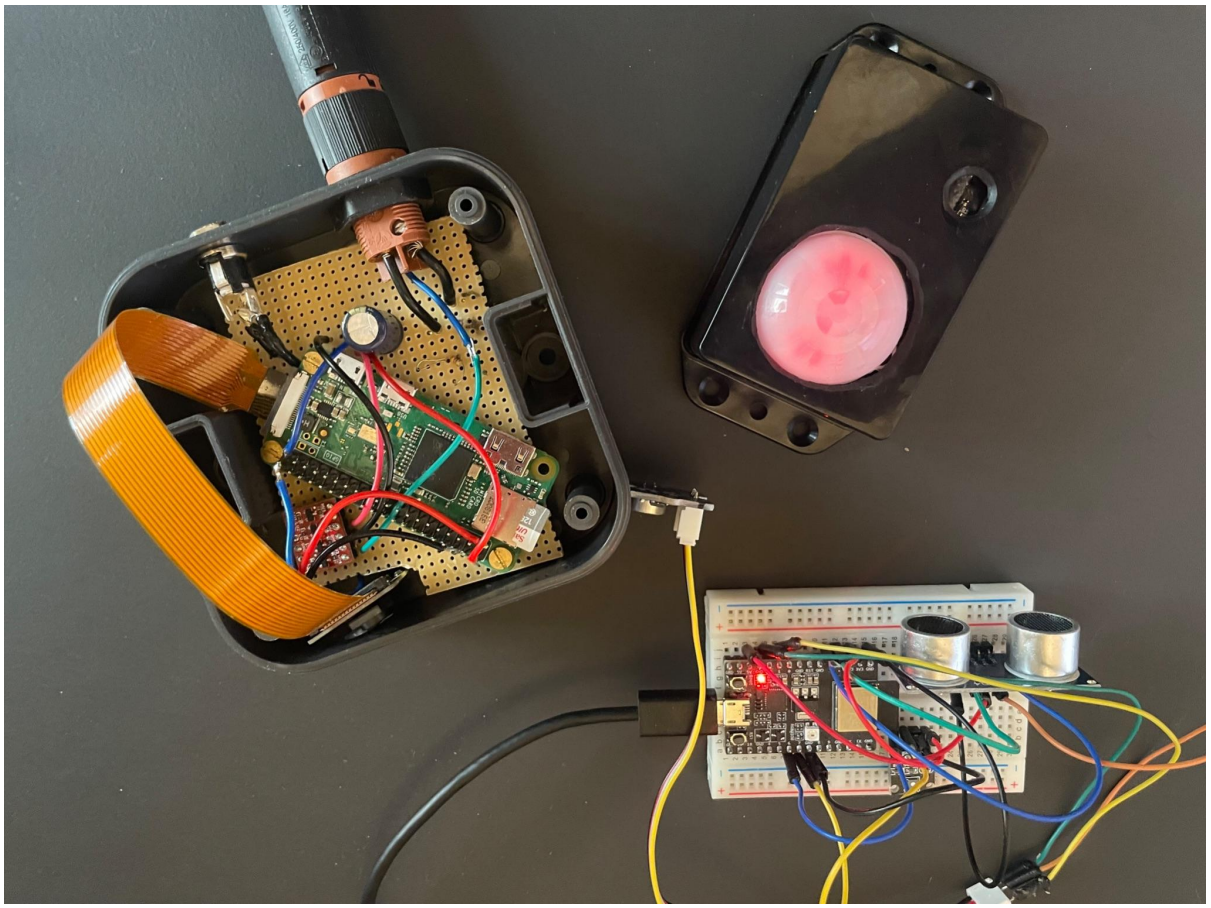
Urban Platform, Kollision. Retrieved 4 June 2022, from: https://kollision.dk/en/urban-platform

The rest of the figures are own productions.

Appendix

Light Hedges

Prototype Hardware: Central unit and 2 x Sensor nodes.



Central Unit - Main

```
import mqtt_broker
import led_controller
import datetime

mqtt_client = None

ultra_val = 0.1 #50
sleep_counter = 0
led_a = 0


def pir_mode():
    global sleep_counter

    light_level = set_light_level(mqtt_broker.als_val)

    if mqtt_broker.pir_val == 1:
        sleep_counter = 0
```

```
    else:
        sleep_counter += 1

    if sleep_counter < 300:
        led_controller.brightness_control(light_level)
    else:
        # print('Going to sleep')
        led_controller.brightness_control(10)


def set_light_level(als_val):
    old_min = 0
    old_max = 40
    new_min = 20
    new_max = 255
    old_range = (old_max - old_min)
    new_range = (new_max - new_min)

    if als_val > old_max:
        light_val = 100
    elif als_val <= old_min:
        light_val = 20
    else:
        light_val = int((((als_val - old_min) * new_range) / old_range) + new_min)

    return light_val


def get_tod_val():
    now = datetime.datetime.now()

    hour = 12
    minute = now.strftime("%M")
    total_minute = int(hour) * 60 + int(minute)

    if total_minute <= 480:  # from 4 to 8
        value = 0.5 * total_minute - 120
    elif total_minute <= 720:
        value = 0.18 * total_minute - 31
    elif total_minute <= 1080:
        value = -0.14 * total_minute + 200
    elif total_minute <= 1320:
        value = -0.17 * total_minute + 230
    else:
        value = 0

    value = int(value)

    return value


def get_temp_val():
    temp = mqtt_broker.temp_val
```

```
    old_min = 0
    old_max = 30
    new_min = 0
    new_max = 100
    old_range = (old_max - old_min)
    new_range = (new_max - new_min)

    value = (((temp - old_min) * new_range) / old_range) + new_min

    if value < 0.0:
        value = 0
    elif value > 100.0:
        value = 100
    else:
        value = int(value)
    return value


def get_humidity_value():
    humidity = mqtt_broker.hum_val
    value = 1.7 * float(humidity) + 66.7  # Low output when low humidity

    if value < 40:
        value = 0
    elif value > 90:
        value = 100

    value = int(value)
    return value


def get_ultrasonic_value():
    global ultra_val
    step_size = 0.3
    ultra_in = mqtt_broker.ultrasonic_val

    old_min = 1000
    old_max = 20
    new_min = 1
    new_max = 10
    old_range = (old_max - old_min)
    new_range = (new_max - new_min)

    value = (((ultra_in - old_min) * new_range) / old_range) + new_min

    if ultra_val > value + step_size or ultra_val < value - step_size:
        if value < ultra_val:
            ultra_val -= step_size
        elif value > ultra_val:
            ultra_val += step_size
```

```
if __name__ == "__main__":
    mqtt_client = mqtt_broker.init_mqtt()
    r = g = b = w = 0

    try:
        while True:
            pir_mode()
            get_ultrasonic_value()

            tod_val = get_tod_val()
            temp_val = get_temp_val()
            hum_val = get_humidity_value()

            for j in range(led_controller.num_pixels):
                y = led_controller.simple_noise(j, led_a, 0, 120, 50)

                if y > 0:
                    r = (y / 100 * temp_val)
                    g = 0
                else:
                    g = ((y * -1) / 100 * hum_val)
                    r = 0
                b = (abs(y) / 100 * tod_val)

                led_controller.set_led(j, r, g, b, w)

            led_controller.show()
            led_a += ultra_val

    except KeyboardInterrupt:
        mqtt_broker.stop_mqtt(mqtt_client)
        led_controller.color_fill(0, 0, 0, 0)
```

```
import board
import neopixel
import math

# Choose an open pin connected to the Data In of the NeoPixel strip, i.e. board.D18
# NeoPixels must be connected to D10, D12, D18 or D21 to work.
led_pin = board.D21

# The number of NeoPixels
num_pixels = 578

# The order of the pixel colors - RGB or GRB. Some NeoPixels have red and green reversed!
# For RGBW NeoPixels, simply change the ORDER to RGBW or GRBW.
ORDER = neopixel.GRBW

brightness = 0

led = neopixel.NeoPixel(
    led_pin, num_pixels, brightness=1, auto_write=False, pixel_order=ORDER,
)


def simple_noise(x, a, offset, amp, w, movement=0.03):

    y = int(offset + amp * (math.sin((2 * x / w) - (a * movement)) +
                                    math.sin((3.14 * x / w) - (a * movement))))
    if y > 255:
        y = 255
    elif y < -255:
        y = -255

    return y


def sine_window(x, a, phase):
    movement = 0.03

    h = abs(math.sin(x / (num_pixels / 4) - (a * movement)) - phase)

    value = int(h*255)
    return value


def color_fill(r, g, b, w):
    led.fill((r, g, b, w))
    led.show()


def set_led(l, r, g, b, w):
    led[l] = (r / 255 * brightness, g / 255 * brightness, b / 255 * brightness, w / 255 *
brightness)
```

```
def show():
    led.show()


def brightness_control(set_brightness):
    global brightness
    if set_brightness < brightness:
        brightness -= 1
    elif set_brightness > brightness:
        brightness += 1

    if brightness > 255:
        brightness = 255
    elif brightness < 0:
        brightness = 0
```

Central Unit - MQTT broker

```
# subscriber.py
import paho.mqtt.client as mqtt

pir_val = 1
als_val = 20
temp_val = 15
temp_min_val = 0
temp_max_val = 20
hum_val = 60
ultrasonic_val = 200


def on_connect(client, userdata, flags, rc):
    print(f"MQTT connected with result code {rc}")
    # subscribe, which need to put into on_connect
    # if reconnect after losing the connection with the broker,
    # it will continue to subscribe to the raspberry/topic topic
    client.subscribe("raspberry/#")
    client.subscribe("esp32/pir")
    client.subscribe("esp32/ultrasonic")
    client.subscribe("weather/#")


# the callback function, it will be triggered when receiving messages
def on_message(client, userdata, msg):
    #print(f"{msg.topic} {msg.payload}")

    if "uptime" in msg.topic:
        uptime = int(msg.payload)/1000000
        # print(f'Uptime in seconds: {uptime}')
    elif "pir" in msg.topic:
        global pir_val
        pir_val = int(msg.payload)
```

```
    elif "als" in msg.topic:
        global als_val
        als_val = int(msg.payload)
    elif "temp" in msg.topic:
        global temp_val
        global temp_min_val
        global temp_max_val

        if "min" in msg.topic:
            temp_min_val = float(msg.payload)
        elif "max" in msg.topic:
            temp_max_val = float(msg.payload)
        else: temp_val = float(msg.payload)
        print(f'temp: {temp_val}, min: {temp_min_val}, max: {temp_max_val}')

    elif "humidity" in msg.topic:
        global hum_val
        hum_val = msg.payload

    elif "ultrasonic" in msg.topic:
        global ultrasonic_val
        ultrasonic_val = int(msg.payload)
        print(f"Ultrasonic input: {ultrasonic_val}")


def init_mqtt():
    client = mqtt.Client()
    client.on_connect = on_connect
    client.on_message = on_message

    # set the will message, when the Raspberry Pi is powered off, or the network is
interrupted abnormally,
    # it will send the will message to other clients
    client.will_set('raspberry/status', b'{"status": "Off"}')

    # create connection, the three parameters are broker address, broker port number, and
keep-alive time respectively
    client.connect("192.168.0.152", 1883, 60)

    # set the network loop blocking,
    # it will not actively end the program before calling disconnect() or the program crash
    # client.loop_forever()
    client.loop_start()

    return client


def stop_mqtt(client):
    client.loop_stop()
```

Central Unit - Services

```
from pyowm import OWM
from pyowm.utils import config
from pyowm.utils import timestamps
import time

import paho.mqtt.client as mqtt

# broker_address="iot.eclipse.org" #use external broker
client = mqtt.Client("weather")  # create new instance

# create connection, the three parameters are broker address, broker port number, and
keep-alive time respectively
client.connect("192.168.0.152", 1883, 60)

# ---------- FREE API KEY examples --------------------

owm = OWM('###')
mgr = owm.weather_manager()


def weather_service():
    observation = mgr.weather_at_place('Copenhagen,DK')
    w = observation.weather

    status = w.detailed_status  # 'clouds'
    wind_speed = w.wind().get('speed')  # {'speed': 4.6, 'deg': 330}
    wind_dir = w.wind().get('deg')  # {'speed': 4.6, 'deg': 330}
    hum = w.humidity  # 87
    temp = w.temperature('celsius').get('temp')  # {'temp_max': 10.5, 'temp': 9.7, 'temp_min':
9.0}
    temp_min = w.temperature('celsius').get('temp_min')
    temp_max = w.temperature('celsius').get('temp_max')

    # w.rain                    # {}
    # w.heat_index              # None
    cloud = w.clouds  # 75

    client.publish("weather/status", status)  # publish
    client.publish("weather/wind_speed", wind_speed)  # publish
    client.publish("weather/wind_direction", wind_dir)  # publish
    client.publish("weather/humidity", hum)  # publish
    client.publish("weather/temp", temp)  # publish
    client.publish("weather/temp_min", temp_min)  # publish
    client.publish("weather/temp_max", temp_max)  # publish
    client.publish("weather/clouds", cloud)  # publish

    print("Packages send")


if __name__ == "__main__":
    while True:
        try:
            weather_service()
```

```
            time.sleep(10)
        except Exception as ex:
            print(ex)
```

Sensor Node - Main

```
#include <WiFi.h>
#include <PubSubClient.h>
#include <SPI.h> // call library


#define ALS_PIN 4 // Assignment of the CS pin
#define ALS_POWER_PIN 8
#define PIR_PIN 2

const char* ssid = "XXX";
const char* password = "xxx";

const char* mqtt_server = "xxx.xxx.xxx.xxx";

WiFiClient espClient;
PubSubClient client(espClient);
long lastMsg = 0;
char msg[50];
int value = 0;

uint8_t last_pir_val = 0;

void setup() {
  pinMode(PIR_PIN, INPUT);

  Serial.begin(115200);

  SPI.begin(7, 6); // initialization of SPI port
  SPI.setDataMode(SPI_MODE0); // configuration of SPI communication in mode 0
  SPI.setClockDivider(SPI_CLOCK_DIV16); // configuration of clock at 1MHz
  pinMode(ALS_PIN, OUTPUT); //configure pin connected to chip select as output
  pinMode(ALS_POWER_PIN, OUTPUT); //configure pin connected to chip select as output
  pinMode(8, OUTPUT); //configure pin connected to chip select as output

  setup_wifi();
  client.setServer(mqtt_server, 1883);
  client.setCallback(callback);

  initTime();
  digitalWrite(ALS_POWER_PIN, HIGH);
}

void loop() {
  if (!client.connected()) {
    reconnect();
```

```
  }
  client.loop();

  // Get pir val
  uint8_t pir_val = digitalRead(PIR_PIN);
  if (pir_val != last_pir_val) {
    last_pir_val = pir_val;
    Serial.print("Pir val: "); Serial.println(pir_val);
    char pir_string[8];
    itoa(pir_val, pir_string, 10);

    client.publish("esp32/pir", pir_string);
  }

  long now = millis();
  if (now - lastMsg > 10000) {
    lastMsg = now;

    uint64_t uptime = getUptime();
    char uptimeString[12];
    dtostrf(uptime, 1, 0, uptimeString);
    client.publish("esp32/uptime", uptimeString);

    //Get chip ID
    uint32_t chipId = getChipId();
    char tempString[8];
    dtostrf(chipId, 1, 0, tempString); // Convert the value to a char array
    client.publish("esp32/chipid", tempString);

    //Get local time
    String ts = getLocalTime();
    char dt[12];
    ts.toCharArray(dt, 12);
    client.publish("esp32/datetime", dt);

    // Get ambient light intensity
    uint8_t light_val = getLightIntensity();
    char als[8];
    itoa(light_val, als, 10);
    client.publish("esp32/als", als);
  }

  delay(100);
}
```

Sensor Node - MQTT broker

```
void setup_wifi() {
  delay(10);
  // We start by connecting to a WiFi network
  Serial.println();
  Serial.print("Connecting to ");
  Serial.println(ssid);
```

```
  WiFi.begin(ssid, password);

  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.print(".");
  }

  Serial.println("");
  Serial.println("WiFi connected");
  Serial.println("IP address: ");
  Serial.println(WiFi.localIP());
}

void callback(char* topic, byte* message, unsigned int length) {
  Serial.print("Message arrived on topic: ");
  Serial.print(topic);
  Serial.print(". Message: ");
  String messageTemp;

  for (int i = 0; i < length; i++) {
    Serial.print((char)message[i]);
    messageTemp += (char)message[i];
  }
  Serial.println();

  // Feel free to add more if statements to control more GPIOs with MQTT

  // If a message is received on the topic esp32/output, you check if the message is either
"on" or "off".
  // Changes the output state according to the message
  if (String(topic) == "esp32/output") {
    Serial.print("Changing output to ");
    if (messageTemp == "on") {
      Serial.println("on");
    }
    else if (messageTemp == "off") {
      Serial.println("off");
    }
    else {
      Serial.print("Completely not understandable: ");
      Serial.println(messageTemp);
    }
  }
}

void reconnect() {
  // Loop until we're reconnected
  while (!client.connected()) {
    Serial.print("Attempting MQTT connection...");
    // Attempt to connect
    if (client.connect("ESP8266Client")) {
      Serial.println("connected");
```

```
      // Subscribe
      client.subscribe("esp32/output");
    } else {
      Serial.print("failed, rc = ");
      Serial.print(client.state());
      Serial.println(" try again in 5 seconds");
      // Wait 5 seconds before retrying
      delay(5000);
    }
  }
}

uint32_t getChipId() {
  uint32_t chipId = 0;

  for (int i = 0; i < 17; i = i + 8) {
    chipId |= ((ESP.getEfuseMac() >> (40 - i)) & 0xff) << i;
  }
  //Serial.printf("ESP32 Chip model = % s Rev % d\n", ESP.getChipModel(),
ESP.getChipRevision());
  //Serial.printf("This chip has % d cores\n", ESP.getChipCores());
  Serial.print("Chip ID: "); Serial.println(chipId);

  return chipId;
}
```

Sensor Node - Sensor

```
int getLightIntensity() {
  uint8_t intensity = 0;
  digitalWrite(ALS_PIN, LOW); // activation of CS line
  intensity = SPI.transfer(0) << 3; // Aquisition of first 5 bits of data without leading
zeros
  intensity |= (SPI.transfer(0) >> 4); //Aquisition of last 3 bits of data and appending
  digitalWrite(ALS_PIN, HIGH);

  Serial.print("Light intensity = ");
  Serial.println(intensity);

  return intensity;
}
```

Sensor Node - Services

```
#include "time.h"

void initTime() {
  const char* ntpServer = "pool.ntp.org";
  const long  gmtOffset_sec = 3600;
  const int   daylightOffset_sec = 3600;

  //init and get the time
  configTime(gmtOffset_sec, daylightOffset_sec, ntpServer);
}
```

```
String getLocalTime() {
  // datetime format: ddmmyyHHMMSS

  struct tm timeinfo;
  if (!getLocalTime(&timeinfo)) {
    Serial.println("Failed to obtain time");
    return "notime";
  }
  //Serial.println(&timeinfo, "%A, %B %d %Y %H:%M:%S");

  char timeString[12]; //ddmmyyHHMMSS
  strftime(timeString, sizeof(timeString), "%d%m%y%H%M%S", &timeinfo);
  //print like "const char*"
  Serial.print("Datetime: "); Serial.println(timeString);

  return timeString;
}

uint32_t getUptime() {
  uint32_t  uptime = esp_timer_get_time();
  Serial.print("Uptime: "); Serial.println(uptime);

  return uptime;
}
```

Weather AI Code

```
import requests
import argparse
import time
import random
from datetime import datetime
from pythonosc import udp_client


def get_weather():
    lat = 55.81396
    lon = 12.20177
    appid = 'd3927f9863f8453b48f2f519d50a7950'
    r =
requests.get(f'https://api.openweathermap.org/data/2.5/weather?lat={lat}&lon={lon}&appid={appi
d}')
    status_code = r.status_code
    print(status_code)

    if status_code != 200:
        print(f"Request error: {status_code}")
        return

    d = dict()
```

```
    print(r.json())

    temp_k = r.json()['main']['temp']
    temp_c = float('{:.2}'.format(temp_k - 272.15))
    print(f'Temperature: {temp_c}°C')

    weather_id = float(r.json()['weather'][0]['id'])
    weather_description = r.json()['weather'][0]['main']
    wind_speed = float(r.json()['wind']['speed'])
    wind_dir = float(r.json()['wind']['deg'])
    print(weather_id)
    print(weather_description)
    print(wind_speed)
    print(wind_dir)

    d['temp'] = temp_c
    d['weather_id'] = weather_id
    d['weather_description'] = weather_description
    d['wind_speed'] = wind_speed
    d['wind_dir'] = wind_dir

    return d


def get_time():
    now = datetime.now()

    current_hour = now.hour
    current_minute = now.minute

    t = dict()
    t['hour'] = float(current_hour)
    t['minute'] = float(current_minute)
    t['minutes'] = float(current_hour*60+current_minute)
    print(t.get('minutes'))
    print(f"Current Time = {current_hour}:{current_minute}")

    return t


def send_osc(d, t):
    client.send_message("/wek/inputs", [d.get('temp'), d.get('wind_speed'), d.get('wind_dir'),
t.get('minutes')])
    print('OSC send complete')


# Press the green button in the gutter to run the script.
if __name__ == '__main__':
    parser = argparse.ArgumentParser()
    parser.add_argument("--ip", default="127.0.0.1", help="The ip of the OSC server")
    parser.add_argument("--port", type=int, default=6448, help="The port the OSC server is
listening on")
    args = parser.parse_args()
```

```
    client = udp_client.SimpleUDPClient(args.ip, args.port)

    while True:
        t = get_time()
        d = get_weather()
        #send_osc(d, t)  #nightTrain
        send_osc(d, t)  #dayTrain
        time.sleep(1)
```