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"From Abstractness to Concreteness – experiential knowledge and the role of prototypes in design research"

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From Abstractness to Concreteness – experiential knowledge and the role of prototypes in design research

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New patterns of prototyping: developing concepts with playful exploration and probing. A case study within arts and design.

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Abstract

This paper explores the initial phase of a series of prototype-based design investigations in the field of visual and interactive computing from an artistic and design-oriented perspective. We propose a novel paradigm for interacting with prototypes, particularly suited for the contexts of design and art. Accordingly we demonstrate how this interaction, referred to as "probing", differs from the traditional approach of prototyping (i.e. experimenting). These findings are exemplified and illustrated by an actual prototype that is presented alongside. By introducing this prototype, which can be understood as an artistic framework, we derive a model that systematises the creative work with and on prototypes into an epistemological typology. Through this "probing" we come to realise the importance of embracing and utilising the quirks, flaws and limitations that arise, which can become prominent features of the design with unique qualities. Finally, we provide insights and a model how these concepts can be applied to prototype-based design and development in general.

Art & Design; Probing; Playful Interaction; Transformational Stepping

This paper examines and gives insights into and examples of the early stage in a series of prototype-based design explorations in visual and interactive computing from an artistic and designerly perspective. With our background in art, computer animation and 3D modelling, we wanted to challenge and explore how our knowledge, professional experience and artistic intent could be organised and constructed in a co-creative dialogue centred around a concept of a machine which, through its construction, could ensure desirable yet surprising outcomes. Thus, through co-creation, we could learn and reflect upon the virtual and the physical simultaneously. We use the concept of a potential machine to find out if we can become cartographers, explorers and painters at the same time (Olsson 2007) as we design the machine itself. In this paper, we want to show how 3D objects, movement and light sources can facilitate new forms of image and map-making, through a series of transformational steps mediated as a shadow world and captured on a white surface. From previous projects, we highlight the importance of making use of the quirks, errors and shortcomings that constantly appear (Siess et. al 2019) and that—if used smartly—can become major features of the design with specific new qualities. "We must integrate the element of the unknown into the design process as a constitutive, productive factor for design—not simply as a lack of data, but as a driver of design development.” (Folkmann 2014) The paper presents a model of how our prototype work is executed and includes examples and findings. We also show two case studies of the preparation for the second iteration of the machine prototype. They were created as an installation piece for the *Evangelische Stadtkirche am Marktplatz* in Karlsruhe, Germany and a project that generates real-time music performances from shadow maps by interpreting them as a “music score”.

The difference between simulation and virtuality

At this point, we would like to pose the question of whether a prototype should always be interpreted as a simulation, or whether it is also a suitable source of inspiration. To clarify: The goal of a simulation is to replicate “physical” (i.e. “real”) phenomena as accurately as possible. Therefore, simulation strives to create objects that pretend to be their “real” counterparts (Esposito 1998: 270). Our prototype, on the other hand, does not pursue this goal at all, but literally turns this relationship on its head, since it is not intended to reproduce the real world, but rather to serve as an inspiration for the generation of ideas which, in turn, will then have an impact on physical reality. In the late 1990s, this difference had already been extensively addressed—albeit in a completely different context, i.e. in the distinction between simulation and virtuality. We would now like to argue that the ontology of the prototype cannot be read in the context of simulation exclusively—in which it undoubtedly provides valuable contributions to the very practice of design—but can also be interpreted in the context of the virtual and thus be used for (visual) arts as well. The virtual, as Esposito or Ryan note, pursues much richer intentions than simulation, but seeks to create genuine transformative qualities for which the question of a “real reality” is completely indifferent (Esposito 1998; Ryan 2015). Accordingly, the key question is not whether a prototype can represent a real phenomenon as accurately as possible, but rather whether a prototype significantly impacts the interacting artists/designers to empower them in their endeavour to reshape reality. Much like the proverbial oak in the acorn—a quote erroneously attributed to Aristotle—the prototype only plants the “seed”, from which, depending on the context and especially on the interacting subject, a new (proverbial) tree grows (Lévy 1998). Thus, the prototype, or virtual model, serves as a starting point for the development of new ideas and ways of understanding the world. Since it is not concerned with accurately reproducing reality, but rather with empowering the artist or designer to shape and reshape reality in meaningful ways, it demands new paradigms of interaction that embrace and “exploit” the ambiguity and plurality of the prototype. Schiesser conceptualised this characteristic of a medium using the term *Eigensinn*, which can be roughly translated as “obstinacy” (Schiesser 2004). This term conceptualises the “drive” of any artistic material (i.e. in our case, the prototype) for certain aesthetics, mechanisms and functions in constant interaction with the obstinacy of the interacting subject, creating a “force field” between subject and prototype that initialises and nurtures the creative process. Since any creative process could benefit from transformational qualities that forsake the ideal of replicating external circumstances as faithfully as possible (Ryan 2015), we believe this brief discussion of the virtual vs. simulation resonates with the new paradigm of prototyping that is presented in this paper. It is important to emphasise that the virtual is not necessarily synonymous with the digital (Lévy 1998). Thus, a physical prototype can possess virtual qualities if it features genuine transformative characteristics and deviates from the ideal of simulation.

Models of creativity for supporting collaborative prototyping

To establish a common ground regarding ideas and models of creativity, we gathered four different models of creative action. They all serve our online collaboration with concepts, terminology and perspectives that help us shape the collaborative space between us as we generate, elaborate, and evaluate concepts regarding our prototyping with the machine. We believe that this methodological perspective is necessary to collectively develop and use different ways of thinking and analysing creative practice.

Ruth Knoller conceptualises creativity in a comprehensive "formula", in which creativity (C) emerges as a function (f) from knowledge (K), imagination (I) and evaluation (E), as well as a positive attitude (a) as a key part in the equation: C=fa(K, I, E) (Isaksen 2011).[1] How can a machine's attitude (i.e. its *Eigensinn*) be designed and explored, in order to push knowledge, imagination and evaluation into play? Furthermore, we wanted to address Boden's idea about "conceptual space": How can prototypes be set up to host conceptual spaces that can be explored, stressed, and played with spatially? Finally, Yuk Hui's ideas regarding autofinality (A-B-C-A) come into play, since in a creative process "the result is not yet completely defined: even finality itself is situational" (Hui 2019). How do we specify and design the rules that determine computational behaviour and how do you become aware of the details of the computer system that interprets such rules? To avoid that the technological systems become self-contained and self-referential, limiting the potential for artistic intervention and creativity.

The prototype

Key inspirations

For inspiration and reference to the mechanism and layout of an interactive and procedural machine, we initially turned to three different sources as our starting points:

1. "Wheel" by M. Tansey and F. Buener (Taylor/Tansey 1999)—an analogue "inspiration machine" comprising three independent rings, each featuring 180 labels, which suggest the degrees in a triangle that can be combined to form phrases. Each rotation produces one of 5,832,000 possible word combinations that act as a motif for a subsequent creative process. This "machine" can be interpreted as a "proof of concept" that even with a "banal"—and "monoaesthetic" (Schiesser 2004) medium such as words/phrases—acting as an initial starting point, it seems possible to create interesting and fruitful inspiration. This phenomenon gave us reassurance and certainty that our first prototype, despite its equally banal structure comprising purely basic shapes, such as triangles and rectangles as shadow casters, could nevertheless

[1] See also: https://www.russellawheeler.com/ruth-noller-creativity-formula

produce meaningful (i.e. inspirational) output.

2. “Schattenspiel”, (shadow play) by Hans-Peter Feldmann—an assortment of toy figures and bric-a-brac arranged on slowly revolving turntables. The light shining on the objects causes shadows to be cast onto walls. The shadows evoke wonderment, which encourages the audience to see simple everyday objects in a new light. We interpreted this piece as a “proof of concept”/confirmation that shadows contain an enormous bandwidth of transformational and inspirational qualities.
3. “Zoetrope”, “Daedalum” or “Wheel of the Devil” by British mathematician William George Horner (1786–1837). This machine is one of the first devices that could achieve animation through the rapid succession of otherwise static images (Horner 1834). The invention strongly influenced the basic configuration of our prototype—since the “Zoetrope” was not built to do any physical labour yet recalls the modus operandi of “real” machines—at least in its visual appearance.

Design and configuration

The integration of all key inspirations into a singular device serves to outline the fundamental form and function of our first prototype. Dubbed the “Landscape Wandering Machine”, this prototype was constructed as a rigged and animated 3D model comprising 48 objects arranged in fixed positions on three concentric rings that can be rotated independently. Six moving light sources were utilised to illuminate the scene, casting shadows onto a plain tableau at the centre. Initially, the prototype’s configuration was relatively basic, yet the resulting shadow images captured from the tableau were deemed promising for further exploration and experimentation due to the non-deterministic interplay of the shadow casters. However, it is important to note that these images, similar to the phrases in Tansey’s and Buener’s “Wheel”, are not the final product/outcome, but rather serve as an initial starting point for further transformations; thus, they are referred to as “maps” in subsequent discourse. In a sense, this prototype occupies a meta-state between abstraction and concretisation, as it was created and tested entirely within the digital space of CAD software, and initial experiments and probes were conducted exclusively in that realm. However, it also gave rise to the first haptic model, which was produced by 3D printing (Figure 1, right image).

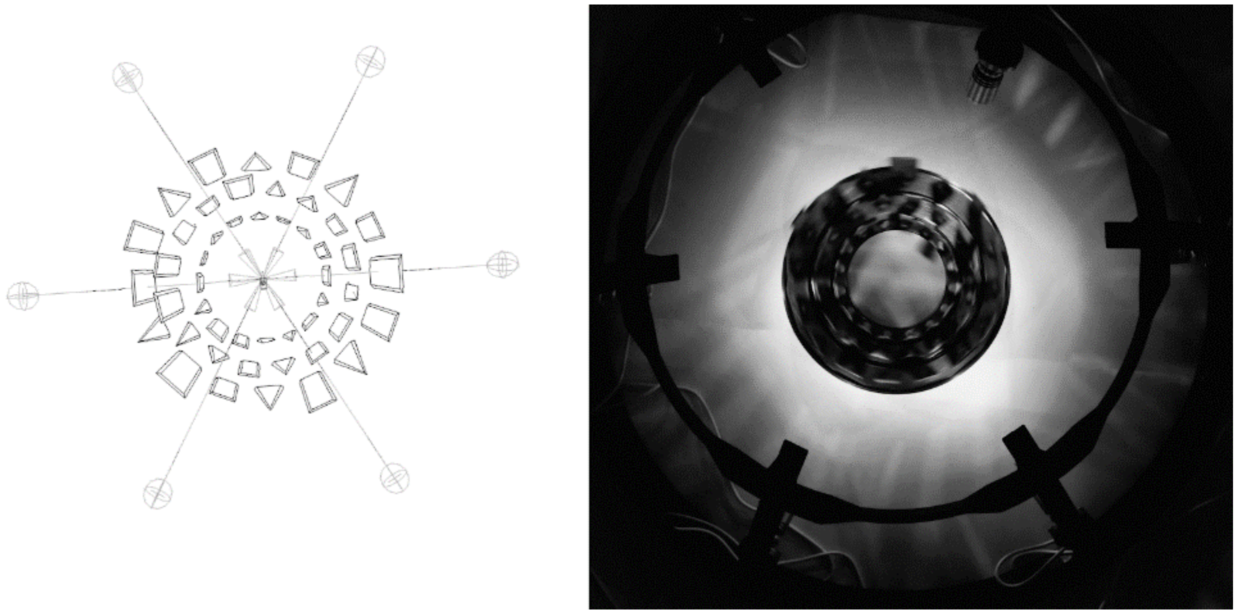

Figure 1: The digital prototype and 3d printed prototype with LED based light rig.

“Sketching” with probes

Using the initial concept of “obstinacy” (*Eigensinn*) described above, we started working on this prototype. We should mention here that we regard a prototype in this early conceptual stage of exploration, development and design as a conglomerate loosely assembled in a common media format. The aim of the prototype is to create a “gravitational centre” that tries to initially pull the disparate elements together as a compositional assembly, “bringing parts, materials, functions, structures, processes, activities, and events together in such a way that they have an emergent presence or an appearance in the world.” (Nelson and Stolterman, 2003). For our part, the role of the prototype, as described by Herbert, relates to designers’ sketches, “not of passive recording but of active participation in formulating the design” (Herbert 1993). The choice of using simple geometrical objects such as rectangles and triangles was in a direct and effortless way to transform the words and statements of “the Wheel” into a visual realm. This is because our intention was to work on a design that thrives and communicates back to us visually during the entire research and machine construction process. The physical prototype and later the *Knowledge Horizon Trajectory model* (KHT, see Fig. 2) became a vehicle for our tacit knowledge exchange from our former practices and experiences. “The tension here is between the knowing of the corporeal, so fluid and effortless, pushing against the need to verbalise through the cognitive” (Budge 2016).

At the beginning of the first iteration, we stayed true to the “traditional” concept of prototyping: by maintaining a 1:1 relationship between the digital and the real model, we created a “twin” with which we could simulate the state of the respective counterpart. Not least because of the physical distance between the two artists involved (Sweden–Germany), this aspect was essential. It was a deliberate design decision to articulate, as well as to blur the borders between digital and mechanical machines and interfaces. This created an almost contradictory interestingness and ambiguity that nurtured our individual imagination, since “in the art-based design research, the imagination is the intellectual medium that synthesises antitheses, turns difference into likeness, unifies oppositions and does so in pleasing and striking ways" (Murphy, 2017). To our surprise, the images that emerged in both prototypes were rather complex structures that were formed from overlapping shadows and were very different from the simple shapes of triangles and rectangles from which they were created. Here, the idea of using probes as a sketching technique emerged as a method for the design and exploration of the shadows that the prototype created.

In contrast to the experiment, which takes place in a controlled environment that aims to achieve replicability as well as objectivity and involves the experimenter having at least one hypothesis of the expected outcome, the aim of probing is to be feasible in a pluralistic environment and embrace ambiguity as a creative force. Thus, the probe does not aim to achieve any "epistemic validity", but instead strives to expose the *Eigensinn*, i.e. the inherent uniqueness of the symbiosis between the medium and the interacting subject. The designed and ready-made or crafted probes then became a process of knowledge acquisition or learning from the previously unknown within the areas of the conceptual and concrete space of the prototype. The knowledge acquired by the probes not only pertained to the particular domain of the machine, but also to the process of creating the machine and its component parts. Thus, we acquired knowledge by using probes on how to evolve the machine and how to construct and run it, based on what it can visually output. The probes helped us create a "richly textured but fragmented understanding of a setting or situation, to inspire what might be" (Boehner et al. 2012). This approach does not explicitly define and reduce the machine to a sole function but instead enables us to continually generate something visually, to develop hidden potentials to be discovered or rediscovered. By using probes and probing the prototype, we were able to create complex, associative and multi-layered maps (our chosen output) that could be visually captured on the intended surface on which in turn new families of association and structures of meaning were to be established. It pointed us in the direction of *Klecksography*, a creative method where inkblots are used to create stories or poems about the shapes formed by the ink. The uncertainty engendered by these ambiguous figures was very much in line with what we expected in this early stage. As recorded sketches, they "provide a flexible and dynamic external memory in which designers can place ideas for later inspection, and they also present visual cues that allow designers to associate functional issues with emerging structures" (Suwa and Tversky 1996; see also: Tovey et al. 2003). In retrospect, the physical and computational space of the shadows in our first prototype was a fairly straightforward process to construct, but for each probing activity, the level of complexity increased and paved the way for even more new considerations regarding the designed computation and the quality of the outcome—from methodological choices in the "machine's" design to parameterisation.

The Knowledge Horizon Trajectory model (KHT)

To be able to visualise and find a common ground in which we could identify and collectively reflect on our prototyping activities, we created a model of our pursued approach of prototyping. This was achieved by articulating a circular field, referencing the gravitational centre of the established knowledge (see also: Nelson and Stolterman (2003)) in which our compositional assembly was placed. For each probing activity, we then drew a line ("trajectory") from the model's centre to show whether the probing activity confirmed our prior knowledge—what we refer here as our knowledge horizon (KH)—whether it exceeded our assumptions, or whether it pointed us in the direction of "unknown unknowns" (e.g., there may be aspects that are currently unknown to us, and we may not even be aware that we lack knowledge of these areas.). In addition, the model facilitated our comprehension and articulation of constraints, limitations as well as possibilities and potentials that extend beyond the primary focus of the prototype, engendering discussions of potential issues and concepts related to scenarios that have yet to arise. Furthermore, the metaphor underlying the KHT can also be extended to further aspects. One such aspect to be discussed here is the function of “gravity”, i.e. the autonomous force which influences and distorts the “forcefield” established through the KH. In our model, the artist(s) could serve as such a force, attracting distributed aspects/objects that already exist within the KH through their sheer presence and, in particular, their personality (i.e., their “wilful obstinacy”/*Eigensinn*). By transformational manoeuvring, (re-)combining and (re-)composing these (heterogenic) aspects/objects, new constellations of epistemic objects can be created (i.e. new ideas emerge), which, in turn, possess the potential to expand the KH through their own gravity/inertia.

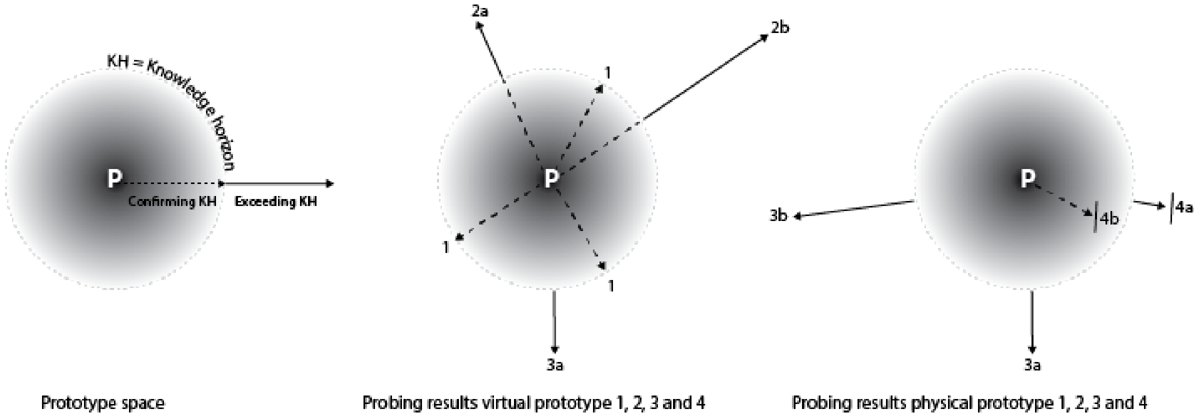

Figure 2: KHT model with examples of a probe’s possible trajectories within the creative space in relation to the “knowledge horizon”.

From abstractness to concreteness: Applied examples of the prototype’s epistemology

The following section aims to illustrate how we aggregated forward and noted the trajectories exhibited in the KHT model by showing some specific examples of the probing activities that we conducted with our prototype.

Probes used to explore, stress and play with specific known features inside of the knowledge horizon (trajectory 1 in our model)

HDRI. Given that the intensity and position of light naturally have a significant impact on the resulting shadow maps, even seemingly insignificant changes in the parameters of the light sources resulted in substantial variations. Our initial approach to this phenomenon was an attempt to “freeze” these parameters in order to establish reproducibility. Thus, the brightness values on the tableau’s surface were transferred into a static 360° high dynamic range image (HDRI). As this process is a standard procedure in computer graphics, it was determined that this method could also be successfully applied to our prototype. However, it was also noted that this significantly restricted the ambiguity and unpredictability of our machine which, while desirable in a “traditional” interpretation of a prototype, did not prove beneficial for our paradigm of interaction, which focuses on the inspirational qualities of the “machine”.

Virtual camera. The generation and rendering of the shadow images were carried out in the digital realm using a “virtual camera” that converted the shadow maps that had been created through ray tracing into image files. As this “camera” is designed to simulate a physical camera, it permits multiple parameters to be set, some of which had a significant impact on the shadow images. Specifically, we probed the combination of animation and motion blur/shutter speed, as well as the depth of field and digital noise through film simulation. Although these experiments yielded interesting results, they ultimately confirmed already-known information. In fact, they revealed yet another meta-level: due to the presence of these alienation effects (“*Verfremdungseffekt*”) in the shadow images, they contaminated the images of an ambivalent, unpredictable, virtual machine (our prototype) with artefacts of a calculable, functioning and ultimately simulating system (the render engine).However, the work on the camera’s parameters also highlighted how this plethora of settings required a different and more intuitive input method that is capable of consolidating multiple individual parameters into meaningful concepts, thereby enabling a creative form of “playing” with the prototype. This probing endeavour is presented in the next paragraph.

Rigged multimodal interaction. To be able to *exploit* the multitude of parameters and adjustments that are theoretically possible in the digital realm, we implemented a MIDI controller that was directly connected to our CAD software and that was able to manipulate and tweak six light sources simultaneously. Besides the more intuitive user interface, we also merged some individual parameters into groups that can be tweaked using one haptic knob/key. The results confirm the value of implementing a playful approach to interact with multiple parameters simultaneously, as it facilitates a rapid understanding of the shadow space and its unique characteristics for future parametrisation.

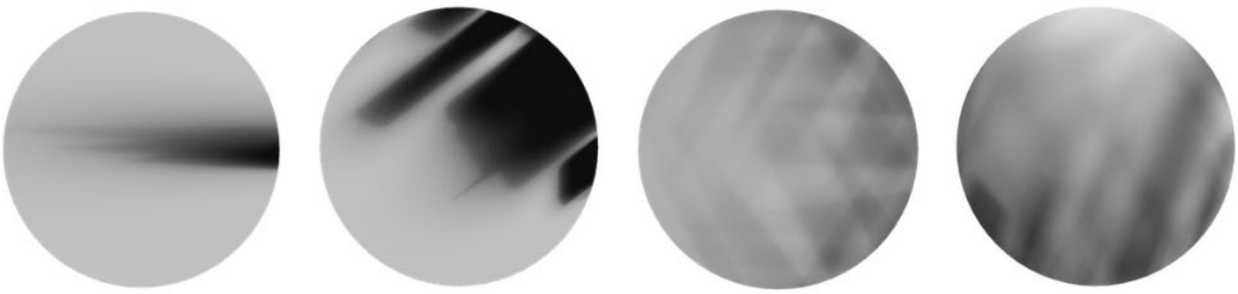

Figure 3: Exploiting, layering, staging, posing, and composing.

Probes used to explore, stress and play with a specific known feature that will eventually exceed/break the gravitational field of the prototype and therefore exceed the knowledge horizon

Probing with different image formats such as tif, tga and png (trajectory 2a): In our work on transformational stepping (see below), we noted that the dynamic range of 8-bit images was not sufficient to produce high-quality displacement maps. Thus, the OpenEXR file format with its 32-bit pixel depth will be our candidate in the next prototype. Since this format features a broad range of capabilities that require a corresponding workflow, we expect that a more in-depth understanding of its capabilities will be necessary—which can itself be developed through probing explorations.

Probing via a concept of transformational stepping using displacement maps (trajectory 2b): In the quest of “moulding” a “mountain”, we used the concept of recursion in a series of displacement map renderings. We tried to interfere with the machine by introducing different masks (2D as well as 3D) into the machine’s recursive rendering process to slowly steer it towards something that resembled the shape of a mountain. The results were beyond our expectations. The mountain-like landscape included several unforeseen properties and qualities and underlined that the prototyping processes, by using lights and rotating objects, could produce quite complex results.

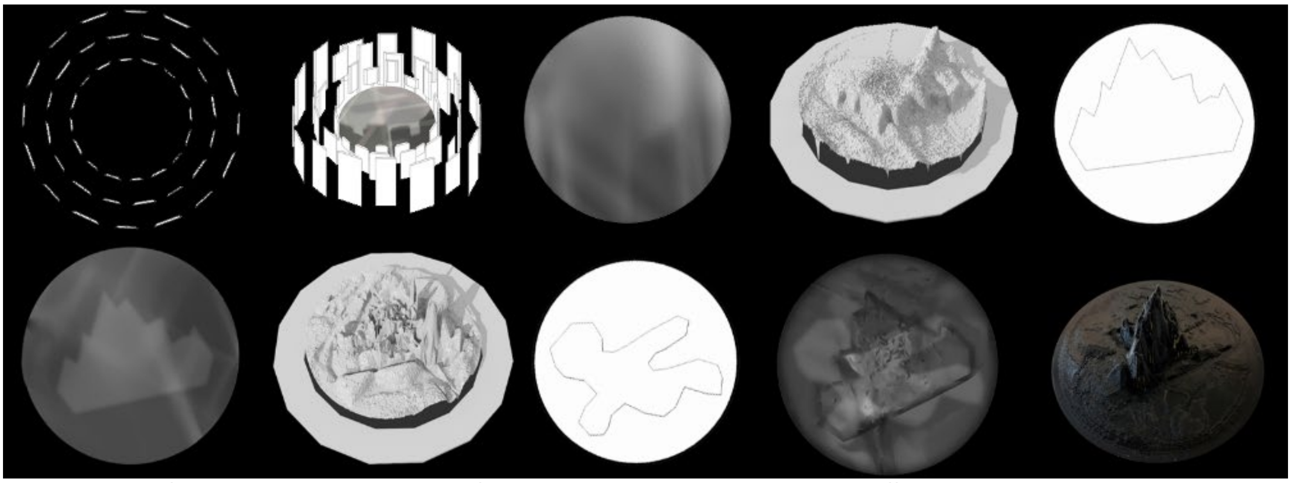

Figure 5: Transformational stepping. To interfere with the machine by introducing different masks into the machine’s recursive rendering process, leading from map to a 3d printed model.

Since the generation of the “mountains” relied on the recursive use of displacement maps, the quality of their rendering, as discussed in Section 2a, was found to be of exceptional significance. This process also challenged the rendering engines that were utilised, pushing them to their limits. By reusing and transforming 2D renderings—typically the final result of a design process—into 3D objects, a plethora of quirks and errors in the images were revealed, which would otherwise not have been apparent. It was noted that these subtle errors that were revealed through this transformational process (Boden 2003) possessed their own distinct and appealing aesthetic. Although the method of rendering in a CAD environment is well-established (i.e. confirming the KH), the “overdriving” of this process led to new insights. This trajectory takes the prototype from a stable to an unstable state, “at the edge of the knowledge horizon”, until a new stable condition is ultimately reached that exceeds the KH.

Unknown properties of the concept of the machines that were discovered in unknown parts (negative space) of the prototype and that can be introduced in the next iteration of the prototype

Trajectory 3a: The materiality of the disc became an issue and demonstrated how the material aspects of the disc itself in both virtual and physical models are significant and will be addressed in future prototypes. Should we deliberately play with different materials or lock it as a static parameter, focusing on other aspects of the machine’s components?

Trajectory 3b: Certain characteristics of the physical light sources we used were difficult to transfer to the digital domain. Specifically, the LED optics exhibited chromatic aberrations and diffractions that introduced highly "interesting" effects to the shadow images. We discovered that each lamp possessed its own unique qualities, which could also be tweaked by adjusting the optics. In principle, the digital prototype would be capable of reproducing these unique qualities, provided the individual characteristics of the lamps were known. However, it was the "haptic" and intuitive quality of the physical object that ultimately inspired us to consider further exploration in this direction.

Constraints and limitations

Trajectory 4a: Self-Illumination: As previously discussed in the chapter on virtuality and simulation, the goal of the physical and digital prototype was not to achieve complete equivalence of both domains (i.e. implementing a "digital twin"), but rather to facilitate and exploit the specific *Eigensinn* ("obstinacy") of the respective medium. This allows for the opportunity to create material properties in the digital prototype that are difficult or impossible to replicate in the physical world, yet which still could impact the resulting shadow maps. For example, we probed emitting, semi-transparent and fully absorbing materials for the silhouettes. Since these properties of the material either demand specific measures or cannot be replicated at all with the physical prototype, we hit a hard boundary with this probe. Although they were initially frustrating, these constraints also nurture the creative process since they define and outline the "conceptual space" for each respective domain. It therefore becomes apparent why the prototype's transformations and its general transformative qualities are of such importance to the creative process: By translating from the digital into the physical realm and vice versa, the specific *Eigensinn* of the opposite domain becomes apparent.

Trajectory 4b: An observation that we were able to make by utilising the haptic prototype was the specific characteristics of the light sources we employed. The attributes of said sources (such as beam angle, falloff, etc.) also defined the physical dimensions of the prototype. While in a digital environment, a light source can be infinitely small or infinitely distant, this is not possible in a physical space. Here, we encountered a hard boundary that constrained the replication of the properties of the digital prototype in the analogue realm.

Playful explorations towards a second prototype

Skopéin

While previous investigations yielded distinctly digital outcomes, on this occasion, a digital prototype was employed as an "instrument" to furnish input for a media art installation titled "Skopéin". The installation was exhibited from late August to September 2022 at the *Stadtkirche* in Karlsruhe and explores the symbolic nature of the depiction of a "Heavenly Jerusalem" through an immersive 8m x 8m projection (Figure 6).

Figure 6: The Skopéin-Installation in the main church in Karlsruhe/Germany.

The artwork acknowledges the “atmosphere” of the venue by incorporating the colour scheme and the brutalist architecture of the church in its aesthetics. The projection, which comprises a 120-second animation, reduces the topos of a “Heavenly Jerusalem” to a pure abstract formal language. This animation was exclusively created in digital space by creating and animating an abstract and perpetually unfolding object, algorithmically. Through its reflective surface, the object depicts and distorts its surroundings which are visible in the multiple reflections, thus conferring the significant importance of these environments, although they can only be perceived “indirectly”. These environments were generated using our prototype by inverting the “mountains” produced in the “mountain probe” (see above), resulting in cave-like structures.

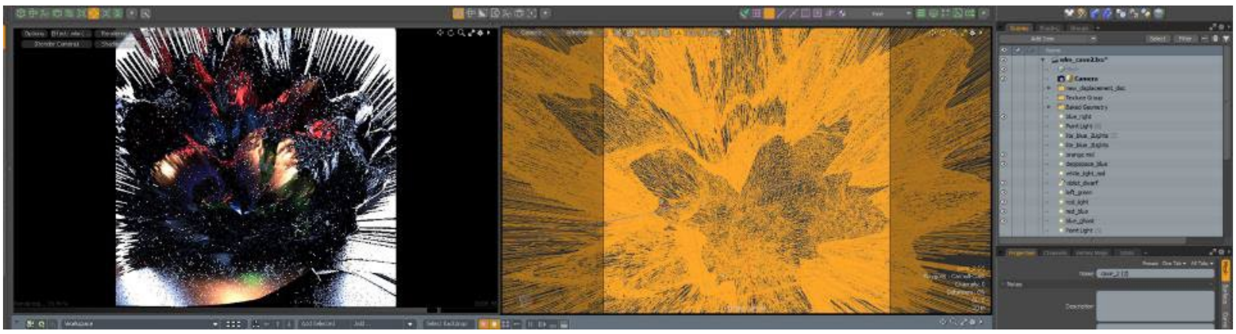

Figure 7: Maps transformed into 3d geometry illuminating it using various light sources as probes revealing and creating abstract spaces.

In these “caves” we manually placed lights as probes, both exploring the cave and illuminating it using various light sources, thus enabling the creation of highly abstract and “engaging” environments that fully met our aim of creating an abstract Jerusalem that might exist in the heavens.

Figure 8: Examples of illuminated “caves” produced by maps created by the machine.

The seemingly trivial transformational characteristics (grayscale image to 3D displacement) proved to be instrumental in providing valuable content by breaking the otherwise deterministic structure of a procedurally generated digital image by exploring features of the “cave” space with different light types to articulate its spatial qualities. Later we exploit each lightsource's respective properties in order to facilitate the appearance of “interesting” artefacts and errors while illuminating parts of the cave. In contrast to true randomness (which would have been an algorithmic alternative to breaking the deterministic nature), the “caves” still incorporated some degree of order. In retrospect, it can be stated that the success of this artwork can be traced to these particularities since they produced visual edge cases, in which the image oscillates between symmetry and chaos (Figure 8). As already outlined, creativity emerges in a “conceptual space” that embraces ambiguity and renders the expected finality to an affordance with no final conclusion. This phenomenon is not only relevant to the artist in the production process, but also to the audience of the artwork. Consequently, the artwork’s edge cases function as an affordance to facilitate the audience’s imagination. Thus, the “Heavenly Jerusalem” is synthesised in each contemplative act.

SoundScapes

The final transformation that we wish to expound upon in this discourse, which seamlessly aligns with the interaction paradigm we already conceptualised as “playing”, can be observed in our “SoundScapes probe”. This study utilised the physical prototype that features a video camera mounted above it that captures footage of the central tableau whereupon the shadow images are cast. Utilising the Processing programming language, the camera data is converted in real time into MIDI signals, which can then be transmitted to synthesisers or other MIDI-enabled instruments, such as samplers or drum machines. For this process, the individual colour channels of the camera's video feed were split and compressed to conform to the range of values that the MIDI protocol can accommodate.

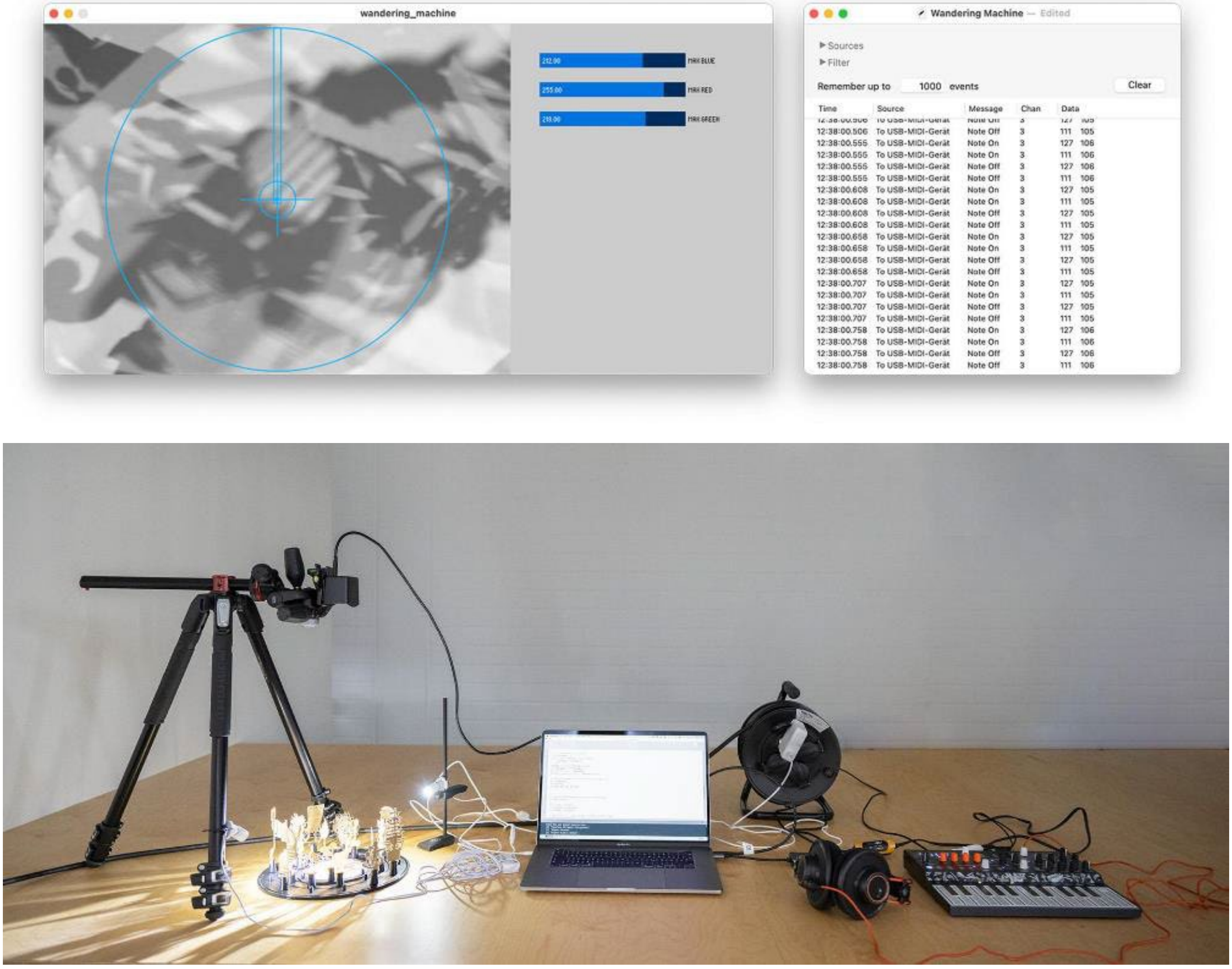

Figure 9: Screenshot of the Soundscape-project: the life camera feed (top left image) is converted into MIDI-commands (top right image) via Processing. Bottom image: The whole setup where the prototype is steering a synthesiser.

As illustrated in Figure 9, we also developed a rudimentary graphical user interface (GUI) to facilitate the alignment of the camera with the tableau and control the mapping of camera data to MIDI commands. While MIDI is capable of processing a wide range of control and notation data, we are currently only utilising a small subset of its capabilities, specifically, NoteOn, NoteOff, velocity, pitch and channel. Despite this limitation, our initial results have been promising as the setup allows us to play the machine like an instrument by altering the configuration of the silhouettes or the rotation of the concentric rings. In this manner, the shadow maps are transformed into a serial "score" that can be progressively read and interpreted. These promising results also provide the framework for contemplating a further experiment that utilises a digital prototype in lieu of a physical prototype. As already outlined, we have previously experimented with MIDI *input* devices which, in the context of the soundscape probe, can now be expanded to include the component of *output* if we use the digital prototype in a real-time rendering environment. In this manner, the prototype is transformed into a genuine virtual "instrument" that can be "played" but still incorporates the creative momentum that is created by the ambiguity and the unexpectedness of an inspirational device. Through this setup, whereby users interact with the instrument, they create a conceptual/virtual space—hence the name *SoundScape*—which corresponds with the creative space that is contoured by our model of the KHT. Therefore, the instrument both *is* and *creates* spaces, which users can decide to *explore* and *exploit*.

Preparing Iteration 2 of the machine

Even though the initial prototype produced intricate shadow images using basic shapes, we aimed to incorporate more detailed silhouettes in the subsequent prototype. Inspired by Peter Greenaway's project "100 objects that represent the world" (Greenaway, 1992), and his method of using symbolic items to communicate the life on earth, we set out to apply this method under the paradigms of our prototype: On the one hand, we are thereby *exploiting* Greenaway's project structure, and on the other hand, we are setting the stage for our own *exploration*, which seeks to determine which objects should be employed in the second iteration of the machine.. We ended up with a collection of 31 silhouettes in three different scales and appearances that possess a high degree of visual appeal (i.e. "interestingness"), in three distinct dimensions to address trajectory 1 in our model (Fig. 10). This was done in order to further "probe" with parameters and further exploit layering, positioning, posing, and composing within the new shadow space on the surface.

Figure 10: The new set of silhouettes developed for the next prototype.

In addition to our experimentation with the virtual light properties, we also conducted tests with their physical counterparts to investigate the disparities between the two, despite their comparable scale. As depicted in Figure 11, we utilized a constructed light rig featuring three distinct silhouettes to playfully explore and quantify the angles, intensity, and distance of the physical LED-based lights to acquire a more thorough understanding of where to place the lights and at what angle. This was done in order to identify the optimal positioning of the lights and silhouettes to interact and generate shadows on our circular surface. As a result of this pre-prototype activity, we made several modifications to our design. Specifically, we transitioned from flat to elevated rings to enhance the distribution of the silhouettes' shadows across the three rings, altered the overall composition density by reducing the number of silhouettes from 48 to 31, and employed prime numbers (7, 11, and 13) as fixed positions of the shadow casters on the concentric rings to minimize overlap.

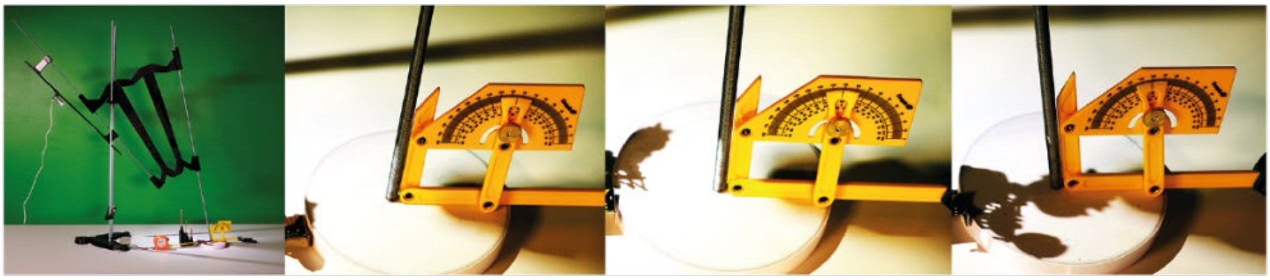

Figure 11: 3D printed light rig for playful and direct interaction with the light source, to rapidly understand which angles and distances of the lighting are most favourable.

Conclusion

Through the work and experiences described in this paper, we would like to emphasise that increased complexity in creative development still calls for both disciplinary depth and integrative skills when working with prototypes. Thus, there is a demand for a deeper challenge between virtual and physical objects, and a desire to explore their incompatibilities, rather than merging them together into one. When we engage in such activities and have ideas and concepts that emerge out of vague situations, prototyping using different media and materials plays an important role in conceptualising the known and unknown. We can never initially know whether the compositional assembly is appropriate or suitable, or if the chosen or created components are insufficient. Here, we would like to address the importance of imagination, bridging us from the proverbial *what-is* to the *what-if* (Hopkins 2019). The model we initially used soon began without any intention from our side to function as a notation system, a cumulative way to mark our findings in the KHT model while designing, tweaking, and testing the prototype and the parts as we progressed. This helped us to document our findings and shortcomings, inside of the knowledge horizon within the model. Using the trajectories to direct us to new areas of unexplored terrain, provides us with what might also be used in the next prototype iteration. Finally, in relation to our work on the prototype model, we would like to emphasise that in prototyping activities, it is important to know when to *explore* new ground by directing your attention elsewhere, and when to *exploit* and look more deeply at the material you have at hand.

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