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What is Now.

Interaction moulds present.

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Contents

Abstract

This thesis deals with the portion of time which we actually experience: the present. Especially through which means it is created. My basic hypothesis is that interaction moulds present.

With the dawn of occidental philosophy in ancient Greece at the latest mankind thought upon the nature of time, how it manifests itself, which meaning it has had for being and many other aspects. A debate and examination seen right through into our times. This thesis joins the debate by focusing solely on the portion of the present and how it is established. The concept "interaction moulds present" reflects on the findings in quantum physics and the branches of social science in constructivism.

In the course of this thesis, several concepts of quantum physics and constructivist social science are explained to outline the meaning of interaction in these fields. Additional attention is turned to the understanding of interaction in human-computer-interaction and interactive media art. Two fields strongly associated with the word interaction nowadays. Furthermore, ideas of system theory and their reciprocal interaction will be drawn from the fields of social science and HCI and applied throughout the thesis.

Thereupon, parallels are shown of interaction in quantum mechanical systems and constructivist social science, always in regard to how the present is moulded through interaction.

Several consequences of this concept will be broached briefly in this thesis, too. As well as an approach that discusses how further approximation of various systems is possible to turn interaction into a universal principle, valid for any system. Additionally, as the examination of the concept is strongly focused on the present, a general idea on how to put the present in context with the past and future will be presented.

With the findings made, interactive media artworks will be examined which enable the audience to reflect upon the fact that interaction moulds present. As interactive media art is one of the few forms of art which is able to create an actual reciprocal interaction.

In the light of the findings and gained insights, an interactive art work was created as part of this thesis. Like the examined artworks, it attempts to enable its audience to reflect upon the concept which is established in this paper.

A. Introductory Background

1. The Hypothesis: Interaction Moulds Present

"Interaction moulds present". Three words are the core of this thesis at hand. Three words reflect the findings in quantum physics and the social theory of constructivism.

The present, now, is the portion of time in which we live, we perform, we act. This present is established by interaction—interactions between persons, objects and systems.

Quantum physics states that particles in their pure quantum physical state have a broad range of possibilities into which they may develop. The interaction of particles with their environment creates a certain state and therefore their current present. CF. [1]

Things are behaving similarly in the theory of constructivism according to Paul Watzlawick. He states that everyone is constructing his or her own reality due to the rule set, which develops from interaction between persons. CF. [2]

People, objects, particles etc. are perpetually interacting with each other; interactions form conditions and shape rules, therefore one may say: Interaction moulds present.

1.1. Statement of motivation

The motivation to ask the question how is the present constituted arose mainly from two exhibitions and a lecture by the physicist and professor for quantum optics and quantum information Anton Zeilinger.

The initial motivation for this work came from a visit to the biggest retrospective of the painter Claude Monet in the past 30 years, in 2010. The works were ordered chronologically and gave a magnificent overview of Monet's development. In the course of the exhibition it became clear that Monet was not painting objects, but lighting conditions. This is especially evident in his series, like Haystacks or Portal of the Cathedral. It seemed, he was trying to capture an ephemeral moment in space and time. Research in his work made it clear that this was indeed Monet's intention. cf. [3, pp. 260–281]

Out of this initial motivation the development of *Lichtspeicher* started. A device to capture the ambient light of a certain moment and to function as an anchor to one's memory. In the process of that project the question arose what constitutes that one moment in time. The chapter E.1.2. elaborates further on this project.

In 2012 Anton Zeilinger and his students exhibited different setups from their lab displaying quantum physical effects at the documenta 13 in Kassel, Germany. One of the experiments was a Mach-Zehnder interferometer. A simple experiment showing many of the characteristics of quantum physics including the superposition of the states of a particle and objective chance. cf. [4] As one of the students explained the setup, a thought crossed my mind: if the actual measurement in the end of the interferometer defines the state of the particle then this might be the moment in which our world is constituted.

Further research involved a lecture by Anton Zeilinger in which he talks about information as the very foundation of the universe. In this context he mentioned, Paul Watzlawick's theory of radical constructivism. [5, min. 13:04] While reading Watzlawick's constructivist communication theory the similarities in particle and human interactive behaviour became strongly apparent.

Eventually, after seeing impressionist art, experiencing quantum mechanics and learning about constructivist communication theory, the salient question for this thesis' topic became clear: How is the moment of present established?

1.2. Premises of this thesis

Before the thesis is expounded, several assumptions must be stated to avoid confusion in the course of this thesis. For the sake of providing a balance between amount and content this thesis will answer to certain matters insofar as they are in the focus of this thesis. Following I will give an overview of these questions and subjects.

First of all this thesis tries to deliver a concept of how the present is established. To determine any metric length of the moment of present is not its main goal. I will take a brief look into this subject in chapter C.1..

In this thesis I follow the assumption that the present is situated between past and future. That is the predominant assumption of how time is structured. cf. [6, col. 1186], [7, p. 41] Ideas how the present is incorporated into the past and future, will be suggested in chapter C.3.. This matter is important to structure our conception of time and without this division we would not be able to speak of a present at all. cf. [7, p. 41] At this point it is sufficient to say that the past is memory and it can be realized—vergegenwärtigen. Things are brought back into your mind and are therefore present. The future is chance and is not predictable. However, interaction forms rules and the future becomes predictable. As Husserl and Heidegger state one's being (*Dasein*) is directional (*gerichtet*). cf. [7, p. 91f.] Therefore only things which you are focusing yourself on may be predicted to a certain degree.

This brings us to the matter of perception. Within the limits of this work it is not possible to provide a comprehensive concept of perception. It is understood that we are designed as human and statements about perception are possible within this range only. Despite this constraint, an approach to form the concept into a universal principle will be discussed in chapter C.2..

As humans we assume that we are restricted to a successive perception of events and therefore a successive perception of time. cf. [7, p. 34] It is not possible for us to stand outside the 'flow of time', and perceive it any other way. For example Boethius, a philosopher of the early 6th century, claimed that the divine spirit is facing the successive flow of time as pure constant present, unlike humans who are bound to that successive perception:

> "Während der menschliche Geist die Vergangenheit nicht mehr und die Zukunft noch nicht besitze, ruhe der göttliche Geist als stets Gegenwärtiges in sich selbst und habe die unendliche Dauerhaftigkeit der sich sukzessive vollziehenden Z[eit] als reine Gegenwart vor sich. Damit ist für ihn auch bereits das gegenwärtig, was sich in der Z[eit] noch ereignen und dem menschlichen Geist erst später zugänglich sein wird." [6, col. 1205]

Theories by the physicists Don Page and William Wooters in 1983 on particle entanglement and how it could be used to measure time showed similar behaviour as claimed by Boethius:

> "Their idea was that the way a pair of entangled particles evolve is a kind of clock that can be used to measure change. […] One way to do this is to compare the change in the entangled particles with an external clock that is entirely independent of the universe. This is equivalent to god-like (sic!) observer outside the universe

> measuring the evolution of the particles using an external clock.In this case, Page and Wootters showed that the particles would appear entirely unchanging (sic!) – that time would not exist in this scenario.“ [8]

So an outside entity would not be able to detect change and therefore time. However, the opposite is the case if the measurement is done from within the system:

> „This is for an observer inside the universe to compare the evolution of the particles with the rest of the universe. In this case, the internal observer would see a change and this difference in the evolution of entangled particles compared with everything else is an important a (sic!) measure of time.[…] time is an emergent phenomenon that comes about because of the nature of entanglement. And it exists only for observers inside the universe. Any god-like observer outside sees a static, unchanging universe […].“ [8]

In 2013 Page's and Wooters' theory was verified by an experiment Ekaterina Moreva and her team at the Istituto Nazionale di Ricerca Metrologica (INRIM) conducted. cf. [8]

Therefore, it is conjectured that the perception of time as a successive 'flow' is owed to interaction itself. The perpetual interaction of elements in our world—as quantum physics suggests [1, min. 9:32]—imply that there is no status quo of our world. If our world were in a status quo, movement respectively interaction would be missing which gives us change and therefore a course of time. A conclusion already made by ancient philosophers like Aristoteles, Augustinus, Ibn Rušd (Averrores) and others. cf. [6, col. 1999, 1203, 1213] At this point one can refer to Heidegger, too, who mutually derives time and being from each other by saying that being is ever present, thus spatial-time structured. [7, p. 94] Via the spatial component of presence—*Anwesenheit*—and the time component of present—*Gegenwart*—being is connected with space. [7, p. 94]To complete the connection, Heidegger claims that time exists because it is constantly elapsing and in this constant elapsing it is always present. According to Stepath time could be used synonymously with movement in this case:

> "[Heideggers] Prämisse lautet: Zeit hat Existenz. Obwohl Zeit andauernd vergeht, ist sie in diesem Vergehen doch beständig, also immer da bzw. anwesend. Alternativ für Zeit hätte man hier den Begriff der Bewegung benutzen können." [7, p. 94]

Stepath summarizes Heidegger's claim that being and time are related to space—thus being is connected with time. Time as movement is not comprehensible in space but has still existence—thus time is connected with being.

> "Das *Sein* hat wie die Zeit einen Bezug zum Raum. (Auf diese Weise wird Sein mit Zeit verknüpft.) Zeit als Bewegung ist zwar nicht räumlich fassbar, hat aber dennoch Existenz.(Auf diese Weise wird Zeit mit Sein verknüpft.)" [7, p. 94]

In this way being—and with it the human existence (*Dasein*[1])—and time necessitate each other, as well as they depend on each other.

Finally, the reader should note that this thesis is a draft of an idea. As such it does not claim to be exhaustive and complete. Therefore the contents of this thesis are open to discussion.

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1 The being or existence of man Heidegger designates as „Dasein". cf. [7, p. 92]

2. Concepts of Time

In this chapter a short overview of time concepts will be provided. This overview is neither complete nor is its classification irrevocable. The aim in the end is to point out the environment in which the concept interaction moulds present resides.

Defining the nature of time is an ancient effort of humankind. With the start of early civilizations, man tried to understand the concept of time. Triggered by observations like the cycle of day and night, the change of seasons or the yearly reoccurring flooding of rivers, like those of the Nile in Egypt, meant that time was the structural framework for rituals, which linked social life with cosmic processes. This link is broken after the development of monotheistic religions and rituals are no longer connected to the formerly mentioned. At this point time starts to develop a meaning in itself.

In the late 4th century the philosopher and theologian Augustinus stated a fundamental problem when thinking about time when he exposes the difficulty between the familiarity and daily use of time and the inability to explain what time actually is if so asked.

> "Was ist also die Zeit? Wenn mich niemand darnach [sic] fragt, weiß ich es, wenn ich es aber einem, der mich fragt, erklären sollte, weiß ich es nicht" [9]

Throughout the centuries of mankind's evolution, many concepts arose and many of them emerged from precedent concepts. New concepts were often combined with the current state of knowledge. Therefore the presented categories are meant to give guidance in a field which consists of unstable boundaries.

2.1. Basic structure

A commonly presumed element of theory when thinking about time is its division into three parts: past, present and future, with the past being what happened, the future as what will be and the present, the time in which we exist. The main assumption in the western world is that the past lies behind us, we stand in the present and face towards the future. Some cultures, however, assume the future to be at the back, since we can not see it, whereas the past is in front of us, because it lies wide open before us. [6, col. 1186]

However, it must be noted that this trisection is already a substantial interpretation of the structure of time. There are other concepts which structure time differently, for example into being and not-being [7, p. 41]

Contents in this thesis adhere to the familiar structuring into past, present and future.

2.2. Reversible and irreversible time

Reversible and irreversible concepts of time started to develop early through the observation of nature and are already strongly evident in the early ancient Greek's philosophy. CF. [10, P. 15]

Reversible time concepts are based on reoccurring natural events like the change of day and night, the seasons and also regular recurring man-made rituals. [6, COL. 1187] Also Newtonian physics are based on a reversible time concept. [10] When described mathematically, simple processes like throwing a ball from point A to B do not make different statement about their condition at any point of the process when the process' time is reversed. Time still passes during the process, but it is not evident in the mathematical description. CF. [11, P. 21] Therefore Newton distinguished between a „relative", i.e. the reversible, and an „absolute" time. CF. [6, COL. 1246] Irreversible concepts derive for example from the span of life CF. [6, COL. 1188], considering if one could bathe in the same river twice as Heraclitus did CF. [10, P. 16], or observations of processes like gas expanding from a small into a large container CF. [11, PP. 21–24]. The process of gas expanding for example is irreversible, because the thermodynamic laws and the principle of entropy therein express irreversibility of processes in nature. Entropy is the physical value of order. The higher the entropy, the lower the order. The 2^{nd} thermodynamic law states "[f]or an irreversible process in an isolated system, the thermodynamic state variable known as entropy is always increasing." [12] To reverse the process of an expanding gas, energy must be invested and therefore increasing the entropy again in another context. CF. [11, P. 23] The fact of entropy is interpreted as an arrow of time. CF. [6, COL. 1247]

Reversible and irreversible concepts of time appear to oppose each other. There have been many attempts to explain the correlation between both. CF. [10]

2.3. Independent time

Independent time may be understood as a concept in which time is not strictly associated with happenings in space. According to this concept time may exist without depending on change in spatial dimensions or in one's conscious.

In many ancient concepts of independent time often a deity was responsible for the creation and control of time. Humans were embedded in a divine plan and their lives were more or less guided by the deity.

In the Old Testament God is the one who is setting the right time and therefore man can not utilize it freely. A concept connected to Kairos—the right or opportune moment[2]. Generally though there is a divine plan for man's history. cf. [6, col. 1199–1200, 1207–1208], cf. [13]

In Islam the concept for man's fate is very similar—God resolves man's every move. However, it is assumed that God is newly re-creating the world at every moment over and over again. Although reality exists only for a moment, it appears continuous to us due to God's perpetual gracious actions. Such a concept is called atomism. cf. [6, col. 1223–1224]

The philosopher Boethius supports this view on God's rule over time. He claimed that the divine spirit is facing the successive flow of time as pure constant present, unlike humans who are bound to their successive perception. Therefore events are already present to God which may be accessible to the human mind only later. cf. [6, col. 1205]

Later on, when modern scientific method dawned, concepts of time were developing into a mixture of independence of space and dependency on motion.

Thomas of Aquin still regards time as not equivalent to motion, as motion can be faster and slower, unlike time which is running always at the same speed. However, we may sense time only by motion because we recognize a before and after in the motion. He bases the reality of time on the moment which ontologically means that the flow of time is equivalent to motion. cf. [6, col. 1214] In this sense he is also represented in chapter A.2.5. „Moment of present".

Pierre Gassendi has a similar view on the perception of time. For him change in the world, which can be sensuously experienced, is necessary to notice the flow of time. cf. [6, col. 1227]

Even Sir Isaac Newton still clung to a concept of independent time. He distinguished between an independent so called absolute time and relative time. The absolute time was steady and flowing without reference to anything external. It was a construct to coherently explain nature in its entirety. The relative time was a measurement of any duration which could be experienced with one's senses, like hours, days, months etc. cf. [6, col. 1228]

Besides reckoning time as material many philosophers defined time, at least partly, as a psychological phenomena or construct. The continuum of time is such a phenomena according to Hasdai Crescas. cf. [6, col. 1221] This thought was summarized by Spinoza

2 See also chapter A.2.5..

and intensified to the point that time is only a subjective way of imagination. [6, col. 1229]

Or as Berkeley would put it:

> "Time therefore being nothing, abstracted from the succession of ideas in our minds". [6, col. 1231]

As one can see, the idea of an independent time is prevalent throughout history and still is. At first glance this seems more compatible with our world view. But upon a closer look the idea of an independent time leads mostly to artificial constructs and finally takes ideas from concepts of time being motion dependent.

2.4. Relative time and space-time continuum

This section deals with concepts in which time and space are interdependent. Basically this means that time is dependent on movements in space. They mostly relate to movement as a means of measuring change and thus time.

The ancient Greek philosophers had already developed such concepts. Most famously Aristoteles introduced this method in his work *Physics*. cf. [6, col. 1199]

> "[...] die Z[eit] ist die «Zahl der Veränderung hinsichtlich des davor und danach»; «numerus *motus* secundum prius est posterius» [...]" [6, col. 1212]

This concept and its many modifications was and still is popular with many scholars throughout history. For example the school of Pyrrhonian scepticism basically doubted the existence of time but should it exist it must be connected to change. cf. [6, col. 1202]

During the Middle Ages Joahnnes Scotus Eriugena formulates an ontological understanding of the world in which time and space are the primordial rules for the very existence of any being, matter or knowledge. However, Eriugena is doubting that time is solely dependent on change. He sees that time is the certain dimension of duration or a quiescent state (*mora*) and motion (*motus*) for all changing things in the world. This concept of *mora* and *motus* was applied and modified by other scholars during the middle ages like the lexicographer Papias, Gilbert of Poitiers or Allain de Lille. cf. [6, col. 1210–1211]

An interesting thought comes from the Arabic philosopher Ibn Rušd (also known as Averrores). In his view time and motion are indistinguishable in their material. Time is not dependent on any motion outside of the soul, it is a potential within the soul—a radicalisation of Aristoteles' view. However, from this follows that it is enough to recognizing yourself as a changing being within your soul to notice the flow of time. cf. [6, col. 1213]

The Jewish scholar Moses Maimonides strongly doubts the existence of time without any motion. For him time is mere accident and an inevitable consequence of motion. Time can not be even thought of without motion, because immovable things do not even belong to the concept of time. cf. [6, col. 1221]

The most prominent theory of our days are Einstein's theories of special and general relativity. In these theories the idea of any independently existing time is completely abandoned and replaced with the concept of space-time. In special relativity, Einstein postulates that "[t]he laws of physics are the same for all observers in uniform motion relative to one another (principle of relativity)." and that "[t]he speed of light in a vacuum is the same for all observers, regardless of their relative motion or of the motion of the light source." [14]. That means that distances in space and time depend on the inertial system from which they are observed. Two events which are observed as simultaneously inside an inertial system, are not observed as simultaneous from an inertial system moved relative to the first one. cf. [11, p. 15] General relativity, in fact a theory of gravity, additionally incorporates the fact that the effects of acceleration and gravity are indistinguishable. cf. [6, col. 1248] Time in this concept becomes dependent on the strength of the gravitational field. cf. [11, p. 25]

2.5. Moment of present

Often embedded into concepts of independent and relative time are various concepts about the moment of present. It constitutes either a contrasting element to eternity or a turning point in time if utilized. In some cases it is even the sole ontological basis of time or reality.

Ancient Greek philosophy differentiated between several concepts of time: *χρόνος* (chronos) is the continuously advancing long-drawn time which contrasts the other concepts *αίων* (aion), one's alloted power and therefore time of life, *ήμαρ* (emar), the day as it is experienced, and *καιρός* (kairos). cf. [6, col. 1190–1192], cf. [13] *Καιρός* is the crucial or opportune moment, which needs to be utilized, as the Greek philosopher Pindar explains. [6, col. 1193]

Aristoteles introduces the νυν (nun) to demarcate start and end points of a duration. Concurrently a nun connects and divides past and future. cf. [6, col. 1199] Whereas *καιρός* is a qualitative moment in time with a temporal extension, a νυν is without any qualitative statement nor temporal extension, it is not even considered a part of time.

According to the Arabian philosophers Ibn-Rušd (Averrores), Al-Kindi and Ibn Sina (Avicenna) the moment of present incorporates a dichotomy as it provides division and continuity of time and allows to distinguish between past and future. In Al-Kindi's sense this feature only emerges when a moment is contemplated by one's thinking and defines the character of time. For Ibn Sina the soul holds this function, as the sole purpose of the soul is to break the continuous flow of time to mark a before and after. CF. [6, COL. 1212–1213]

Also the concept of atomism in Islam may be mentioned here again. In this concept the world, which exists of simple immutable particles, is newly created at any moment over and over again. Due to that, reality exists only for a moment. But it appears continuous to us because of God's perpetual gracious actions. CF. [6, COL. 1223–1224]

For Thomas of Aquin, as already mentioned in chapter A.2.3., the reality of time is based on the moment which ontologically means that the flow of time is congruent with motion. The same relationship exists between moment and time as between moving and motion. Additionally he adheres to the Arabian idea of the dichotomy of the moment. On the one hand it grants time continuity if it is considered the common terminus of past and future. On the other hand it divides past and future if it is considered as past's and future's discrete ending. CF. [6, COL. 1214]

In the era of Humanism, time was no longer treated as a mere theoretical problem but as the moment of man's action. According to L. B. Alberti time is the whole set of possibilities which are given in the changing circumstances. One has to use these possibilities economically—in a sense of *καιρός*—and should adapt to the circumstances. This is the essence of a harmonic lifestyle. During this period the historicity of man was discovered, too, and time becomes the narrative framework for the historian. CF. [6, COL. 1225]

Apparently Buddhism also strongly stresses an understanding of time based on the moment. Though any theory which substantiates time is avoided. As the Indian philosopher Nagarjuna was convinced for those beings whoever reached the full resolution of life time does not exist anymore. He concludes that time as independent being of its own, does not exists. CF. [6, COL. 1260]

Later on Seng-Zhao theorises that two forms of present (*now*) exist. An eternal present which is never in motion and never ends. And the actual present which constantly differs. If man realises everything in the eternal now, time will be pacified and the full resolution to life is found. cf. [6, col. 1261]

The Chinese scholar Fazang developes a model of time on ten levels. First he defines nine different times—a past of the past, present of the past, future of the past, a past of the present, a present of the present, a future of the present, a past of the future, a present of the future and a future of the future—which are all combined in a moment of thought on the 10th level. cf. [6, col. 1261]

2.6. Conclusion of time concepts

This overview of philosophical time concepts showed the rich culture of thinking about time. Most concepts would fit in more than one category. Thus they were arranged by their emphasis on certain viewpoints. It should be noted that most philosophers agree to one axiom about time: time can be conceived through change.

This conclusion was followed by supporters of time concepts relative to change or motion in space—like Aristoteles, according to whom time is a number of change. This number is made perceivable by the before and after of the carrier of this change. [6, p. 1203] This definition—an operationalization of time to measure change during an interval—is still very much the same idea of how to utilize a time scale in physics. So are defendants of concepts of time independent of motion or change—like Thomas of Aquin, who believed that time is not equivalent to motion as motion changes its speed and time always runs at the same speed. But still he falls back to motion to allow us to sense time, because we recognize a before and after in the motion. Even theories which focus only on the moment as the constituting element of time, refer to a greater structure to free themselves from contradictions towards our perceived flow of time. In ancient Greek philosophy even three time concepts were focusing rather on the present (Aion, Emar and Kairos) compared to one, Kronos, the long-drawn flow of time which, however, incorporated the aforementioned.

This may be caused by man's fundamental experience of a successive perception of events. As Stepath points out time is a constituting structure of our thinking, speaking and perceiving, therefore a requirement of our conscious. [7, p. 34]

Nowadays, due to the theory of relativity by Einstein, it appears naive to doubt that time exists without any connection to space and motion. As space and time are dependent on each other in the concept of space-time. cf. [6, p. 1248]

As mentioned above, the large portion

of time concepts agree on the one point that time can be conceived through change. An important conclusion later on, when we examine why interaction is inevitable.

B. Aspects of Physics, Social Science and Interaction

This chapter will explain the concepts superposition and objective chance in quantum physics, characteristics of Paul Watzlawicks constructivist communication theory and general notions about interaction in these two fields with additions from human-computer-interaction and interactive media art. The findings of these fields will be compiled at the end to explain why interaction moulds present.

1. Quantum Physics

The Mach-Zehnder interferometer is a simple experiment which may be used to demonstrate different quantum mechanical effects—amongst others the particle-wave dualism, superposition and objective chance. Two factors which are important to the concept of interaction as we are going to see in later chapters.

Quantum mechanics, as the underlying mechanics of our world, is strongly based on probability and forecasts of possible outcomes.

The term *quantum physics* derives from Max Planck's quantum hypothesis in which he determines that energy is emitted in small discrete packages, the so called *quantum*—for light such a quantum is called *photon*. CF. [15, P. 16] Out of this hypothesis developed the field of quantum mechanics, which examines the behaviour of matter on the atomic and sub-atomic level.

The term wave-particle duality expresses the fact that a particle shows properties of particles and waves. A fact which would lead to contradiction in classical physics, because waves in a classical sense propagate in space. They are acting constructively or destructively through interference and they may act on different locations with different strength. Particles in a classical sense, on the contrary, can only be in one place at a certain time. Only there they may act, but always with its full energy, charge, momentum etc. cf. [16]

Superposition in quantum physics means that two or more system properties are overlaying each other, a system is existing in a state of many possibilities. When measured, a property of the system can be established and this is generally termed as the "system is reduced". cf. [15, pp. 149–150], cf. [17, sec. superpositionsprinzip], cf. [18]

1.1. Mach-Zehnder interferometer

The experiment set-up is quite simple. It is built up of a light source to emit a beam of photons, two detectors to registers photons, two fully reflecting mirrors and two beam-splitters which are similar to mirrors but reflect only half of the light-intensity and let the other half pass through.

As one can see in figure 1 the light source sends a beam into the first beam-splitter which deflects 50% of the photons up and the other 50% pass through straight on. Due to the fully reflecting mirrors the beams are deflected again so that they meet in the second beam-splitter after exactly the same distance. At this point the superposition of the (light-)waves takes place, because the second beam-splitter divides each beam again. The beam which took the upper way, half is deflected up, the other half passes straight through to the right. And half of the beam which took the lower way passes straight through up and the other half is deflected to the right. At the exits of each way is a detector ready to register the incoming beams. cf. [15, pp. 182–183], cf. [18]

According to classical physics, the expected result of the measurement would be that *Detector I* (the upper one) would trace 50% of the photons and *Detector II* (the right one) would trace the other 50%. However, the actual measuring result shows without exception that *Detector II* traces 100% of the photons and *Detector I* 0% of the photons. This corresponds to the quantum mechanical expectation, assuming that one does not distinguish which way a photon took. cf. [15, pp. 183–184], cf. [18]

This results comes about due to the constructive and destructive interference of the photons' waves. The two waves which are exiting the interferometer to the right are overlaying each

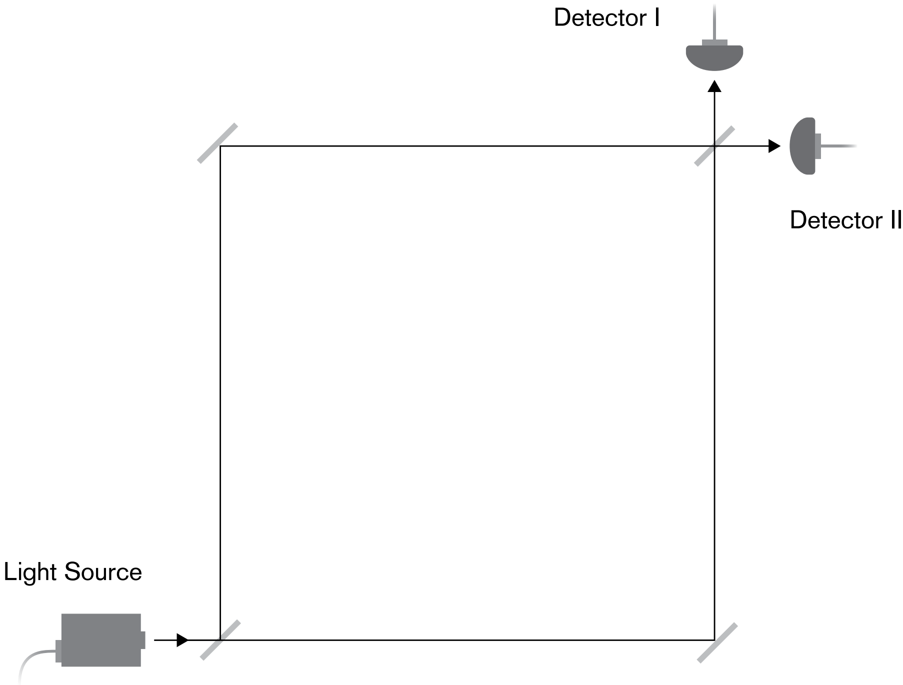

Figure 1: Schematic setting of Mach-Zehnder interferometer

other in a constructive manner, so that of each wave, valley meets valley and peak meets peak. The resulting wave has the same intensity as the light of the source. Whereas the waves which are exiting the interferometer upwards are cancelling out each other, because here valley meets peak and peak meets valley. No light is emitted upwards. This measuring result is shown with some light intensity, even when only one photon at a time travels through the interferometer. This result is also reproducible with whole molecules. CF. [15, P. 188], CF. [18]

In case that, after reuniting both beams in the second beam splitter, information about the way of the photon exists and thus the way of the photon is deterministically ascertained, the measuring result will not correspond to the quantum mechanical expectation. *Detector I* would not trace 0% and *Detector II* would not trace 100% of the photons. CF. [15, PP. 189–190] In this case and in this specific experiment both of the detectors would trace 50%

of the photons. Therefore it is not possible with a 100% probability to predict which way the photon will take before it arrives at the beam-splitter. One can explain the measuring result only by assuming that there is a real objective chance. cf. [18]

1.2. Conclusion

The following conclusion of the Mach-Zender interferometer experiment is drawn by professor Anton Zeilinger in his book Einsteins Schleier.

The photon which is sent from the source corresponds to a probability wave Ψ. The probability wave's intensity indicates the probability to find a particle in a certain place. It should be noted that the probability wave is merely an allegory and should not be compared to a real wave in space; rather it is a tool for calculation. cf. [15, p. 191]

If analysing the aforementioned experiment then Zeilinger states that after the first beam-splitter we have a probability of 50% to find the photon in the upper way and 50% probability to find it in the lower way. In physical terms this is expressed as following:

$$\Psi = \Psi(\text{lower way}) + \Psi(\text{upper way})$$

In total the probability is 1, which corresponds to 100%. In our case the probability to find the photon in the upper way is the same as to find it in the lower way the probabilities are ½ for each way, which corresponds to 50%. Therefore, if we were to put a detector in each way before the second beam-splitter, the detectors would have a chance of 50% to detect the photon. Zeilinger conjectures that we may speculate that the photon had already been "en route" on a certain route until it was detected. However, he reminds us that, reviewing only the available facts, we can solely say that with 50% probability one of the detectors will detect the photon. Any assumptions about the way the photon took, will result in a contradiction of the superposition of the waves. Zeilinger explicates, as soon as we prove that the photon, for example, is in the upper way the probability to find it in the lower way will drop to zero. As we have only one particle that is being measured. [15, pp. 192–193]

He explains further, the interference of the probability waves after the second beam-splitter causes the experiment to result in always the same way, so that the probability to detect the photon on the right exit is 100% and on the upper exit 0%. If the experiment is not ending in this way then the probability wave of the particle has collapsed somewhere along the way when retrieving information about the particle. cf. [15, pp. 194–195], cf. [18]

Finally he clarifies that as the

probability wave is not a real wave expanding in space and particles do not act deterministically by, for example, following a certain way, we may only talk with certainty about a phenomena we are observing. This would be the observation that a photon is entering the interferometer, and also that we detect this particle on a certain way either inside the interferometer or at the end of the interferometer. Schrödinger's Wave Equation helps to put these phenomena into relation. However, everything that is happening in between these phenomena can not be explained with certainty. CF. [15, P. 195]

The physicist Wolfgang Pauli explains that in comparison to classical physical fields these probability waves or fields may not be measured in different locations at the same time. If a measurement is done then this is the passage to a new phenomenon with new initial conditions and a whole new set of possibilities is to be anticipated:

> "Zum Unterschied von den Feldern der klassischen Physik kann man diese Wahrscheinlichkeitsfelder, die auch als 'Erwartungskataloge' bezeichnet worden sind, nicht zugleich an verschiedenen Orten ausmessen. Macht man an einem Ort eine Messung, so bedeutet das den Übergang zu einem neuen Phänomen mit veränderten Anfangsbedingungen, zu denen eine neue Gesamtheit zu erwartender Möglichkeiten, demnach ein überall anzusetzendes Feld gehört. Die Phänomene haben somit in der Atomphysik eine neue Eigenschaft der Ganzheit, indem sie sich nicht in Teilphänomene zerlegen lassen, ohne das ganze Phänomen dabei jedesmal wesentlich zu ändern." [19, P. 20] IN [10]

From here Zeilinger deduces that we may not speak of the particle's route, or any information, unless we make an appropriate experiment. CF. [15, P. 181] The location of the particle is in a state of superposition and thus its route is subject to chance. CF. [15, PP. 42–46]

As I follow the argumentation above, I draw the conclusion that unless we are interacting with a system and create information about its state by measurement, we can not talk about it with certainty. The interaction creates the particles present. A statement affirming the concept that interaction moulds present.

2. Radical Constructivism

Radical Constructivism is an interdisciplinary discourse which draws its aspects from many fields such as biology, cybernetics, philosophy, psychology, social sciences and others.

Their common ground is the claim that reality is not discovered but invented. Constructivism is concerned with epistemological questions as how knowledge is acquired. CF. [20], [21] Any knowledge is a process of construction and the outcome of this process is called reality. CF. [20] Ernst von Glaserfeld—one of the founders of radical constructivism—leans on theories of Jean Piaget's and Silvio Ceccato's. The former proclaims that knowledge is not a "copy of the world" but rather the result of adaptation. The latter states a theory that knowledge is not "duplicating" any ontological objects but these objects are results of "creative" activities. [22, P. 29] As a result from this he reasons that perception and knowledge are constructive and not representing activities:

> "Wahrnehmung und Erkenntnis wären demnach also konstruktive und nicht abbildende Tätigkeiten." [22, P. 30]

Additionally, constructivism tries to separate the concept of knowledge from any ontology. CF. [20], CF. [22, PP. 29–30]

To build up an understanding of social systems and interaction in the context of constructivism we are going to look into Paul Watzlawick's work of constructivist communication theory.

2.1. Watzlawick's Constructivism

Paul Watzlawick followed the basic assumption of constructivism that everyone's reality is a construct. In his opinion one's reality is the result of communication. He used these assumptions in his work as a family therapist, psychologist, communications theorist, and philosopher who worked in the Mental Research Institute of Palo Alto. [23, P. 7]

In his understanding communication is an exchange of information. Information fed to an effector through an adequate effect, secures an effector's stability and its adaptation to the environment. This is a view coined by cybernetics. [2, PP. 30–33]

Furthermore he explains his understanding of the concept *communication*. On the one hand it is the scientific field of communication theory. On the other hand it is a name for a behavioural entity (*Verhaltenseinheit*). [2, PP. 50–51]

Though for pragmatic reasons Watzlawick maintains the term *communication* and in the following it will be referred to as such.

He divides communication into two meanings:

1. A single communication is called message.

2. A reciprocal process of messages between two or more persons is called interaction.

As to how communication manifests itself, Watzlawick answers that communication is more than words. Also it includes all paralinguistic phenomena (e.g. cadence, speed of speech, pauses, laughter etc.), posture, body language and so on—behaviour of any kind is communication. He points out that behaviour has no antonym and therefore one cannot not behave. Thus if we accept that any behaviour in interpersonal situations is communication then we obtain Watzlawick's meta-communicative axiom: One cannot not communicate. CF. [2, PP. 50, 51, 53][1]

1 Watzlawick alludes that dialogues in one's fantasy, e.g. introjection, in hallucinations or with one's own existence are possible. These internal communication process are subject to the same rules as interpersonal communication, he speculates. CF. [24, P. 51] One has to think of the philosopher Ibn Sina (Avicenna) who pointed out that it is enough to feel the change in oneself to feel time: "[…] es genügt, sich selbst als wandelbar schon in der eigenen Seele wahrzunehmen, um die Z. wahrzunehmen […]." [25, COL. 1213].

Watzlawick views on interaction as seen in cybernetic or system theory considers interactions as systems. Following, it will be explained which properties constitute a system.

To begin with, a system implicitly requires time. The system's interaction —the process of action and reaction— require an ordering structure. This ordering structure alone makes it possible to describe the changes in the system's condition. Time is this ordering structure of an interaction. CF. [2, P. 151]

Furthermore, a system is an aggregation of objects and relations between the objects and their attributes:

> "[…] 'ein Aggregat von Objekten und Beziehungen zwischen den Objekten und ihren Merkmalen' […]" [26, P. 18] IN [2, P. 116]

Whereas objects are the components of a system and attributes refer to an object's properties. The relations ensure the system's coherence. [2, P. 116]

In the sense of 'communication theory', Watzlawick deduces, if the objects are human individuals then their distinguishing attribute is their communicative behaviour. Therefore interpersonal systems can be described best as persons-communicating-with-other-persons and not as a certain number of individuals. [2, p. 116]

In contrast, the relations of two or more objects cannot be as clearly defined as the objects (persons) themselves. Relations are based on a problem the persons are engaged in. The objects deem a problem important or unimportant. This decision depends on their interest in that problem. cf. [24, p. 116]

Therefore interpersonal systems are two or more communicating persons, which define the nature of their relation. [2, p. 116]

Peter M. Hejl, a scientist also working in the field of cybernetics/system theory and a contemporary of Watzlawick, elaborates on the concept of a common problem: In his understanding a social system is defined by a problem, which needs explication or clarification, chosen by an observer (i.e. person) or group of observers. Having said that, this means also that the system's borders are constituted by the interactions of its components (i.e. persons and other objects). [22, pp. 127–128]

Resuming to Watzlawick's definition of a system, he continues to distinguish between closed and open systems based on how they are interwoven with their environment. Closed systems are systems which cannot exchange energy, matter or information etc. with its environment. A chemical reaction in a closed container is an example. Whereas open systems, like organic systems, may exchange information with their environment. cf. [2, p. 117] We may ask now what is the environment of a system. He cites a definition by Hall and Fagen that "for a given system its environment is the sum of all objects whose change influence the given system. As well as all objects whose attributes are changed by the given system's behaviour." [26, p. 20] in [2, p. 117] For open, organic or social systems this definition does not set clear boundaries. His solution is that these systems are not merely a loose pile of elements but they are put into a hierarchy. Looking at a system inside the hierarchy from the bottom, the systems act as an entity. Looking at it from the top the system acts only as a part. With this model it is possible to explain the dyadic interactions of systems inside a family, society or even culture. He reasons that communicating persons are in horizontal as well as vertical relations with other persons or subsidiary systems. cf. [2, p. 118]

Later he reasons that open systems, as organisms are, gain their stability or even evolve into higher complexity because they are in constant exchange, i.e. communication, with their environment. In this sense communication and existence are inseparable.

In addition Watzlawick mentions that systems are not reductionist cf. [2, p. 119], they are connected cyclic and in reciprocal ways cf. [2, p. 122], and they are acting by the principle of equifinality. Equifinality is "[…] the principle that in open systems a given end state can be reached by many potential means." [27]

In his last point Watzlawick mentions the retrenching nature of communication. This is due to the fact that in a process of communication every exchange of messages reduces the number of the next possible messages.A circumstance caused by the axiom: one cannot not communicate. Each message becomes part of the communication process' context and therefore determines the following interactions. cf. [2, p. 126]

2.2. Conclusion

In the preceding chapter an account of Watzlawick's understanding of communication and definitions of general and interpersonal systems was given. These definitions will be used further on to enable us to compare diverse types of systems.

He illustrates that open system, like organisms or persons, have relations with other organisms and they are bound to exchange information respectively communicate. As mentioned before, he states this in his axiom: One cannot not communicate.

Furthermore he states that open systems, which are in horizontal and vertical relation with other systems, gain their stability and even evolve by constant communication. He concludes that communication and existence are inseparable.

However, at the same time Watzlawick points out the retrenching nature of communication. As each exchange of information reduces the number of possibilities for the next exchange.

From all these points I deduce that communication creates a system's present. An important step in showing that the present is established through interaction.

3. Definition of Interaction

Interaction is a widely used term and defined slightly different in each field. In the context of this thesis we shall look at the fields of physics, the constructivist branch of social science, human-computer-interaction (HCI) and interactive media art. After analysing each field for their understanding of interaction, their similarities will be exposed.

The Brockhaus Encyclopedia has three definitions for interaction. The first relates to interaction in computer science. A reciprocal influence between man and machine, to wit the ability of the application or user interface to solve a task by the means of dialogue with the user.

> **Interaktion, 1)** *Informatik*: Dialog, die wechselseitige Beeinflussung von Mensch und Maschine (→ Mensch-Maschine-Kommunikation), d.h. die Fähigkeit eines Anwendungsprogrammes, eines Betriebssystems, einer → Benutzeroberfläche u.a., Aufgaben im Dialog mit dem Anwender zu lösen. [28, SEC. INTERAKTION]

Second interactions relate to the fields of medicine and pharmacy. In these fields the term describes an amplifying or nullifying effect if several drugs are administered at the same time.

> **2)** *Medizin und Pharmazie*: Verstärkung oder Aufhebung von Wirkungen, wenn mehrere Arzneimittel gleichzeitig oder in Form von Kombinationspräparaten verabreicht werden. [28, SEC. INTERAKTION]

And third interaction relates to psychology and sociology in which it means actions of two or more persons relating to each other, for example in the form of verbal communication. Generally in doing so the doers are geared to complementary expectations, behaviours and actions.

> **3)** *Psychologie und Soziologie*: das aufeinander bezogene Handeln zweier oder mehrerer Personen, z.B. in Form sprachl. Kommunikation. Dabei orientieren sich die Handelnden i.d.R. an einander komplementären Erwartungen, Rollenvorstellungen u.a., Verhaltensweisen und Aktionen. [28, SEC. INTERAKTION]

Already this definition of a general encyclopedia shows that the term interaction has different meanings in every field. The term and the comprehension of interaction have undergone a strong transformation since its introduction in the social sciences around the 1900s. Katja Kwastek gives a good overview of the development of the concept in her essay „Interactivity – a word in process“:

> „[…] by the early 1960s the concept of interaction had developed from an idea of reciprocity in biological, chemical and physiological processes into elaborate theories of social interaction (sociology), into a whole new science trying to establish the idea of feedback processes as a basic theorem of life and technology (cybernetics), and into a field of research and development in the computer sciences (HCI).“ [29]

Kwastek notices that in parallel to this development respective concepts of interactivity were developed in arts. cf. [29] A development the professor of media and cultural studies Ryszard W. Kluszczynski finds in the changing understanding of communication theory over the course of the 20th century. In the late1940s communication theory models relied on the assumption that the meaning of the message is solely created by the sender. Following theories stuck to this base of communication theory and emphasized adjunctive aspects like the flow of the communication, stabilizing aspects of communication, role and importance of editorial factors and finally the relative course of communication which turned the theory over so that the recipients are involved in giving meaning to the communication.

This finally turned into an understanding by modern researchers that "[…] any form of communication is considered […] a form of interaction." This even includes forms of communication that do not involve a feedback loop, like a TV broadcast. cf. [30, pp. 35–37]

Kluszczynski summarizes this development in the following way:

> „The concept of communication understood as a transmission process is thus displaced and replaced by the concept of communication understood as a process of interaction.“ [30, p. 37]

Therefore we need a clear understanding of how interaction is understood in the research fields which are carrying this thesis.

3.1. Characteristics of interaction

Additional to the aforementioned fields of sociology, psychology, cybernetics and HCI, interaction is a widely used term in many other areas like biology cf. [31, pp. 28–43], design and system theory cf. [32, pp. 69–75], physics cf. [17, sec. Wechselwirkung] and more cf. [29]. This widespread, yet incomplete, enumeration shows the difficult nature of defining and classifying interaction.

To present the full extend of the research on interaction would not be feasible due to „[…] the sketchy state of research concerning classifications of interaction processes in the various disciplines;", as Kwastek mentions, adding that „[…] the interdisciplinary nature of the field, where entirely different perspectives on the same phenomenon impede a comprehensive synopsis." and „[…] most of all, the object of research itself is constantly changing and therefore subject to ongoing revisions of the related discourses." [33, P. 19 F.]

Therefore it is not possible to give a concluding definition of the term interaction and interactive. Hence, we shall investigate the definitions and understandings which are relevant to this thesis.

As already mentioned in the chapter Statement of Motivation, chapter A.1.1., the principle "interaction moulds present" is based on the understanding of interaction in four fields. This includes the field of (quantum) physics, furthermore branches of social science in constructivism with close relation to the theories of Paul Watzlawick and Peter M. Hejl, and in the end the understanding of interaction in the field of HCI is building a bridge from understanding human action and interaction to the interaction in Media Art.

3.1.1. Characteristics of interaction in quantum physics

According to the "Lexikon der Physik" published by the Spektrum Akademischer Verlag, interaction is the reciprocal influence of two physical systems on each other.

> „Wechselwirkung, die gegenseitige Einwirkung zweier physikalischer Systeme aufeinander." [17, SEC. WECHSELWIRKUNG]

When talking about interaction in physics, mostly the four basic forces in the universe are meant.Nowadays physicists assume that four basic forces exists: gravitation, electromagnetism and so called strong and a weak forces. They „[…] govern how objects or particles interact and how certain particles decay. All the known forces of nature can be traced to (sic!) these fundamental interactions." [34] Gravitation was discovered by Sir Isaac Newton in the 17th century. It „[…] acts between all objects having mass […]". [34] Because of it, objects fall to the ground and planets orbit the Sun. Electromagnetism, discovered by James Clerk Maxwell during the 19th century, „[…] is responsible for the repulsion of like and the attraction of unlike electric charges;" [34] Additionally chemical behaviour of matter as well as light's properties are explained by this force. The weak and strong forces were discovered during the 20th century in the attempts to examine the atom's core. “The strong force acts between quarks, the constituents of all subatomic particles, including protons and neutrons. The residual effects of the strong force bind the protons and neutrons of the atomic nucleus together in spite of the intense repulsion of the positively charged protons for each other. The weak force manifests itself in certain forms of radioactive decay and in the nuclear reactions that fuel the Sun and other stars. Electrons are among the elementary subatomic particles that experience the weak force but not the strong force.” [34] Viewed from the point of their relative strength the strong force is “[...] regarded as the most powerful force in nature [...] followed in descending order by the electromagnetic, weak, and gravitational forces.” [34] However the strong and weak forces are extremely limited in their range. Electromagnetism and gravitation in comparison act on an infinite range. cf. [34] The former as „[...] an electromagnetic wave, such as the light from a distant star, travels undiminished through space until it encounters some particle capable of absorbing it.“ [34] And the latter „[...] acts between all objects of the universe, no matter how far apart they are [...]“. [34]Attempts have been made to unify all four forces. The weak force and electromagnetism are joined as the electroweak force. Together with the strong force they form the “standard model” of particle physics. Gravitation, as of now, could not be incorporated into a unified field theory. cf. [17, sec. Wechselwirkung], cf. [34]

The overview of the four basic forces above tells us how matter in all of the universe interacts with each other. However, to be able to discover all these forces and dynamics, man had to measure them in one way or another. Going back to the definition that interaction is a reciprocal influence of two physical systems on each other: measuring a system's properties is an interaction between the measuring system and the system to be measured. cf. [35, p. 89] So when observing a system, one interacts with that system. cf. [15, p. 22]

Reference to chapter B.1. and the aspect of superposition must be made here. For macroscopic objects, like a piece of paper, a book or a tree, this interaction bears no consequences. This is due to the effect of decoherence. Decoherence appears when information about the system's condition are transferred into its environment. As long as such information is not existent the system is in coherent superposition. Coherent superposition is the case, using the example of the Mach-Zehnder interferometer of chapter B.1.2., as long as we detect the wave interference. The moment we try to detect which route the photon took, its superposed wave interference vanishes. In theory macroscopic superposition is possible but due to constant interaction of quantum mechanical systems, which form the matter macroscopic systems are made of, these states are practically not appearing. cf. [15, pp. 156–158], cf. [36] However, on the microscopic level—e.g. molecules or particles—the interaction very much influences a systems' condition. On this level we cannot assume anything about a system's condition because it is in superposition. cf. [35, p. 90] As we saw in the Mach-Zehnder interferometer experiment we may not speak of the route of the particle, or any information, unless one makes an appropriate experiment. cf. [15, p. 181] Anything else about the particle's whereabouts or condition is mere assumption. Without observation, e.g. measurement, one cannot assign any properties to a system. Even more, one must not assume that properties assigned in one context may exist in another context of observation. [15, pp. 214–215]

Through the interaction of the observing system with the quantum mechanical system, the observing system achieves—actually creates—certainty about the quantum mechanical system's condition in its current context. It should be noted that measuring or observing a system is no special case of interaction. cf. [37, p. 89] However, we as humans must observe and therefore interact to understand a system's condition.

3.1.2. Interaction in constructivist branch of sociology

To give us a broader view of what interaction in social systems is, I will expand the definition of systems and interaction delivered by Watzlawick in chapter 2. with Peter M. Hejl's social theory.

Peter M. Hejl was a contemporary of Paul Watzlawick and a scientist who presented a social theory based on results of natural scientific fundamental research and constructivist theories of Ernst von Glaserfeld, Heinz von Foerster and Humberto Maturana and Franciso Varela. cf. [20], cf. [22, p. 181]

3.1.2.1. Hejl's definition of a living system

Being able to follow Hejl's explanation of social interaction requires an explanation of certain prerequisites beforehand.

Hejl talks about the interaction of living systems. A living system is a self-sustaining relationship of self-organizing (synonymously self-generating may be used) processes. CF. [20]

Self-organising systems are processes or systems which appear spontaneously due to specific conditions or as a consequence of conditions. He gives the example of spontaneously organized (respectively generating) enzymes if all the necessary components, i.e. amino acids, are available in the right order. However, a self-organizing system is not self-sustaining in itself. Because in the process of organization the components collapse or are consumed and can not be regenerated or replaced to redo the process. [22, P. 114]

The solution to this lies in self-sustaining systems. A self-sustaining system connects self-organizing systems in a cyclic manner. Self-sustaining systems are systems, whose components are mutually sustaining each other and therefore sustain the whole cycle or system. He uses the metabolism of cells and organs in a body as an example. [22, P. 114]

Finally, living systems may include self-referential systems. Self-referential systems are systems which change the conditions of their components in an operationally closed manner. Therefore self-sustaining systems are necessarily self-referential, but not all self-referential systems are self-sustaining. He refers to the brain as an example for a such a self-referential system. [22, P. 115]

Thus a living system is constituted by concurrence of self-organizing and self-sustaining systems and in some cases accompanied by self-referential systems. Furthermore, every living system has a history which constitutes its current condition and which allows and denies certain changes in the system's condition. CF. [22, P. 118]

According to Hejl the evolutionary growth of the brain enabled this system's capabilities to experience constructs of reality in even more different ways. From this follow two consequences. First, these new capabilities impede the system's ability to select the adequate behaviour to ensure its survival. That is, due to the high amount of possible realities it may construct out the few signals it receives from outside. Hence growth of brain poses a threat. Second, these new capabilities enable a living system to adapt better to changing conditions which are outside of the system's control and prevent its survival. Hence growth of the brain poses an advantage. The subsequent question is, how it is possible to avoid the threat and keep the advantages. The invention of society is Hejl's answer. [22, PP. 122–123] Under this definition of living systems and the assumption that “growth of brain” is a threat to the living system's survival, he explains how society is formed through interaction and what interaction actually means.

3.1.2.2. Interaction of living systems

In the course of expounding his social theory Hejl explains the general process of an interaction of a living system.

Before any interaction takes place the living system is in at least one or a number of conditions. Even on its day of birth a condition is given by the history of its species. Every condition defines a basal class of possibilities for interaction—these are inborn or learned sequences of action which were successful in the past. [22, p. 123]

Generally speaking, interaction is the following: from the possibilities of actions, which are defined by the system's condition, one is actualized which effects a change in the system's condition. Thus the system's changed condition generates a changed class of constructs of realities and possibilities of actions. This leads to altered behaviour during the next interaction. [22, p. 124]

Out of the general interaction process, two constructs may result.

First, if the general process of interaction leads to no more changes in the system's condition, then the case of constitution (*Konsitution*) or construction of objectivity (*Konstruktion von Objektivität*) occurred through the interacting individual. By changing itself in its cognitive realm the individual trivialized the entity's behaviour. This enabled the individual to generate a viable concept of the entity. [22, p. 124]

However, if the process of interaction does not result in trivializing the excluded entity, then the system will perceive centres of activity outside of itself, which are comparable to its own, i.e. other living systems of comparable complexity to its own. In this case it is not possible for the living system to change itself only one-sidedly, in order to arrive at reliable predictions about the environment. From here on, it is necessary to enter a process of reciprocal interaction which leads to a partial parallelisation of self-referential (cognitive) subsystems of the interacting systems. Social realms emerged from the parallelisations, i.e. comparable constructs of reality. He states this as the second resulting construct. [22, pp. 123–125]

Hejl claims that any phenomenon which is usually described as “social” is covered by the aforementioned definition of social realms. Consequently any social behaviour may be understood as a behaviour which emerges from a socially generated definition or construct of reality. [22, p. 125]

In reference to Watzlawick's view, that reality is the result of communication, that one cannot not communicate and thus communication is inseparable from existence, as described in chapter 2.1., Hejl illustrates that communication is an extended form of interaction:

> A social realm offers space for coordinated acting. And if a living system acts appropriately in a social realm, which it constituted with the other living systems, then its actions will be interpreted as intended. If these actions are replaced by a socially constructed system of symbols, we speak of communication. If in the process a communication system emerges which provides the ability to make itself the subject of communication, then we speak of language. [22, p. 126]

As we saw above, actions form interaction. These interactions may take place in a social realm and under certain conditions and then we may speak of interaction as communication.

Watzlawick defined interaction, as mentioned in chapter B.2.1., as a reciprocal process of messages between two or more persons:

> “Ein wechselseitiger Ablauf von Mitteilungen zwischen zwei oder mehreren Personen wird als Interaktion bezeichnet.“ [2, p. 50]

The concept of interaction, as expounded above by Hejl, is including communication and is not a mere result of it, as defined by Watzlawick. Thus I consider Hejl's concept a more comprehensive definition of interaction. Therefore, I come to an important conclusion of this work, based on Watzlawick's communication axiom, a new axiom:

> Axiom 1: One cannot not interact.

In this light the conclusion of chapter 2.2. will be restated as: Interaction creates a system's present.

3.1.3. Interaction in HCI

Human-Computer-Interaction (HCI), sometimes also Human-Computer-Interface or Human-Machine-Interface, is the study of how people communicate with and may act upon computers. The interaction is mediated by a soft- and/or hardware interface, giving human as well as machine the ability to communicate—i.e. interact—with each other.

Donald Norman, a cognitive scientist and usability expert of renown, puts forward a model of manipulating objects in the world.

According to Donald Norman an action consists of seven stages:

- Forming the goal
- Forming the intention
- Specifying an action
- Executing the action
- Perceiving the state of the world
- Interpreting the state of the world
- Evaluating the outcome

These stages can be grouped into „[…] one for goals, three for execution, and three for evaluation." [38, p. 48]

Norman explicates:

„Goals do not state precisely what to do – where and how to move, what to pick up. To lead to actions goals must be transformed into specific statements of what is to be done, statements that I call intentions. A goal is something to be achieved, often vaguely stated. An intention is a specific action taken to get to the goal. Yet even intentions are not

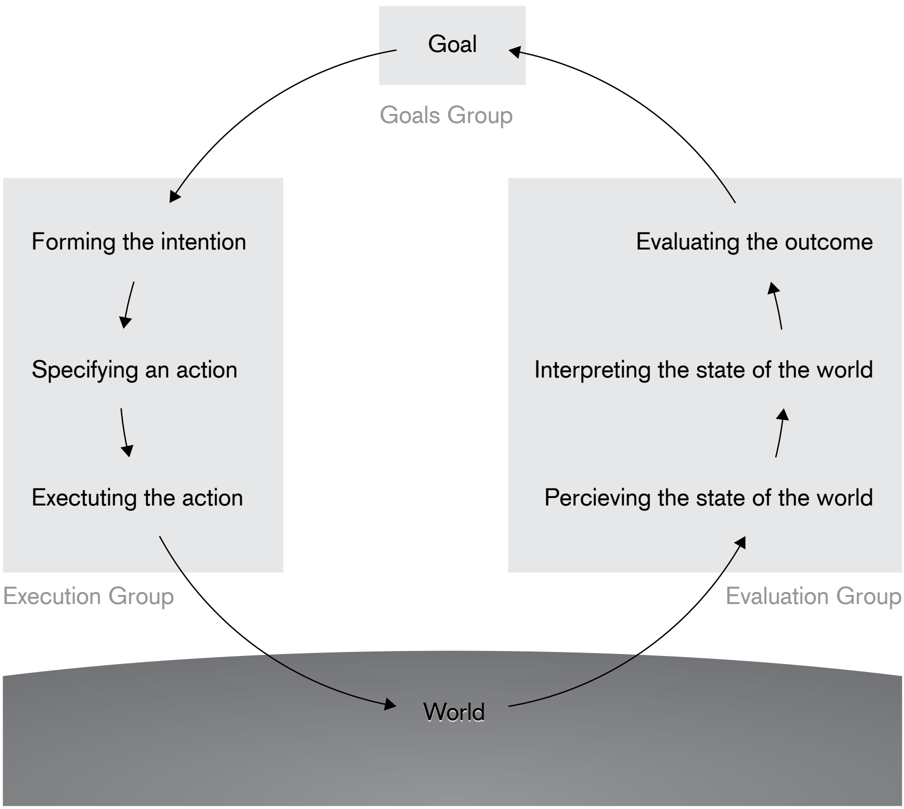

Figure 2: Seven steps of an action based on Donald Norman, ©1988 Donald Norman

> specific enough to control actions.“ [38, p. 46]

Norman also clarifies:

> „In particular, the stages are almost certainly not discrete entities. Most behaviour does not require going through all stages in sequence, and most activities will not be satisfied by single actions. There must be numerous sequences, and the whole activity may last hours or even days.” [38, p. 48]

In the evaluation stages—Perceiving the state of the world, Interpreting the state of the world, Evaluating the outcome—the idea of feedback is added. For Norman feedback is „[…] sending back to the user information about what action has actually been done, what result has been accomplished […]“. [38, p. 27] While explaining further his seven stages model he clarifies:

> “There is a continual feedback loop, in which the results of one activity are used to direct further ones, in which goals lead to sub-goals, intentions lead to sub-intentions.“ [38, p. 48]

This model explains actions seen from one side: the manipulation of a dynamic system by a person. However, Usman Hague states:

> „[…] in ‘interaction’ the transfer function is dynamic, i.e., in ‘interaction’ the precise way that ‘input affects output’ can itself change; moreover in some categories of ‘interaction’ that which is classed as ‘input’ or ‘output’ can also change, even for a continuous system.”. [32]

This is contrary to the fact that “[…] in ‘reaction’ the transfer function (which couples input to output) is fixed;“ [32]

With this knowledge at hand I see it becoming clear that Norman's model can not be the full range yet of what can be called *interaction*. To depict the possible ways and layers on which interaction can happen, a differently structured view is necessary.

The following table (see figure 3) was taken from the article “What is Interaction? Are there different types?” presented by Dubberly, Pangaro and Hague in the interactions magazine in 2009. It gives us an overview of types of systems that exists and how they build onto each other. This table may help to gain a broader view of Norman's model of seven steps of an action.

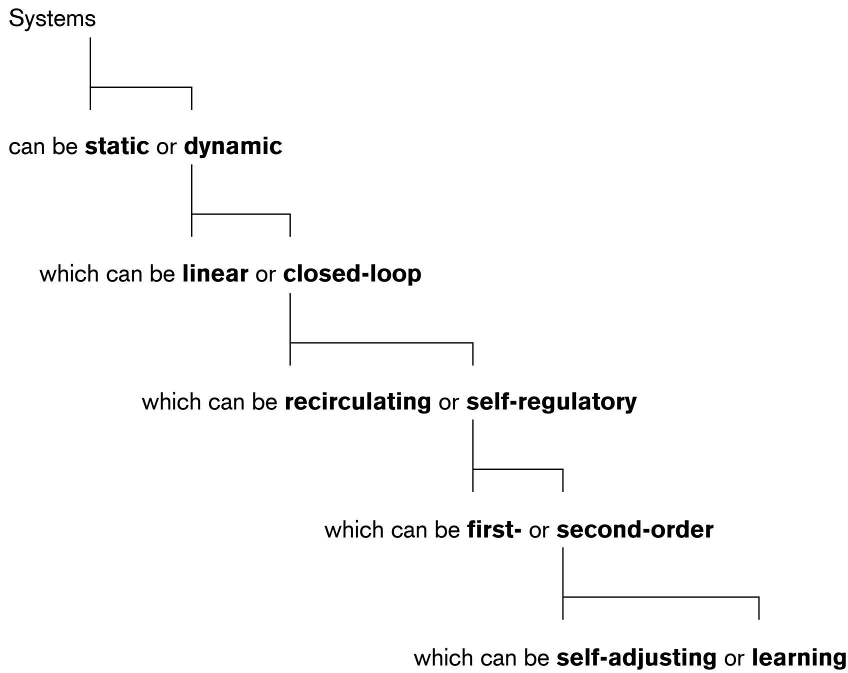

Figure 3: Hierarchy of systems according to Dubberly et. al., ©2009 Dubberly et. al.

Below this table it was further explained that…

- …we have static and dynamic systems;
- …within dynamic systems there are reactive (open-loop) and interactive (closed-loop) systems;
- …some closed-loop systems can be self-regulating but only when they are goal driven;
- …self-regulating systems have a goal which can be adjusted either only from the outside when there is only one loop (first-order)…
- …or they are self-adjusting when introducing a second loop to adjust the first loop, according to how well the second loops meets its own goals. Then these are called learning systems.

From this table we can now determine that Donald Normans model is a closed loop, self-regulatory system of first order. Dubberly et. al. would call it “a good first approximation”. [32]

Also the table shows that interaction is possible on all its levels—except for the static system—to different degrees. The deeper levels offer more extensive ways of interaction.

Dubberly et. al. continue on the basis of this table to characterize types of interactions. Which may be:

- **Reacting:** “The output of one linear system provides input for another, [...]. Action causes reaction. The first system pushes the second. The second system has no choice in its response. the two linear systems function as one.” [32]
- **Regulating:** “The output of a linear system provides input for a self-regulating system. Input may be characterized as a disturbance, goal, or energy.“ [32]
  - “Input as 'disturbance' is the main case. The linear system disturbs the relation, the self-regulating system was set up to maintain with its environment. The self-regulating system acts to counter disturbances.“ [32]
  - “Input as 'goal' occurs less often. A linear system sets the goal of a self-regulating system. In this case, the linear system may be seen as part of the self-regulating system – a sort of dial.“ [32]
  - “Input as 'energy' [...]. A linear system fuels the processes at work in the self-regulating system; [...] the linear system may be seen as part of the self-regulating system.“ [32]
- **Learning:** “The output of a linear system provides input for a learning system. [...] If the learning system also supplies input to the linear system, closing the loop, then the learning system may gauge the effect of its actions and “learn”. [...] You (the learning system) signal your computer (the simple linear process); it responds; you react. After signaling the computer enough times, you develop a model of how it works. You learn the system. But it does not learn you.“ [32]
- **Balancing:** “The output of one self-regulating system is input for another. [...] There are two cases, reinforcing systems and competing systems. Reinforcing systems share similar goals [...]. Competing systems have competing goals.“ [32]
- **Managing and entertaining:** “The output of a self-regulating system becomes input for a learning system. If the output of the learning system also becomes input for the self-regulating system, two cases arise. The first case is managing automatic systems, [...]. The second variation is a computer running an application, which seeks to maintain a relationship with its user. [...] This type of interaction is

entertaining – maintaining the engagement of a learning system.“ [32]

- **Conversing:** "The output of one learning system becomes input for another. While there are many possible cases, two stand out.The simple case is "it-referenced" interaction. The first system pokes or directs the second, while the second does not meaningfully affect the first."And „[...] the case of what Pask calls "I/you-referenced" interaction: Not only does the second system take in the output of the first, but the first also takes in the output of the second. Each has the choice to respond to the other or not. Significantly, here the input relationships are not strict "controls." [...] They may coordinate goals and actions. [...]This type of interaction is conversing (or conversation). It builds on understanding to reach agreement and take action [...]". [32]
- **Additional cases:** More cases exists according to Dubberly et. al.. They deem „Learning systems organized into teams“ and „Networks of learning systems organized into communities or markets“ as most interesting to mention. cf. [32]

Above I investigated many possible models of interaction in the field of HCI. Although at the core of interaction is a sequence of seven steps we realize that interaction should not be examined only from one side. It consists of far more layers. Dubberly et. al. proposed to approach interaction from a point of view of system theory and this helps us to use these models beyond the field of HCI.

3.1.4. Interaction in interactive media art

Works in the distinct field of interactive media art are produced with digital technologies. Besides the use of digital technologies in these works their aim is to scrutinize the cultural, political and aesthetic potential of these technologies. cf. [39, p. 7] Interactive media art emerged from the field of computer science and HCI at the end of the 1960s. Its characteristics of interaction are closely related to those of HCI. [40] in [33, pp. 17–18] Therefore, I will merely examine the way media art treats its content in comparison to the other arts and HCI.

In fact, interactive media art takes up a special role in this due to its interactivity feature.

Professor of media and cultural studies Ryszard W. Kluszczynski describes the pecularity of interactive art as a "negotiated meaning" [30, p. 33] between artist and observer[2]. Whereas other branches of the arts are a "[...] representation of a

2 Kluszczynski calls the observer usually recipient. To avoid confusion between

finite, finished and a priori given world […]" [30, p. 33] in which the artist presents a finished piece to an audience. In interactive art the observer „[…] ceases to be merely a consumer and is in turn a (co-) creator of the work experienced." [30, p. 33] He explicates a shift in the roles of the artist and observer during the rise of interactive art:

"The idea of the author is replaced by the concept of a distributed and shared authorship in interactive art. […] The task of the artist is to create […] the system-context in which the recipient/inter-actor constructs its object of experience and its meaning." [30, p. 33]

In my view, Kluszczynski's statements above clarify, too, that an interactive work oft art only becomes complete through interaction.

A point that Ingrid Spörl proves in similar fashion as Kluszczynski, but rather with focus on the abilities of art work and observer. As she puts it in her thesis „Wahrnehmung der Wahrnehmung" the division of observer and work of art is nullified by the mutual reception. This means that the actions of the observer are continued in the work of media art and the work's reaction then again in the observer's consciousness. This interaction or interplay is specific to media art works and does not appear in any other form of art. cf. [41, p. 30]

David Rokeby mentions the aspect of social responsibility when creating interfaces. cf. [42] As designers and artists are creating interfaces they are "redesigning the ways that we experience the world and each other." [42] Furthermore Rokeby explicates that "[b]y defining a way of sensing and a way of acting in an interactive system, the interface defines the 'experience of being' for that system." [42] In Rokeby's opinion a fact not often considered when interfaces are being created for an economic context.

These aspects—the unique quality of interactive art work to become complete only through the interaction of the artist's work and the observer as described by Kluszczynski, the formation of a common system of observer and art work as Spörl points out, and the interfaces ability to dramatically shape the observer's experience of being as Rokeby stated—imply a strong effect of reflection within the observer. In my view, therefore, a piece of media art is the most prudent way to present the concept of this thesis to an audience.

3.2. Conclusion

We looked into the four fields of physics, sociology, HCI and interactive media art which all use the term interaction in their own sense. Now I shall

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naming I will stick with the word observer and see it synonymous to recipient.

briefly compile their characteristics. Then we shall look into their similarities. In physics interaction is the reciprocal influence of two (or more) physical systems on each other. Physical research discovered that four basic forces govern all interactions of matter in the universe. To make these discoveries, however, it is necessary to measure a physical system and from this I conclude that an observing system must interact with the physical system. In microscopic systems a measurement influences a system's behaviour. Therefore, from our human point of view, interaction with the world is inevitable. Although it may sound like—and a lot of speculation has been done on this subject –, observing and measuring a system is no special case of interaction. cf. [35, p. 89] It is but the only way to achieve certainty about a system.

In social science, with a strong constructivist perspective, interaction for living systems means that one action is actualized from a range of possibilities, which are defined by the system's current condition. This one action effects a change in the system's condition. Consequently this leads to an altered behaviour in the next interaction. This general interaction process may result either in no more changes in the system's condition. Then the living system was able to create a viable concept of the entity it interacted with. Or the interacting living system perceives the outside system as a system comparable to its own complexity. Then one-sided changes in the system's condition are not possible and both systems enter a reciprocal process of interaction. As a result of this interaction, social realms may form.Hejl illustrates communication as an extended form of interaction. Actions take place in a social realm and when these actions are replaced by a socially constructed system of symbols it is called communication. Due to this understanding and based on Watzlawick's axiom, one cannot not communicate, I proposed a new axiom: One cannot not interact.

Furthermore we looked into the field of HCI. First I examined the often used “seven stages of an action” model by Donald Norman. The first stage is merely for forming the goal, the next three are grouped as the stages of execution and the remaining three form the group of evaluation of one's action. He clarifies that any of the seven stages is not necessarily a discrete entity, most behaviour does not require to go through all stages, as well as most activities will not be satisfied by a single action. With the stages of evaluation the whole process becomes a feedback loop.This rather one-sided model is extended by Dubberly, Pangaro and

Haguein as they explain that the way input affects output can change, even to the point that input and output interchange. To illustrate the circumstances in which this may happen they introduce a hierarchical structure of types of systems which offer more extensive ways of interaction in each step. Having outlined the types of systems, they then present most of the ways in which systems may interact: reacting to another system, regulating a simple process, learning how actions affect the environment, balancing competing systems, managing automatic systems, entertaining (maintaining the engagement of a learning system), conversing.

Finally I focused on the meaning of interaction in interactive media art. In the technical sense it works like the field of HCI from which interactive media art originally descended. Though in the field of interactive media art thoughts arose that creators of interfaces bear social responsibility as interfaces forge the way we perceive the world, as David Rokeby points out.Ryszard W. Kluszczynski and Ingrid Spörl stress that the inherent feature of interactivity makes interactive media art stand out in the field of art. Kluszczynski sees interactive art is dependent on the involvement of both artist and observer who are negotiating meaning within the art work. Whereas Spörl describes it as the only form of art which truly picks up the observer's actions and based on this may provide input back into the observer's conscious, hence resulting in annulment of the division of observer and art work.

Looking at all four fields I realize that we may distinguish interaction in these fields with regard to their content. But we cannot distinguish them on their operational level. Interaction on its least complex level happens in a dynamic closed-loop system—in this an entity may refer back with its output to the entity which delivered the input.

In all four fields we see that if there were to be no interaction, no change would be happening. Thus I conclude that we may say that interaction affords change.

In the next chapter I will draw the conclusions of what we have learned so far.

4. Interaction Moulds Present

Below is an outline of past chapters' results which have been compiled and should help to demonstrate the evidence of the initial statement: interaction moulds present.

The assumption of quantum mechanical systems and living systems, e.g. organisms, to be considered as having parallels has been the underlying issue in this research.

It is clear that quantum mechanical systems, living systems, social systems and so on, are not the same. Ludwig von Bertalanyff, one of the founders of General Systems Theory, points out though, that abstractions and conceptual models which accord each other may be applied onto different phenomena or systems. System laws only apply to a narrow amount of facets in these different phenomena or systems. In any other respect, however, they are not alike:

> „Die von uns erwähnte Isomorphie ergibt such aus der Tatsache, daß in gewisser Hinsicht einander entsprechende Abstraktionen und Begriffsmodelle auf verschiedene Phänomene angewendet werden können. Systemgesetze haben nur in diesem Sinn Gültigkeit. Dies bedeutet nicht, daß physikalische Systeme, Organismen und Gesellschaften ein und dasselbe sind. Im Prinzip besteht hier dieselbe Situation, die sich aus der Anwendbarkeit des Gesetzes der Schwerkraft auf Newtons Apfel, das Planetensystem und die Gezeiten ergibt. Es bedeutet, daß in bestimmtes theoretisches System, in diesem Fall die Mechanik, in bezug auf einige sehr begrenzte Aspekte Gültigkeit hat; es bedeutet aber nicht, daß in anderer Hinsicht irgendeine besondere Ähnlichkeit zwischen Äpfeln, Planeten und Ozeanen besteht.“
> [43] in [24, p. 75]

Bearing this in mind, several points will be highlighted which describe similarities between quantum mechanical systems and living systems.

Any system implicitly requires time, because without change there would be no time and vice versa. This is a conclusion made by many philosophers as for example Aristoteles, Eriugena, Ibn Rušd, Moses Maimonides as described in chapter A.2.4.. Also Martin Heidegger mutually derives time and being form each other as shown in chapter A.1.2..A system's processes requires an ordering structure. This ordering structure enables us to describe the changes in the system's condition. Time is this ordering structure of an interaction. This view is recognized by psychotherapists, like Arnold Bernstein, Henry L. Lennard or Paul Watzlawick, as described in chapter B.2.1 for living systems. CF. [24, P. 151] Also this view is commonly accepted by physicists who agree that time is elapsing and that without elapsing time there would be no change. In circular fashion it is claimed that time would not exist without change and change would not exist without time. Nevertheless, the concept that time is elapsing indeed is derived from the principle of entropy as described in chapter A.2.2. CF. [11, PP. 19–24] Most recently with Einstein's theory of Special and General Relativity time and space were inseparably interwoven as described in chapter A.2.4..

As a preceding statement to the next paragraphs, we may say that without interacting with a system or the environment, we can not make any concrete statements about the condition of a system. An opinion which is argued by Anton Zeilinger for quantum physics as shown in chapter B.1.2. and B.3.1.1.. Also Heinz von Foerster, a contemporary of Peter M. Hejl and an advocate of cybernetics and constructivism, points out that an observer is always enclosed in the system he or she is observing. CF. [22, P. 43] These circumstances show that we are enclosed in the ordering structure of time.

Additionally, it is conspicuous that systems are subject to perpetual interaction and constantly interacting. The idea that system do not change at all is not generally excluded. However, the fact that only a measurement can tell us if a system in a certain context is static, requires an interaction with that static system. This points to the conspicuousness that every system must interact perpetually. This conspicuousness is supported by the effect of decoherence as described in chapter B.3.1.1..

Of living systems, though, it can be said that they are subject to constant interaction and constantly interacting. Paul Watzlawick recognized that behaviour respectively communication have no antonym and therefore it is not possible to not not behave or communicate. Supported by Peter M. Hejls social theory I was able to universalize Watzlawick's axiom “one cannot not communicate” into “one cannot not interact” in chapter B.3.1.2.2.. Besides, Hejl notes that social systems are constituted by living systems. These living systems have the freedom to choose if they want to help to constitute a certain social system or not. But this freedom of choice does not mean that one may retreat completely from all social systems. This choice means that one may replace participation in one social system with participation in another:

> “Soziale Systeme werden durch lebende Systeme konstituiert die prinzipiell frei sind, an der Konstitution eines spezifischer Systems teilzunehmen oder nicht. […] Mit der Betonung dieser prinzipiellen Freiheit wird nicht die Möglichkeit unterstellt, sich aus allen sozialen Systemen zurückziehen zu können. Freiheit der »Teilnahme« meint hier vielmehr die Möglichkeit, die Teilnahme an einem System durch die Teilnahme an einem anderen zu ersetzen.“ [22, p. 135]

The constant interactions, in which a system is betaken, finally effect a new condition of the system, Hejl states, as described in chapter B.3.1.2.2..

In quantum physics, information about a system is created from a variety of possibilities for example through the process of measurement and the context in which it is happening, e.g. the experiment's set-up. Thus the Mach-Zehnder interferometer, as explained in chapter B.1.1. and B.1.2., shows that by measuring the route of the particle the particle's state of superposition is cancelled and we clearly detect the way the particle took. So the particle is set into a distinct state. cf. [15, p. 157] Thus I concluded that interaction decides upon a particle's condition.

From Watzlawick's point of view, communication respectively interaction, posses a retrenching effect, too. This is because every interaction decreases the number of available possibilities for the next interaction. Through this process certain rules arise:

> „[…]in zwischenmenschlichen Beziehungen verringert jeder Austausch von Verhalten die Zahl der bis dahin offenen Möglichkeiten. […] Die bedeutet, daß selbst dann, wenn ein bestimmtes Verhalten nicht ausdrücklich erwähnt, geschweige denn vom Partner ausdrücklich gut geheißen wird, die bloße Tatsache seines Eintretens einen Präzedenzfall schafft und damit eine Regel herbeiführt.“ [23, p. 101]

The above outlined gathered points and their connections—systems include an intrinsic order, interaction is inevitable and interaction forms conditions and provides rules –, we can conclude the initial statement: Interaction moulds present.

C. Tracks for Extended Research

The topics that will be presented in the following paragraphs are based on the accomplished results outlined in this thesis. They provide sufficient grounding for some given thought process and discussion openings, on the topics that will be presented.

In the chapters above, a concept of how the present comes into existence was illustrated. After explaining concepts of quantum physics and constructivism and how they implement interaction, they were compared in chapter B.4.. I was able to demonstrate that interaction is the basic principle which moulds the present we are living in.

Below I will touch on the subjects of the span of the present, a potential approximation of diverse systems and how present may be put into context with past and future.

1. Consequences for understanding the span of present

The concept, interaction moulds present, bears consequences on the span of the present. The span of the present was and is a subject of extensive discussion. It is often considered as representing a point on the time bar without any extension. This view may be attributed to Aristoteles who, besides explaining the flow of time with a measuring number, referencing the before and after, claimed that a duration is contained by a start and end point, the so called νυν (nun). The nun is considered a dimensionless point of now which sets the limits of a duration and simultaneously mediates between past and future. Nowadays, the same principle is used in physics to describe processes. cf. [6, col. 1199], cf. [7, pp. 42, 115f] This understanding may have led to the common view that the present is a point in time without extension.

Yet there are arguments from different fields of research that one can invoke against this view.

In terms of physiological research, Ernst Pöppel, for example, discovered that the metric minimum for human sensing is around 30 ms. Although each human sense seems to have its own speed for consecutive input—acoustic 2-3 ms, tactile 10 ms, visual 20 ms—they are synchronized by an internal clock about every 30 ms. This 'clock of the brain' creates a timing grid of the conscious in which events are perceived as one unit. [7, P. 46]

Stepath concludes from Pöppel's research that the basic mechanism which gives us a time-spatial-structured perception, already posses a temporal dimension.

> "An dieser Stelle bleibt festzuhalten, daß offenbar bereits der Grundmechanismus, der uns zeitlich strukturiertes Wahrnehmen ermöglicht, eine zeitliche Ausdehnung bzw. Dauer besitzt." [7, P. 46]

Therefore every living organism has its own speed and timing of perception and therefore a definite span of present can not be provided as it is individual for every being.

Also Planck's discovery of the quantum, as described in chapter B.1.2., may imply that everything in nature posses extension, even its very basic modules like photons, electrons, quarks etc. Combining this fact with the theory of relativity, which interweaves time with space and energy with momentum, gives room for speculation that this extent is the very beginning of the present. CF. [11, P. 57], CF. [18] The concept that a point in time is a point with extent zero acts as a mere tool for calculation, because objects in the quantum world are negligibly small in most calculations. CF. [18]

Based on the physiological and physical facts presented above and the principle discussed in this thesis, the idea of a dimensionless present appears untenable to me.

Continuing with the conclusion that the present possesses extent, I suggested that the span of the present is dependent on the duration of the interaction. This would then lead to the conclusion that the span of present would last from the initiation of the interaction until the change of the system's condition. This would correspond with the physiological findings at the very least and not determine a specific span of the present. Like Paul Valéry puts that any system of objects can form a present.

> „Mit PAUL VALÉRY kann man

> sagen: 'Jedes System von Dingen kann eine »Gegenwart« bilden.'" [44, p. 33]

So far we have investigated what an interaction is, by taking a short glance at what types of interactive systems exist in the whole of chapter B.3.. Now, as a result of the suggestion made in the previous paragraph, another topic emerges: In order to delimit the span of the present, a clear definition of what is and what is not part of a single interaction, a determination necessary to clearly define the span. I will not provide an answer in this paper as this was not the focus of my investigations.

Additionally, because interactions exists for living systems which are long-lasting, e.g. a whole lifetime, it would be necessary to add the subjects 'perception' and 'conscious' to the discussion, as it is obvious that not every current event is perceived as part of our present.

2. Further approximation of living systems and quantum mechanical systems

Viewing the moulding of present as an interaction of systems calls for a harmonization of diverse systems and for more general conclusions.

Similarities on the operational level in virtually different types of systems—e.g. living and quantum mechanical systems—were already determined at the end of chapter B.3.2. and in chapter B.4..

In the field of cybernetics, such harmonization, by looking for similar processes in machines and living systems had been carried out. This was done by the cyberneticists and constructivist Heinz von Foerster by utilizing the

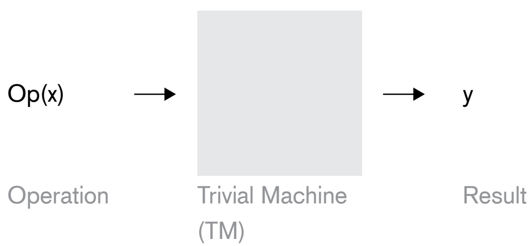


Figure 4: Trivial Machine as described by Heinz von Foerster [22, p.60]

term operator, which is the formal representative of a change-inducing agent. The operator is an abstraction of entities like organisms, systems, machines etc. In order to not completely lose our mundane connection with the term operator, we should keep in mind that an operator is always operating on something. To keep this mundane connection von Foerster follows Allan Turing's idea of calling the operator machine and distinguishes between trivial (TM) and non-trivial (NTM) machines. CF. [22, PP. 59–60]

TMs connect faultless and changeless through their operations certain causes (input) with certain effects (output). Expressed in mathematical terms this is $Op(x) \rightarrow y$ or $y = Op(x)$, where Op is the operation, x is the input and y the output of the TM.

The processes running inside a TM are easy to follow and very much correlate to what one has in mind if thinking about the term machine. CF. [22, PP. 60–61]

The significant difference between a TM and NTM is that the NTM's operations are dependent on its inner conditions (z), which likewise are influenced by the preceding operations. Therefore we need two types of operations to describe the NTM's behaviour. One operation is the response function: $Op_z(x) \rightarrow y$. It connects cause (x) with effect (y) and (z) indicates the machine's inner condition. The other operation is the state function, which changes the inner condition (z) into (z') according to cause (x): $Op_x(z) \rightarrow z'$.

Processes inside a NTM are not easy to analyse, if at all, without knowing the inner functional organisation. Experiments with such a machine may lead to different outputs (y) based on the same

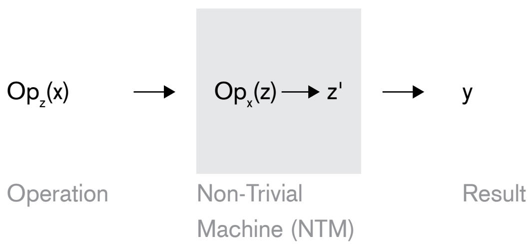


Figure 5: Trivial Machine as described by Heinz von Foerster [22, p.62]

initial input (x), if the input changes the inner condition (z). CF. [22, PP. 62–65]

In summary a TM can be described as:

1. synthetically determined,
2. analytically determinable,
3. independent of its past and
4. predictable. [22, P. 62]

Whereas NTMs can be described as:

1. synthetically determined,
2. analytically indeterminable,
3. dependent on their past and
4. unpredictable. [22, P. 66]

Ideal physical systems functioning according to Newtonian laws, could be described as TMs. However, von Foerster acknowledges that TMs are probably not existing, as even the best engineered machines wear out over time. CF. [22, P. 66] A rather mechanical notion. However, as mentioned above, the idea of machines or operators may be applied to any entity. In this light, I may easily assess living systems as NTMs. As I see it even quantum mechanical systems possess qualities of NTMs. They are analytically indeterminable and unpredictable at the least because they are in a state of superposition.

Taking all this into consideration I assume that a harmonization of living and quantum mechanical systems is possible, especially if seen from the angle of moulding the present.

Even more with such a harmonization one might surpass the constriction of this thesis, made in the beginning[1], that we can only talk about human perception. In the end one might be able to define a general theory of the present for any animate or inanimate entity in existence.

1 See chapter A.1.2..

3. Theories about past and future

To fully describe the present, I feel the need to reference to the past and future.

We have to realise that we can only talk about the present if we separate time because of the ontological difference we make between past, present and future. [7, P. 41] As mentioned in the premise to this thesis[2] it is assumed that the present is situated between past and future. It is an assumption, according to Stepath, which arises from the structure of our conscious and our way of perception, as both of them are ordered in a structure of time. CF. [7, P. 34] A conclusion also made by Paul Watzlawick, as we saw in chapter B.2.1.. So we separate time into three modes[3]: The past as the things that were, the present as the things we are currently involved in and the future as the things to come. [7, P. 41]

Further examinations are necessary regarding how these references between past, present and future are built and what is their effect on the present.

The history or experiences of a system are the reference to what is called past. These experiences have a strong influence on how we perceive or interpret the present.

From a physiological point of view Ernst Pöppel sees a continuous elapsing of segments of consciousness, where the present segment references the preceding one. This on the one hand arranges a flow of time. On the other hand it is a semantic connection which interprets the present from past experiences. CF. [7, P. 50]

The philosopher Henri Bergson also expressed the opinion that the decisions we take are not independent of our experiences, i.e. our past. However, we also interpret our past with regard to the present. Events of the past may be interpreted in a new light with knowledge gained in the present. So the past is changing retrospectively. [7, PP. 68–69]

Stepath see that time and present—for conscious beings—are always subject to interpretation. Time and present do not have a meaning by themselves. We give them meaning by regarding our past as reality, without saying every time that even the past is just an interpretation of the many possibilities seen from our perspective. [7, P. 56]

That the past is referenced through experience is a proposition most people would agree to without hesitation, as do I. As for how the future is referenced, this is a more complex subject. For referencing to the future, I propose

2 See chapter A.1.2..

3 Generally speaking a mode describes the way of being or events. [7, P. 41]

two ways which most of us know from experience: Intention, at least for conscious beings, and chance, divided into subjective and objective chance.

Donald Norman states that, to reach a goal we set for ourselves, we need to specify an action. This step in the seven step model is called intention. Yet, this intention is not specific enough to control the action and out of the intention we form a specific action sequence which is then executed. See chapter B.3.1.3. for the whole seven steps of an action. cf. [38, pp. 46–48] We see that an intention is a direction towards a future event, which did not yet manifest itself in space.

Within Edmund Husserl's understanding of the perception of time we find a similar assignment to intention. He calls this direction towards the future *Protention*. His structure is built around the *Ur-Impression*. It is the core of all perception, and has almost no expansion in time. Around this *Ur-Impression* lies the so called courtyard of present (*Hof der Gegenwart*). It is directed in two ways, which can be described as the past of the present (*Retention*) and the future of the present (*Protention*). These two directions are still part of the immediate perception. Husserl sees perception as a rather passive action. One must realise that Husserl distinguished *Retention* and *Protention* from the extended past and future. Two more spheres are surrounding this first sphere. On the second sphere lie the present of the past, the present of the present and the present of the future. It distinguishes itself from the first sphere by actively performing acts of realization of what was, is and will be. The third and last sphere is structured the same way as the second, but only acts of imagination are taking place here.[4] In the end Husserl calls this whole structure a time field (*Zeitfeld*). cf. [7, pp. 80–89]

Protention is the anticipation of the close future without having it properly processed yet. This is happening on the second sphere. As Norman demands, an action sequence after the intention was set. Additionally Husserl indicates an important fact through his structure: we are only able to perceive a close future and reflect upon that. What lies beyond that close future is outside of our reach.

The future outside of our reach may well be subject to chance—the second way I propose.

Chance exists in two flavours, subjective and objective chance. The phrase, subjective chance, refers solely to our, subjective, current nescience which makes a certain event appear

4 One is reminded of Fazang's structure of time as described in chapter A.2.5..

coincidental. In fact, there would be a well-defined reason for that event. For example if we meet someone on the street by "chance", then we can account for this event by the time we left the house, the route we chose, the distractions we encountered on the way etc. The same applies to the person we meet. In quantum physics, however, reasons for a single event can not be stated. Only statements about the probability of a quantum mechanical event to occur within a certain period of time can be made. If we measure a certain factor under the same conditions over and over again, we will get a range of results, each with a different probability. As we have seen in the Mach-Zehnder interferometer, chapter B.1., we cannot exactly tell which way the photon took inside the interferometer. Thus in quantum mechanics a single event occurs without a reason. It is objective chance that rules these events. cf. [11, p. 126], cf. [15, pp. 42–46] Subsequently this means that the future is essentially and necessarily unpredictable.

With the aforementioned I established that the future is subject to chance. A fact owed to either nescience, in the case of conscious beings, or an independent objective chance. By referring to the possibilities of the future with our directed intention, we rule out all but one of these possibilities as we interact with them. In the end it is the interaction that leads to certain results and thus moulds the present.

D. Art Projects Relating to the Hypothesis

Following, is a selection and analysis of interactive artworks considering their ability to express the principle that interaction moulds the present.

Building on the analysis of the characteristics of interaction in different fields, it will be shown how and what kind of interaction is taking place—this will draw mostly on the characteristics of HCI and interactive media art. Additionally it will be illustrated how these artworks transport the idea of interaction as the principle of moulding the present.

In the search for artworks which deal with the subject of time and present, one comes across many reinterpretations of clocks. Devices or installations which use rhythmical parameters to scrutinize the idea of time. It is possible to easily replace any metre of time with any periodical equivalent process. [7, p. 35]

For example the work *Sneaky Time* by Ozge Samanci literally does this as it replaces a clock's rhythm with the rhythm of the visitor's blinking eye. cf. [45] As stated in the premises of this thesis[1] the primary interest of this thesis is to define a principle by which the present is established. Defining a specific length of the of the present is touched on briefly in chapter C.1..

1 See chapter A.1.2..

1. Peter Weibel: Beobachtung der Beobachtung: Unbestimmtheit, 1973

1.1. Description

The media artist Peter Weibel explains the setup and contents of his art piece *Beobachtung der Beobachtung: Unbestimmtheit* (*Observation of the Observation: Uncertainty*):

> "The cameras and monitors are juxtaposed in such a way that the viewers are unable to see themselves from the front, no matter how much they twist and turn. The self-observers see different parts of their bodies, but never their faces. Shut inside a room, every point in the room is the observer's jailer, perspective of their deathly fate." [46]

1.2. Analysis

Based on the preceding description the art work reveals a strong focus on the idea of observation, even surveillance, and privacy.

However, in my view, by the types of systems that are involved and the way the piece works firm connections to the theme, on how the present is established, are revealed.

First let us take a look at the systems involved in this piece of art. It is described as a closed-circuit installation by several sources, including Weibel himself. CF. [46], [47] A closed-circuit can be accomplished when the input is directly connected with the output. CF. [48, CH. II. THE VIDEO MEDIUM] This output feeds back into the input altered or unaltered. This is equal to a closed loop system as described in chapter B.3.1.3.. In Weibel's work the juxtaposed monitors and cameras, which are pointed at each other, effect such a closed loop system. Assuming a visitor would approach the installation but not enter into the circle yet, an observer outside the closed loop system in a manner of speaking, then no change would take place within the system. A fact already addressed in the premises of this thesis10 when explaining the verified theory of Page and Wooters that an outside entity is not able to detect change within a system. Also we should bear in mind what Heinz von Foerster pointed out: the observer is always considered a part of the system. CF. [20, P. 43] Without this precondition we would not be able to measure a system's properties, as I described in chapter B.3.1.1.. This is a first lead that this work is very much concerned with how the present is established.

Let us now assume the visitor would move inside the closed loop system. The cameras start to record the visitor

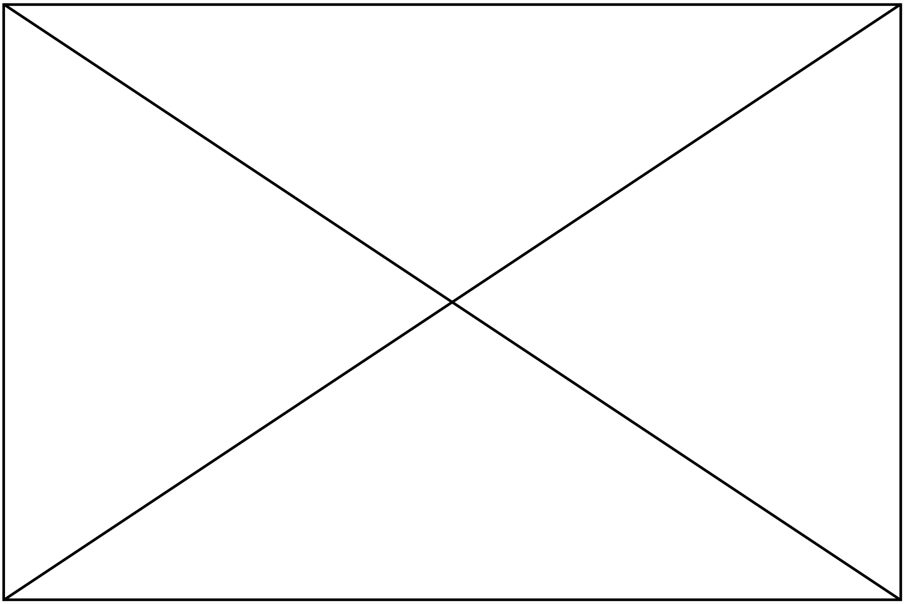


Figure 6: Beobachtung der Beobachtung: Unbestimmtheit; © Peter Weibel; Photo document of the original installation in the exhibition «Trigon '73. Audiovisuelle Botschaften,» Graz 1973

and the visitor is able to see a changing image on the monitors. The observer is measuring change in the system. Usually a human person can not look—i.e. measure—what is behind his or her back. There is uncertainty about what is happening behind one's back. Many possible events may take place—i.e. possibilities in superposition—but without looking one will not be able to say with certainty what is happening. At this point it is worth to recall the statement made by Anton Zeilinger in chapter B.1.2., that we may only talk with certainty about a phenomena we are observing. The monitor shows the visitor a picture of his or her back side and the visitor may achieve certainty about what is happening in his back. This measurement is only valid in this certain context, though. Ought the visitor turn around and try to “verify” what he or she just saw in the monitor, the context of the measurement would change. A new measurement would be made. In this very example the visitor might see another person's back in the monitor. If the visitor turns around he would perceive the same person but he would look into the person's face instead of its back. Therefore the visitor does not achieve the same measuring result as the measuring context was changed. The necessity to make a measurement to overcome uncertainty and the measurement's outcome depending on the context is the second lead that this work is concerned with how the present is established.

As I showed above, through the way *Beobachtung der Beobachtung: Unbestimmtheit* is set up it enables its visitors to ponder upon the necessary preconditions of an interaction, i.e. involvement in the system. Also the visitor may reflect upon the result and also limits of interaction, i.e. certainty achieved only through measurement and in a certain context.

2. Sienčnik, Nataša: Now, 2013

2.1. Description

The object is described as a modified clockwork in a correspondence with the artist. The clockwork was taken from a clock radio of the 1970s. The object was extended with a third coil, its metal frame enlarged and the sheets were replaced with new ones, printed with silk-screen printing. The coils are driven by an Arduino and DC motor. The clock only ever shows the present, which is always newly assembled through the ceaseless motion, however. [49]

2.2. Analysis

At first sight the object looks like a clock. But it makes no concrete reference to any amount of elapsed time. We only see how one moment of present—represented by the word “NOW”—is replaced by the subsequent one. The artist writes that the present is perennially newly assembled through the ceaseless motion of the object. A reference to the many philosophers, like Aristoteles or Ibn Rušd[2], who explained that the passage of time becomes tangible through the movement of bodies, the stars, introspection or any other types of change.

Before analysing the artwork and the system it constitutes, it should be mentioned that the observer is always considered a part of the system, like Heinz von Foerster pointed out. [22, p. 43] Looking at this work as a system we might presume, at first glance, that this is a static system. Especially, if we were isolated from any surrounding systems. If we do not see the sheets change, the object may appear static like a stone sculpture. Time would stand still and

2 See chapter A.2.4.

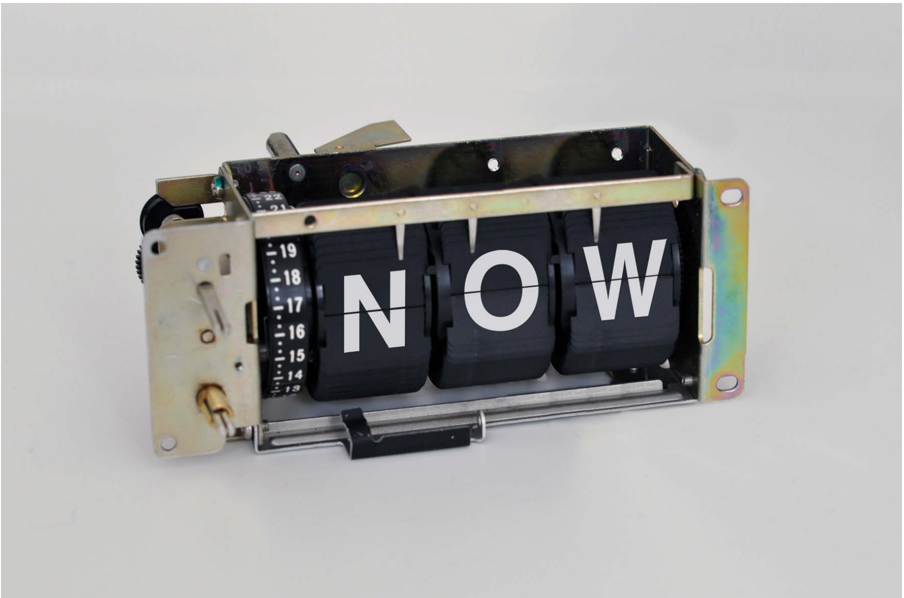


Figure 7: Media art work NOW, ©2013 Nataša Sienčnik

the present would be in a state of eternity. A view reminding of Plato's assumption that eternity is eternal present with neither a before or after. In this timeless eternal realm of ideas reside the archetypes of all things. By creating images of these archetypes through a demiurge time is created. Thus we have the eternal realm of ideas and the elapsing worldly realm. CF. [25, P. 1196]

However, when the object is refreshing the word "NOW" we realize that the system is not residing in a state of eternal present. Using Dubberly's et. al. list of system types[3], we see that the system is a dynamic one at least. Superficially it may appear merely as a linear system, because the audience reacts to the object—which is quite the twist to the usual behaviour of interactive art. However, examining the single parts of the system we realize that this whole system is more complex.

One part is the clock-like object. It is a dynamic system which interacts with its environment in a recirculating manner. The other part is the audience, a living system. A living system, as we saw in the explanations of Peter M. Hejl, is a self-organizing, self-sustaining and sometimes equipped with

3 See chapter B.3.1.3.

a self-referential systems.[4] In terms of Dubberly's et. al. a self-organizing system corresponds to a dynamic, linear system; self-sustaining equals closed loop; a self-referential system is self-regulating in connection with the two aforementioned types and depending on its complexity might be even a learning system. As for humans, I presume that they are learning systems. So we see that the system of a clock-like object and a living system is far more complex than a reacting system.

This complexity has consequences. The system bears proof that humans are learning systems in the interaction with the object itself. Learning is the "[...] modification of goals based on the effect of actions." [32] The living system, when entering the interaction with the clock, will experience a static system. When the clock turns out to be dynamic, the living system will react to this. It will set the goal to assess the behaviour of the clock. Over the course of the process—the clock turning its sheets—the living system assesses the clock's behaviour and rhythmic pattern and modifies its goals accordingly. For example the living system rules out that the clock poses a threat and ensures its survival.

Coming to a closure and back to my initial question how the artworks transport the idea of interaction as the principle of moulding the present. By turning around the accustomed relation that the object reacts to the observer into the observer "reacts" to the object, the audience lives through all types of interactions a single human in connection with a recirculating system may experience. Important in this chain is the step from a static to a dynamic system, which initiates the whole process of learning. A step which we are always reminded of whenever the clock rotates its sheets and again comes to a stop, appearing static. The word "NOW" tells us that we reassess this relationship at any given moment.

4 See chapter B.3.1.2.1.

3. SUPERHOT Video Game, 2013

3.1. Description

SUPERHOT is a first person shooter video game in which things only change, when the player moves. The game's speed is slowed down substantially. Every event appears as if in slow motion. Also when looking around. Only if the player moves or triggers a shot, the game runs in normal speed. The player's aim is to kill all enemies inside a level. If the player dies the game is lost.

When the player starts a level he will be attacked with gunshots by red shining adversaries. These gunshots approach very slowly unless the player moves. As the shots are directly going for the player he must move in order not to be killed.

The game's developers explain:

“With this simple mechanic we've been able to create gameplay that's not all about reflexes - the player's main weapon is careful aiming and smart planning - while not compromising on the dynamic feeling of the game.” [50]

At the time this thesis was written, SUPERHOT was still in functional prototype status. The game's prototype was realized in the Unity Engine.

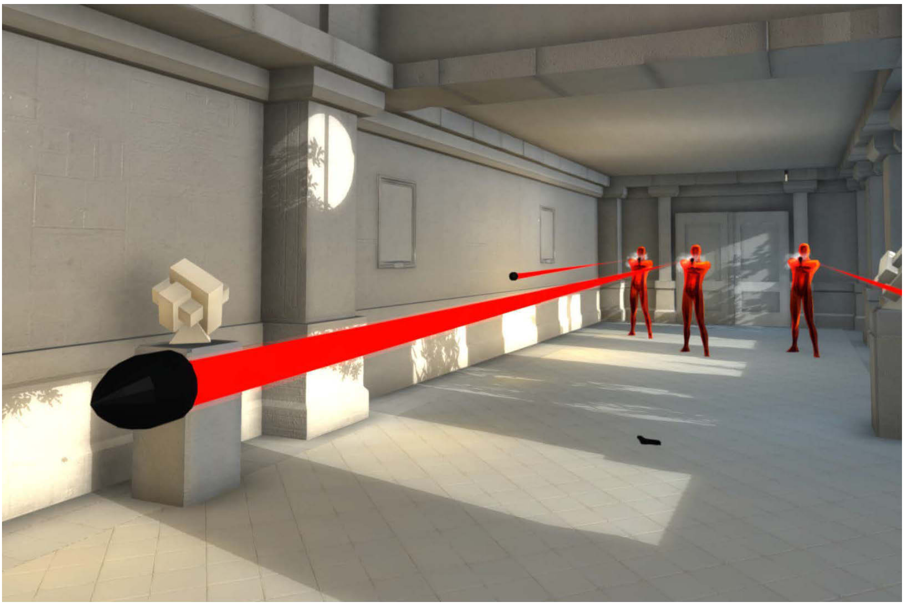


Figure 8: Picture of SUPERHOT video game, ©2013 SUPERHOT

The developers plan to expand the prototype, which may result in changed game features in the future. Therefore, the following analysis is based on the prototype of September 2013.

3.2. Analysis

SUPERHOT emphasizes the need of motion for change to happen. The game's developers radicalised this relationship as they make the flow of time dependent on change. The philosopher Moses Maimonides represented this view by saying that time is an accidental phenomenon and an inevitable consequence of movement.[5] A movement can not exist outside of time and one cannot think of time without movement. Because immobile things are not even inside the definition of time. [25, COL. 1221]

So, any movement in the game excites the flow of time and furthers change in the level. The player's interaction in the game cause the system inside the level to change.

When we dissect the system into its single parts then on the one side we have the player in front of the computer. The player projects his actions instantly and directly onto an alter ego and experiences these actions through the eyes of his alter ego. On the other side we have the computer which controls the actions of several adversaries inside the level. Also the level, which is the environment of the alter ego and the adversaries, is created and sustained by the computer. Therefore the alter ego of the player is simply referred to as player. The adversaries are referred to as the *machine system*, since the computer attunes all their actions and controls them. The level in which player and machine act is referred to as *environment.*

Both, player and machine have a goal. Both want to defeat the other to be the last active system in the environment. Therefore, both systems are essentailly self-regulating according to Dubberly et. al.6

When the player enters the environment the machine will react to this event. It is input in the from of disturbance to the machine. The disturbance is that the player is residing in the environment—a clear irregularity with the machine's goal. The machine will try to regulate its relationship with the environment and the player according to its goal. It will try to defeat the player. Therefore the machine system is a self-regulating system of first-order.

The player acts slightly more complex. He acquires his goal through instructions while being in the environment. By following this goal, which mainly is to defeat the machine system, the

5 See chapter A.2.4.

6 See chapter B.3.1.3..

player acts like a self-regulating system. However, through assessing the situation in the environment and planning ahead the player may anticipate the machine system's moves. The player does not merely regulate but learns about the situation and then regulates.

For both systems we see perfect examples in Donald Norman's seven steps of an action. Both systems have their goal set. Next they form their intention. The machine system intends to shoot into the direction the player is positioned. The player will intend to shoot or move depending on the situation. Then they specify their action sequence. The machine and player system will define exactly where to position themselves and where to aim. Then both execute their action sequence. After the execution both systems perceive the state of the world, e.g. the systems inside the environment. The perception is interpreted according to the expectations and then evaluated with regard to the system's intention and goals [38, p. 47], bearing in mind that these processes are not necessarily happening at the very same time and in reciprocal manner.

It becomes clear that this game is very well able to expose what an interaction is. This fact is even more emphasized as the flow of time cannot be controlled through the machine system but only through the player. Here the direct entanglement of the player's interaction with the proceeding of the machine system make it obvious to the player that the present is established through interaction.

E. Own Project Works Relating to the Hypothesis

The following two works are descriptions of my attempts in implementing the hypothesis “interaction moulds present”. The first work *Lichtspeicher* was an important step on the route to develop this thesis's hypothesis. Whereas the second work *Gegenwartsmaschine* is the direct result of this thesis and my first effort to introduce my hypothesis to an audience in a practical manner.

1. Lichtspeicher

Lichtspeicher was and to date still is my first endeavour in creating a device which deals with the perception of a moment in time.

1.1. Technical description

Lichtspeicher is a portable device to scan, store and compile lighting conditions and ultimately play them back on its outer shell. It is shaped like an icosahedron with the electronics being housed inside and covered by a translucent shell material.

RGB-light-sensors are placed on each corner of *Lichtspeicher* and hence it may scan the ambient light in 360 degrees. The internal electronics store the recorded data of the surrounding lighting conditions for future playback. When activated for the first time *Lichtspeicher* will scan the lighting conditions of its current environment—taking a single snapshot in time. When activated again, the previously scanned lighting conditions is replayed. Then what appears like a low resolution video is displayed on *Lichtspeicher*'s skin. *Lichtspeicher* does not intend to be a pixel by pixel representation—like a TV screen—of ambient light. The ambience of the recorded lighting conditions is seemingly reflected from the inside out. Therefore *Lichtspeicher* is usable only once to record a lighting conditions.

1.2. Background

The idea for *Lichtspeicher* was born after visiting an exhibition about Claude Monet in the Grand Palais, Paris, which took place from September 2010 until January 2011. While looking at his series of Grainstacks (painted in 1890/1891) it became clear that Monet evolved in his works from depicting real scenes to depicting solely the lighting conditions of a scene. An opinion stated also by art historians. cf. [3, pp. 260–281]

It felt like Monet chose a situation, observed it for some time, understood its light and then commenced the painting. Seemingly Monet's coeval Guy de Maupassant had a similar impression when he accompanied Monet in 1886 for some time:

> "Last year [...] I often followed Claude Monet in his search for impressions. In truth, he was no longer a painter, but a hunter. He walked around, followed by children carrying his canvases, five or six of them representing the same subject at different times and with different effects. / He picked them up and put them down in turn, according to the changes in the sky. And the painter, facing his subject, would lie in and wait for the sun and shadows..." [51] in [3]

Monet himself said that he is looking for "instantaneity". [52] in [3] *Lichtspeicher* is attempting the same. By recording the ambient light and playing it back on its skin it tries to reflect an instant in time which was perceived.

Lichtspeicher is shaped as an icosahedron. An icosahedron is one of the five Platonic solids - which are the only solids constructed out of congruent regular polygons, with the same number of faces meeting at each corner. Besides its technical advantage that the sensors may point in all directions with a minimal overlap, the properties of an icosahedron transport a very basal feeling. In his work "Chapter One: Discovery" Félix Luque Sánchez uses the Platonic solid dodecahedron. The artists explains his choice as follows:

> "The aesthetics of the object resides then in its capacity to become unfamiliar, to make it appear as a machine more than a sculpture. To attend this goal we had to express the apparent simplicity of the form, make disappear the technology,

create an indistinct surface, texture, and matter." [53]

The shape communicates an idea of machine and not sculpture. It becomes an object of utility and not a piece of admiration by itself. *Lichtspeicher* is also stepping back behind its appearance to give full credit to the content: the light. As did Monet as he gradually neglected describing the form of landscape and shifted to "[...] the systematic study of the transformations caused by light [...]". [3, p. 266]

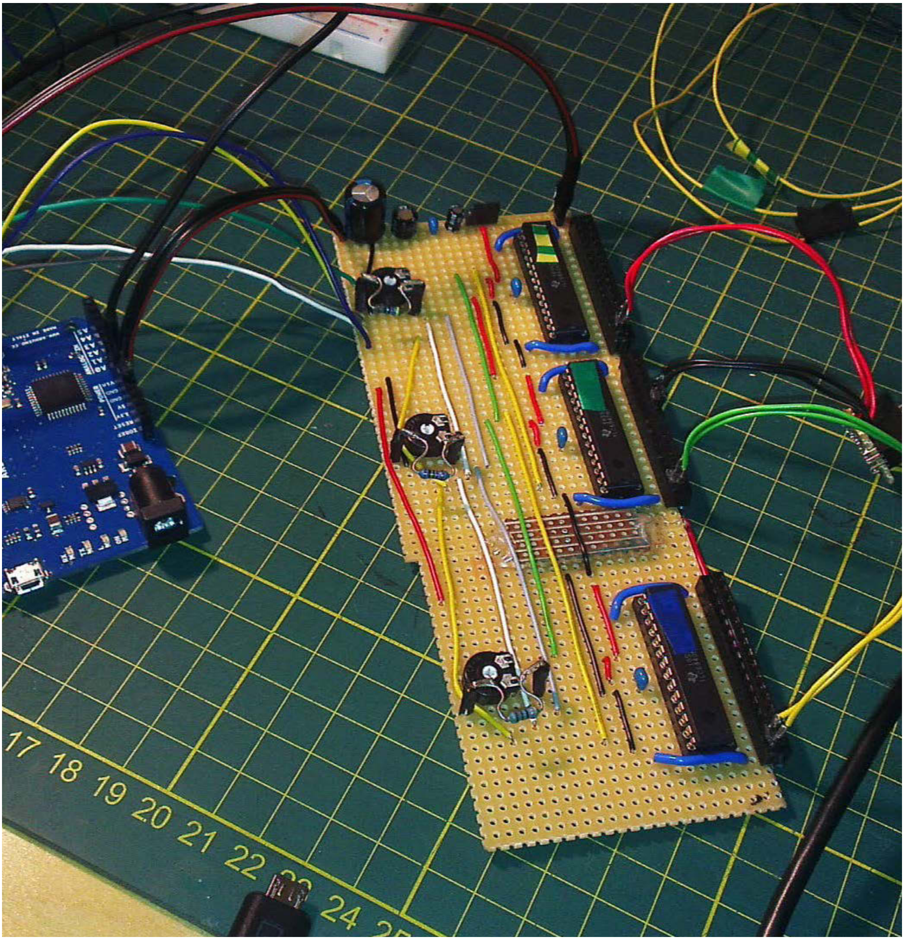


Figure 9: Board to control the LEDs of Lichtspeicher.

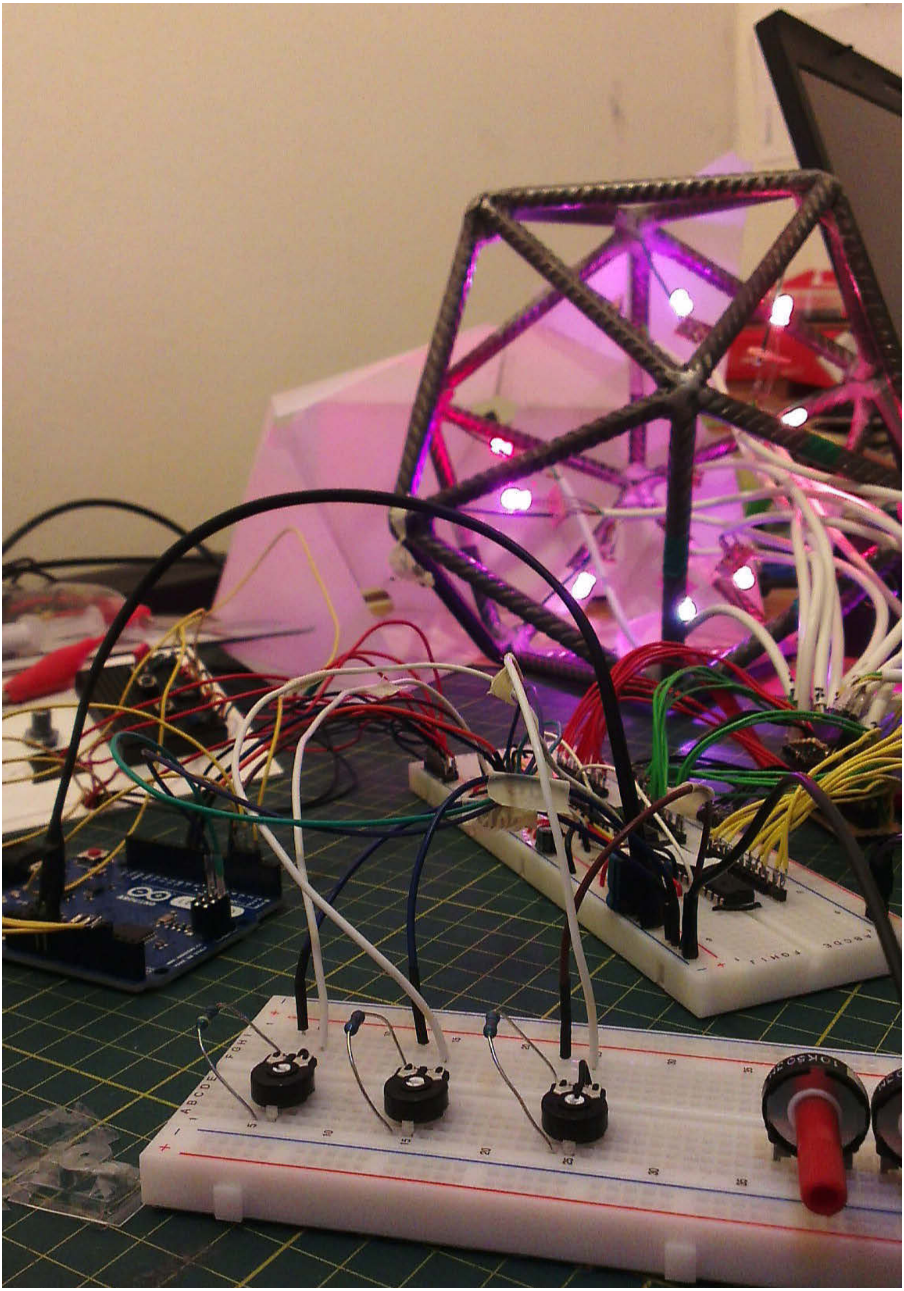
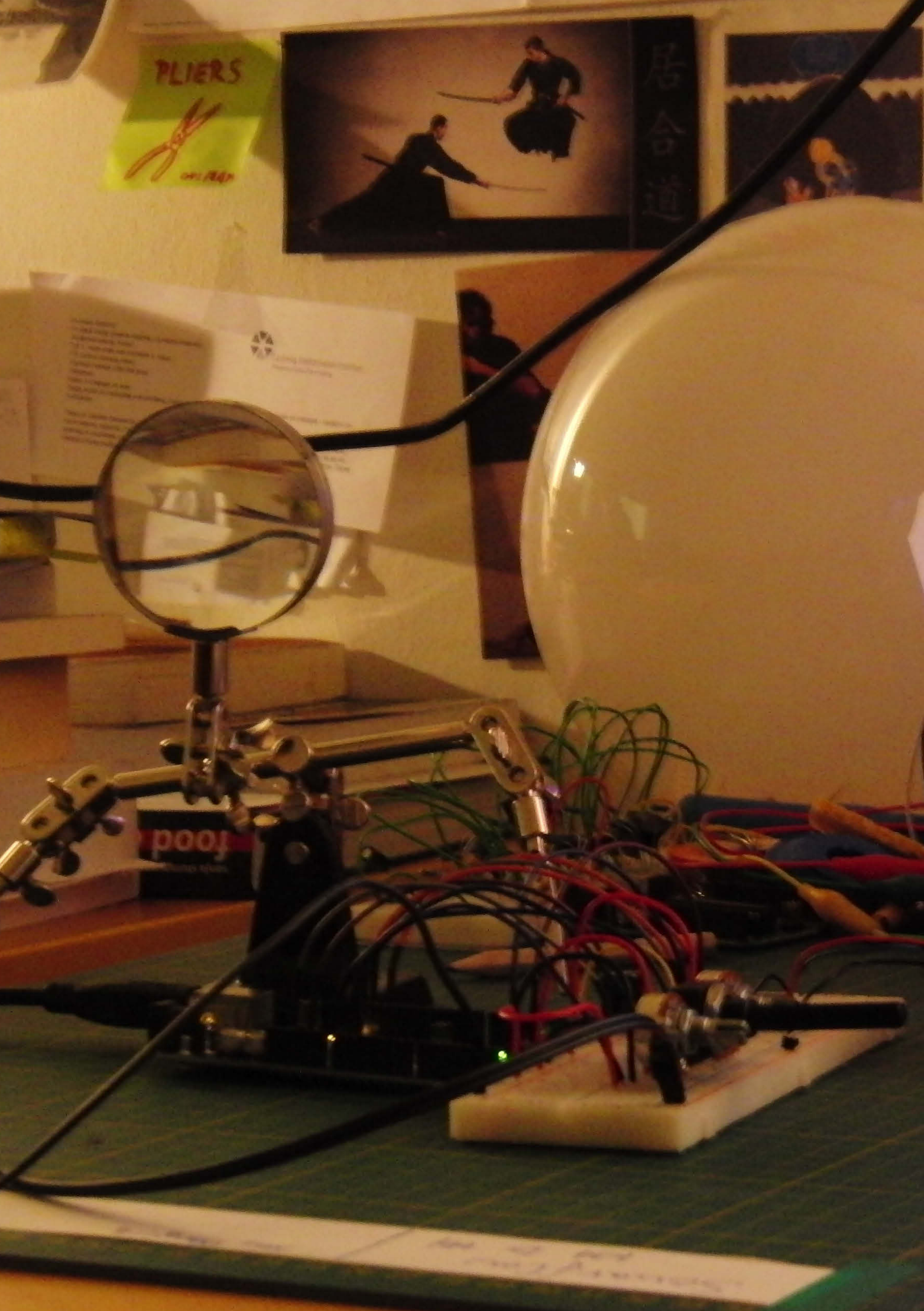


Figure 10: Prototype of LED controller board.

Figure 11: Successful test of lighting every LED up in an individual colour.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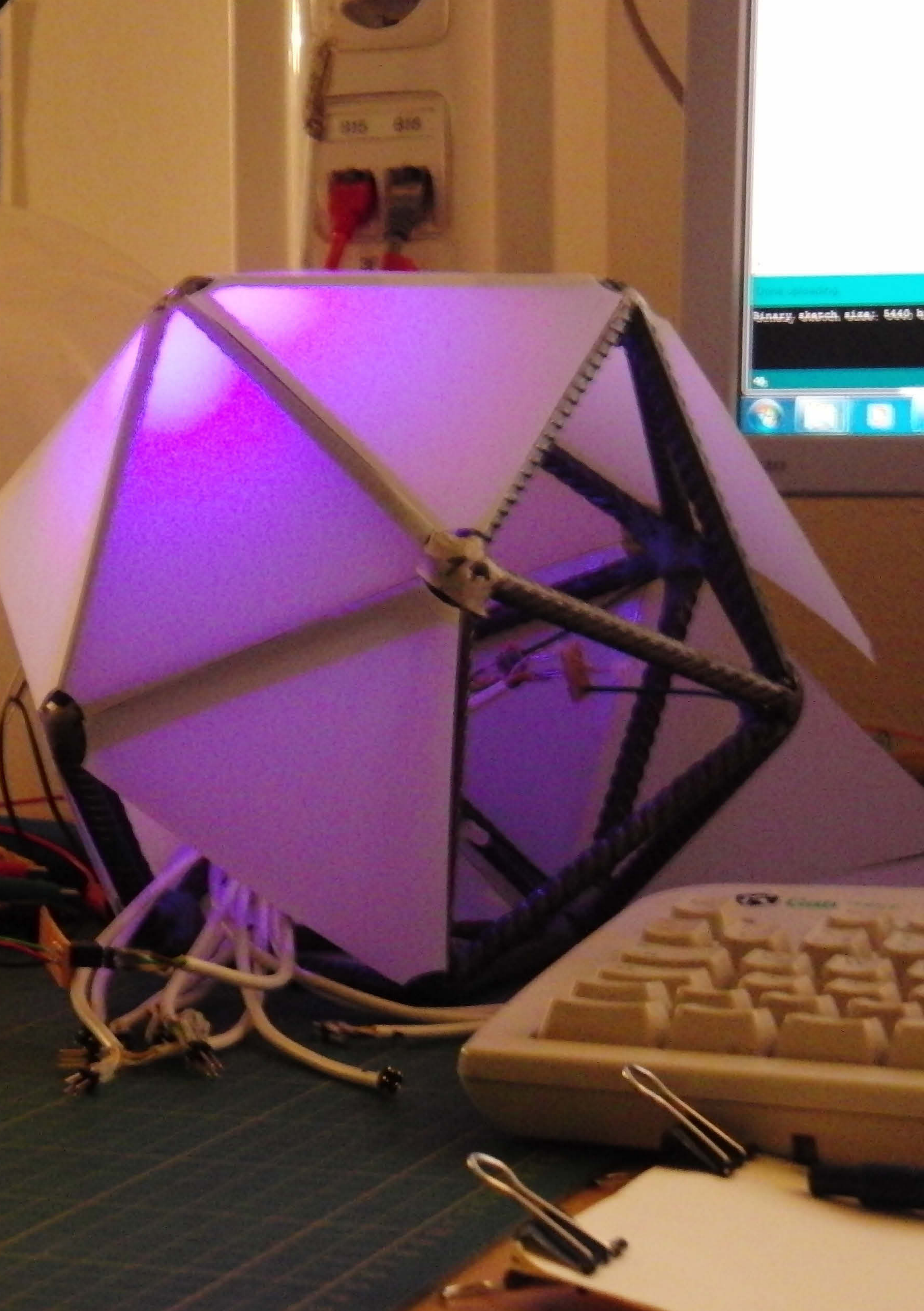


2. Gegenwartsmaschine

Gegenwartsmaschine is an interactive media art work which stresses the concept discussed in this thesis.

2.1. Technical description

Gegenwartsmaschine is an interactive installation, which reacts to the observer's present. On the outside it is an ordinary black box. Through a hole in the box the audince may peeking inside into a lit up space with undefinable dimensions. The light inside is generated by a true random generator each time. The light may be different for every observer interacting with the system.

Inside the box is a noise generator which creates truly random values, RGB-LEDs, smoothly sanded half of a sphere, a phototransistor and an Arduino as a controller for all the hardware.

The noise generator generates random values for the RGB-LEDs, so it may shift its colour. Is positioned directly at the hole through which the visitor may look inside. So the phototransistor will detect a shift in the light level by a person peeking through the hole. When the phototransistor detects a drop below a certain threshold, it will tell the controller to stop shifting the RGB-LEDs' colour. Thus the light will stop shifting when an observer peeks through the hole. As the light of the LEDs shines upon a very smooth surface which has no edges or corners, the observer will have the impression of a featureless space inside the box.

2.2. Background

Besides the subjects discussed in this thesis, like interaction is inevitable[1], the retrenching nature of interaction[2], superposition and the consequences for the future[3], *Gegenwartsmaschine* is referencing two historical situations in the research of quantum physics. On the one hand the technique how the ideal light source was created and subsequently Max Planck's discovery of quantization of light. On the other hand the thought experiment known as Schrödinger's cat.

At the end of the 19th century in search for an ideal light source scientists recognized that the light and its spectrum emitted inside a hollow depends on its temperature only and not on the material of the walls. To perform measurements on this ideal light, a tiny hole is drilled into the hollow—too tiny to have any significant effect on the quantity of light inside. The light inside and the small amount that is exiting is called

1 See chapter B.4..
2 Ibid.
3 See chapter C.3..

black-body-radiation. CF. [15, PP. 10–12] Around 1900 Max Planck asserted, while researching on properties of the black body radiation, that "[...] energy could be emitted or absorbed only in discrete energy quanta [...]". [54, P. 20] A discovery so profoundly different „from anything known in classical physics that he certainly must have refused to believe it in the beginning." [54, P. 19] This discovery was the birth of quantum physics. CF. [15, P. 16]

Therefore, the light conditions inside are similar to those inside a black body and peeking into the black body of the box resembles the procedure to detect the black-body-radiation through a small hole in the hollow.

In 1935, when research in quantum physics had drastically advanced, Erwin Schrödinger devised his famous thought experiment now known as Schrödinger's cat to discuss if superposition of macroscopic systems is possible or not. The thought experiment is composed of a cat locked in a box together with a radioactive atom, a Geiger tube, an electrically released hammer and a vial of poison. When the atom decays, the Geiger tube will register this and cause the hammer to break the vial. In this case the cat will die. And as long as the atom does not decay the cat will stay alive. Additionally one is not able to retrieve any information from inside the box. Supposed that the atom decays within the next hour then after that one hour, in quantum mechanical terms, the cat is in a state of superposition of alive and dead. As there is no exchange of information—e.g. interaction—from inside the box with the outside nothing can be said about the system's condition inside. CF. [15, PP. 99–101] Only by taking a measurement from inside the box can we determine the cat's status.

Gegenwartsmaschine works in a similar manner. As long as nobody peeks into the box the light inside is virtually in a state of superposition, as it changes its colour every half second. Only by looking inside the box, like taking a measurement, a state is fixed.

In contrast to *Lichtspeicher* which focuses on the perception of the moment of present, *Gegenwartsmaschine* highlights the concept of interaction to establish the moment of present. It does so by keeping to a minimum set of interactions. At this stage of development the box is merely reacting to the audience—the minimal form of a dynamic system. The interaction is sufficient for the audience (a learning system) to grasp the idea. To better articulate the concept of this thesis a more elaborate interaction would be necessary.

2.3. Extension of Gegenwartsmaschine

Momentarily *Gegenwartsmaschine* is a dynamic linear system. It merely reacts to the audience, in the way that the light stops shifting as long as someone observes the inside.

To enrich the work and to properly articulate the hypothesis that interaction moulds present, *Gegenwartsmaschine* should be enhanced from a mere reactive system to a dynamic closed loop system. In such a setup *Gegenwartsmaschine* will feed back into itself what it receives from the outside to determine and provide an output adapted to each situation.To achieve this, *Gegenwartsmaschine* will be equipped with sensory capabilities to recognize individual people. This will enable *Gegenwartsmaschine* to link the colour it generated to the person which is gazing inside. Thus a person gazing inside the box would see the same colour every time.

Ingrid Spörl supports this view by saying that the concept of interactivity should be reserved for communicating entities which are able to adapt to each other and are not merely working by a stimulus-response model.

> „Als reaktiv werden starre Systeme mit vorprogrammierten Reiz-Reaktions-Mustern bzw. Sensorinput-Agentoutput-Relationen bezeichnet. Der Begriff interaktiv sollte dem Dialog zwischen lernfähigen Kommunikationspartnern vorbehalten bleiben." [41, p. 31]

The important thing for Spörl is that, in the system of reciprocal exchange of actions between observer and interactive art work, a bit of the range of the preceding responses is maintained. This then is interpreted as interaction. cf. [41, p. 31] This statement accords to what Watzlawick said about the retrenching nature of communication. Each exchange of information reduces the number of possibilities for the next exchange.[4]

Thus with a sensory extension, *Gegenwartsmaschine* would further approximate a true interactive system.

4 See chapter B.2.2..

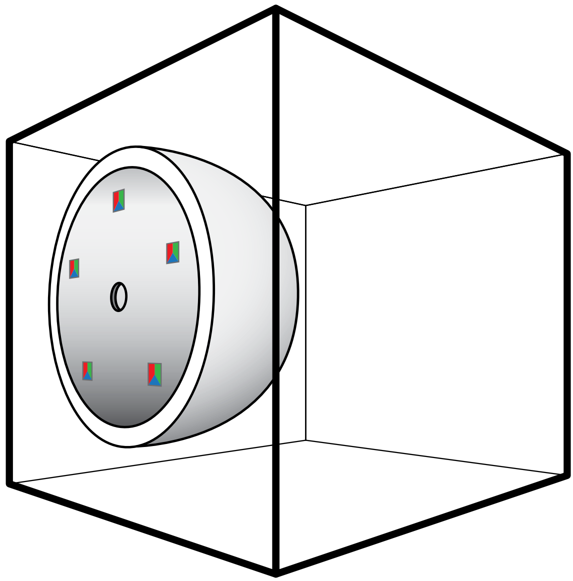


Figure 12: Schematic of internal structure of Gegenwartsmaschine.

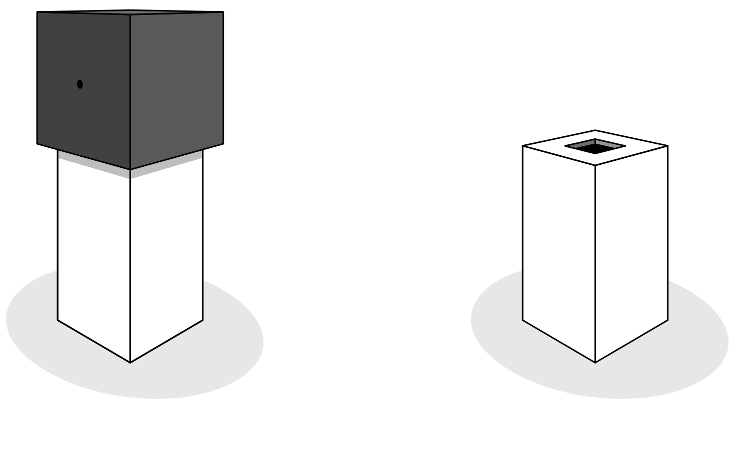
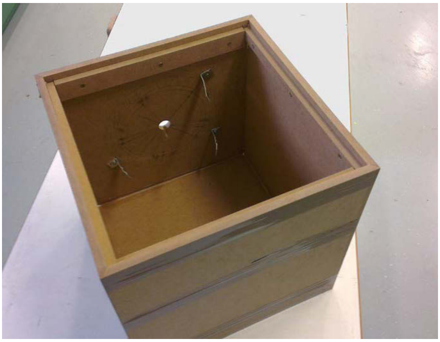
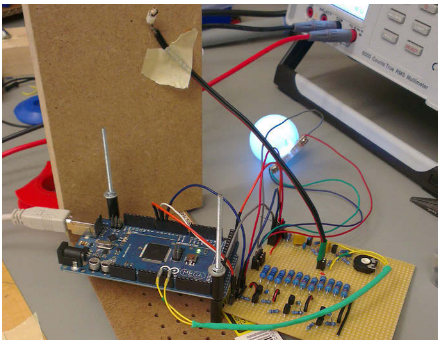
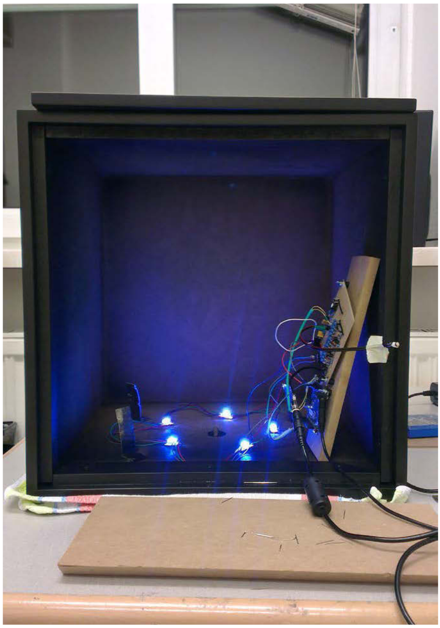


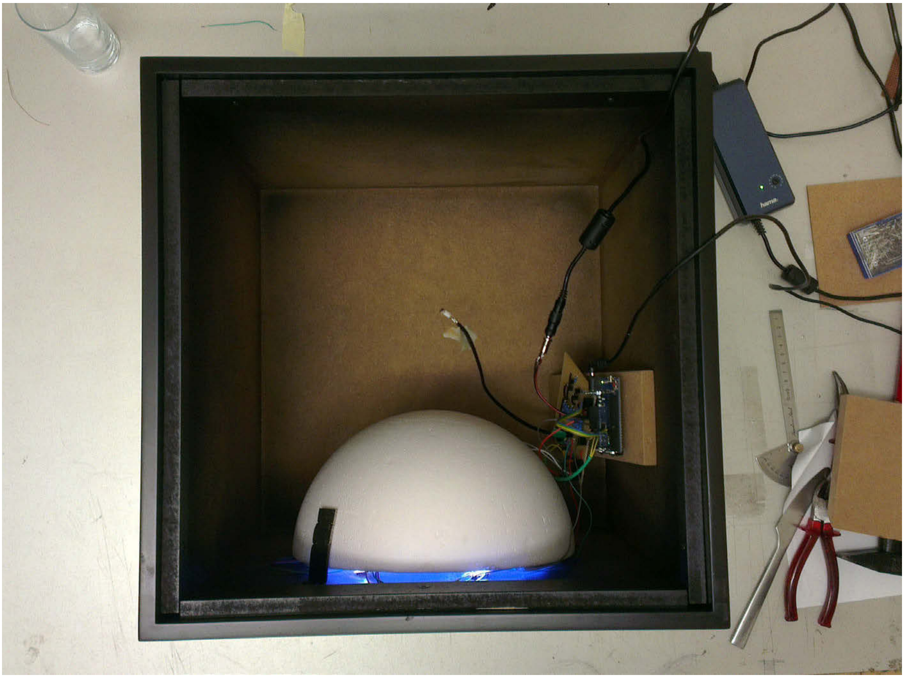
Figure 13: Setup for exhibitions.

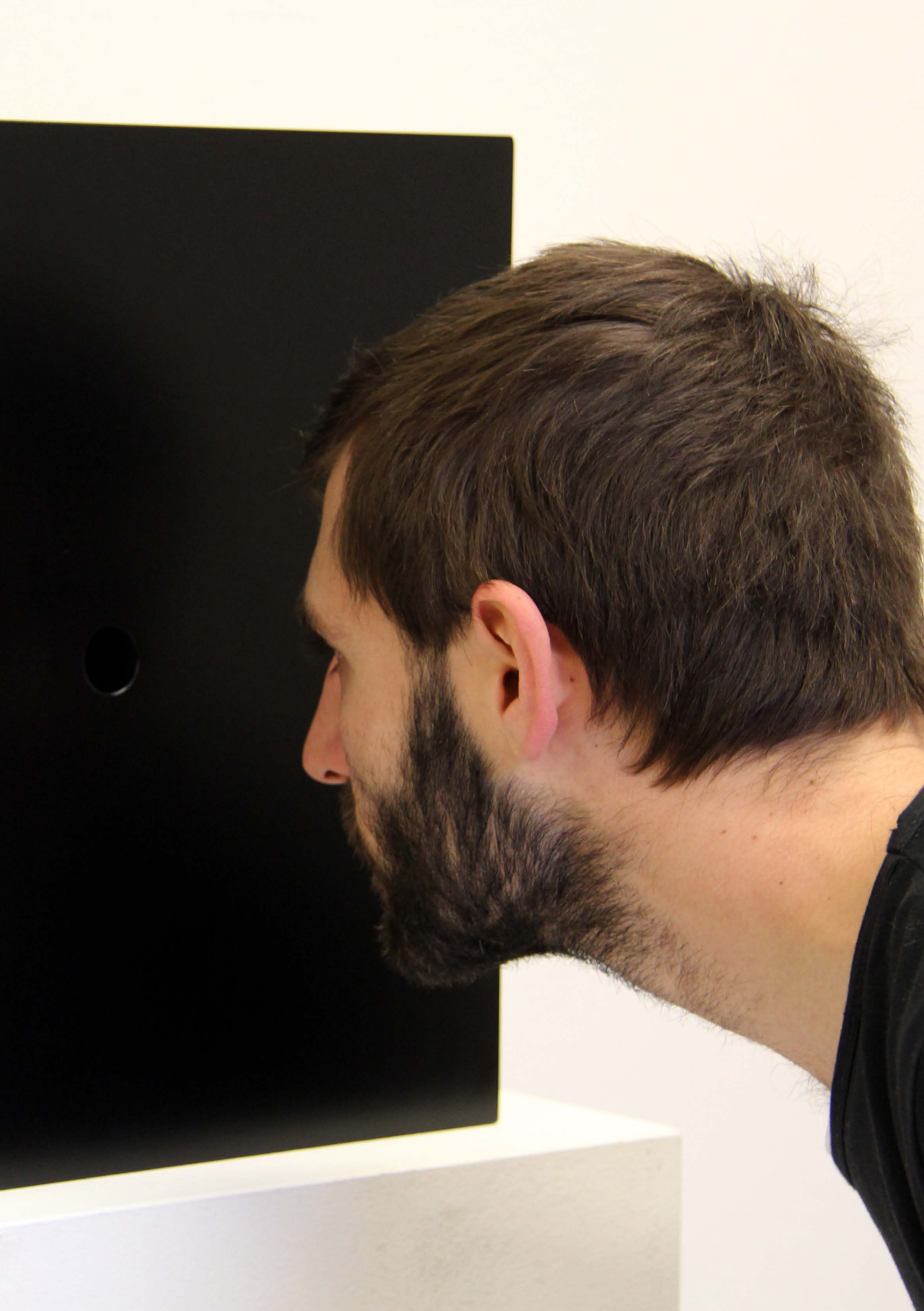


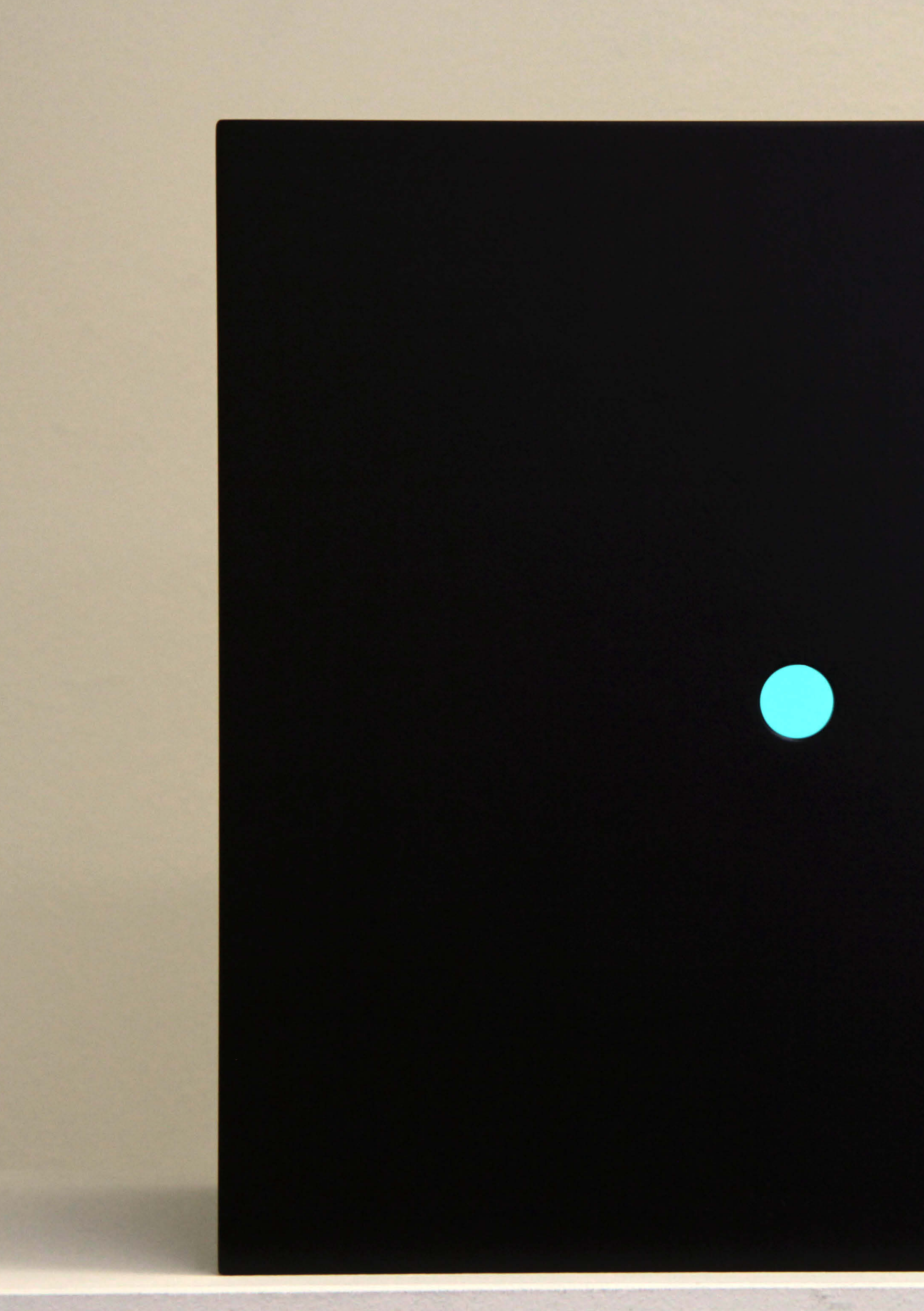


Left side, figures 14–19: Different stages in the construction of Gegenwarts-maschine.
Right side, figures 20–21: Gegenwarts-maschine fully assembled and tested.







F. Final Conclusion

The concept interaction moulds present was illustrated in this thesis through the theoretical investigation into the fields of quantum physics, the constructivist branch of social science, human-computer-interaction (HCI) and interactive media art. The practical work *Gegenwartsmaschine* materialised this concept in the end.

In the beginning we looked at basic concepts of time: its widely accepted structuring into past, present and future and the dichotomy of reversible and irreversible processes. Additionally we learned of diverse philosophical positions on the character of time. As we found, a large portion of time concepts agree that time can be conceived through change. A first important determination regarding the fact that interaction is inevitable.

In the field of quantum physics we examined an experiment with a Mach-Zehnder interferometer to understand the principle of superposition and objective chance. Both principles are important to understand how we reference from the present to the future, a subject later discussed in chapter C.1.. By realizing that interacting, e.g. measuring, with a quantum mechanical system creates a single state from the super-imposed possibilities, we found a parallel to the retrenching nature of communication, as mentioned by Paul Watzlawick in chapter B.2.1..

In the field of constructivist social science we explored Paul Watzlawick's communication theory, his definitions of interaction and especially systems, and his subsequent axiom "one cannot not communicate". As the last important point he mentions the retrenching nature of communication, as each exchange of information reduces the number of possibilities for the next exchange. Hence we said that communication creates a system's present.

In the fourth big chapter, chapter B.3., we looked at the characteristics of interaction in the fields of quantum physics, the constructivist branch of social science, HCI and interactive media art. In physics it is stated that all matter in the universe interacts via four basic forces. To measure and observe these forces and other phenomena we must interact with these occurrences. Without this interaction we can not achieve certainty about a system. Therefore we are bound to interact.In social science interaction of a living system was defined by Peter M. Hejl as one action that is actualized by a range of possibilities, leading to a change in the system and consequently leading to an altered behaviour in the next interaction. Also Hejl saw communication as an extended form of interaction. Thus, based on Watzlawick's axiom, we stated a new axiom: one cannot not interact. The field of HCI offered a broad view on what is interaction. First we looked at Donald Normans established model of seven steps of an action to approximate what interaction means in HCI. We expanded this core knowledge with a perspective of system theory introduced by Dubberly et. al.. In doing so we obtained a taxonomy for interactive systems with which we could scrutinize any system, even outside the field of HCI.Eventually we looked at the field of interactive media art. As It emerged from the field of HCI it exhibits very similar characteristics of interaction. In contrast to HCI, media art discusses implications of technologies in culture, politics and aesthetics. As a form of art it is unique as it is the only art to truly engage in a reciprocal interaction with the audience. Therefore media art turned out to be the most prudent way to materialise the concept of this thesis. Despite the many different understandings of interaction regarding content, we determined that on operational level interaction is indistinguishable in every field. Also we could conclude that interaction affords change.

In chapter B.4. we finally put together our findings, that systems include an intrinsic order which is time, interaction is inevitable and interaction forms conditions and shapes rules. Thus we were able to conclude the initial statement: Interaction moulds present.

Having demonstrated that interaction moulds present, I briefly investigated topics to develop this subject in the future. Three subjects were broached: First, the consequences on the span of the present. The concept of a dimensionless present is eliminated by physiological research and Plank's constant. It is suggested that the span of the present is depending on the duration of the interaction. This in turn asks for a precise definition of what is and what is not part of an interaction, as well as taking into account the subjects perception and consciousness. Second, a further harmonization of diverse systems by using Heinz von Foerster's model of non-trivial machines and universalise the concept interaction moulds present into a principle in the end.Third, referencing of past and future from the present. The past is referenced through our experiences. Whereas the future on the one hand is unpredictable due to subjective and objective chance. And on the other hand it is possible to direct our intention onto a close future.

By applying our concentrated knowledge of interaction and the system taxonomy we analysed two interactive art works, which enable people to realize the concept that interaction moulds present.

And finally my works *Lichtspeicher* and *Gegenwartsmaschine* were presented, explaining their connection with the thesis' concept. In contrast to *Lichtspeicher* which focuses on the perception of the moment of present, *Gegenwartsmaschine* highlights the concept of interaction to establish the moment of present.

With all these steps we were able to illustrate that interaction moulds present. As indicated before this concept may serve as the foundation for further research into an ontological principle.

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