An Artistic Perspective on Distributed Computer Networks. Creativity in Human-Machine Systems

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Declaration

The work presented in this thesis is the candidate’s own.

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Abstract

This thesis is written from an artistic perspective as a reflection on currently significant discussions in media theory, with a focus on the impact of technology on society. While mapping boundaries of contemporary art, post-digital art is considered the best for describing current discourses in media theory in the context of this research. Bringing into the discussion artworks by Martin Howse & Jonathan Kemp (2001-2008), Maurizio Bolognini (Bolognini 1988-present), and myself (mi_ga 2006), among many others, this research defines post-digital art, which in turn defines a complexity of interactions between elements of different natures, such as the living and non-living, human and machine, art and science. Within the analysis of P2P networks, I highlight Milgram's (1967) idea of six degrees of separation, which, at least from a speculative point of view, is interesting for the implementation of human-machine concepts in future technological developments. From this perspective, I argue that computer networks could, in the future, have more potential for merging with society if developed similarly to the computer routing scheme implemented in the Freenet distributed information storage and retrieval system. The thesis then describes my own artwork, *0.30402944246776265*, including two newly developed plugins for the Freenet storage system; the first plugin is constructed to fulfill the idea of interacting elements of different natures (in this case, the WWW and Freenet), while the other plugin attempts to visualize data flow within the Freenet storage and retrieval system. All together, this paper proposes that a reconsideration of distributed and self-organized information systems, through an artistic and philosophical lens, can open up a space for the rethinking of the current integration of society and technology.

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Introduction

One of the most significant current discussions in media theory focuses on the impact of technology on society and the physical change in humans parallel to technology (Hayles 1999, 2012, Malabou 2004). In the arts, such discourse appears in A-Life (Whitelaw 2004), BioArt (Myers 2012, Ginsberg et al. 2014), speculative or fictional design (Dunne & Raby 2013), and new media art (Frieling & Daniels 2004, Tribe et al. 2007) contexts. These discourses are often accompanied with self-organization concepts (Hayles 1999, Bedau 2003) and digitally processed information in post-digital arts (Cramer 2014, Bolognini 2008).

In this thesis, with the aforementioned theory in mind, I propose that the reconsideration of distributed, self-organized information systems through an artistic and philosophical lens will not only add yet another mechanistic or speculative approach to present-future societies, but will also open up a space for the rethinking of the current integration of society and technology. While proposing such a framework, I will use trans-disciplinary research and artistic methods to open up a discourse on self-organized information systems as a potential model to be integrated into future societies. Although my work does not necessarily provide solutions or concrete answers, the power of artistic method lies in its invaluable competency to question objects and situations that are often tacitly accepted as the only existing possibilities.

The proposed hypothesis has come from the comparison of social and computer networks within the above-mentioned discourse in media theory, technological developments within computer networks, and my artistic position. Whether framing the discussion of political, economical, or cultural issues, my artworks question the creativity of machines and do not presume humans to be the only creative force at work. This position unleashes further questions, ranging from abstract, philosophical examinations of creativity to global concerns about what forces dictate the organization of humanity and determine our future as a society. From this perspective, I will argue that computer networks could, in the future, have more potential in merging society if developed similarly to the social networks. The argument is built from three different perspectives: a) theoretical, comprised of related problematics in media and cultural theory, b) technical, including analysis of routing protocols in distributed computer networks, and c) practical, unfolding as aesthetic forms and methods used in my practical project. While trying to generalize various mechanisms and prevailing theories, I suggest that a self-organized approach to human-machine rhizomes and interaction within non-uniform networks demands more attention. In addition, my contributed artwork, an installation titled *0.30402944246776265*, should offer a framework designed for studying information flow in the proposed non-uniform network.

This work therefore develops as follows: The first chapter lays out the basis for my argument and traces the territory of post-digital art, which is defined as using hybrid methods comprised of physical and virtual forms. In this chapter, I discuss the idea of creativity allocated to the calculating machine and how creative calculation might emerge. The examples analyzed include *Mailia*, my own artwork (mi_ga 2006), *Artificial Paradises* by Martin Howse and Jonathan Kemp (2001-2008), and *Programmed Machines* by Maurizio Bolognini (Bolognini 1988-present). Furthermore, post-digital territory is considered within a broader theoretical framework, including ideas of the rhizome, strata, and mapping. Emerging from the works of Deleuze and Guattari, these ideas demonstrate a similarity to post-digital aesthetics by highlighting interaction between heterogenous elements within the defined context. In addition, an extensive analysis is made using the idea of the interaction between elements and their self-organization within a system. Given that interaction might be defined through the simple rules used to describe automata, further analysis dives into the territory of computation, which could also unfold from the lens of creativity. The chapter then introduces Wolfram's (2002) and von Neumann's (1966) experiments with cellular automata generating patterns resembling those found in nature and ends with the introduction of computer networks as an interactive Turing machine or cellular automata (CA). Applying the CA concept to the computer networks, the chapter wraps up the speculative artistic idea that self-organized information systems have the potential to become indivisible from living systems and in so doing assist future societies.

The second chapter analyzes distributed networks and brings the thesis to the point where decisions are made for an artistic framework to emerge. The discussion in this chapter proposes that the Freenet distributed storage system has the potential to become a basis for a non-uniform network model. Highlighted is that, first of all, the Freenet uses a routing algorithm built upon the idea of six degrees of separation as introduced by Stanley Milgram (1967). Secondly, it is simultaneously a distributed storage system and a search engine, which is required of any complete information system. In addition, this chapter proposes that the Freenet might have more potential if bridged with systems of a different nature, like the prevailing World Wide Web or other networks such as Tor or I2P. The possibility of interacting with other kinds of systems would open Freenet for indirect external influence and would bring it closer to the idea of the human-machine rhizome introduced in the first chapter.

The last part of the theses introduces my installation *0.30402944246776265* (2013-2014), which uses a number of interconnected nodes representing the non-uniform network of humans and computers. The Freenet distributed system is used as a basis for interaction between the computers. The additionally developed software piece bridges the Freenet system with the World Wide Web as an information trigger for a non-uniform network. Yet another plugin visualizes interaction between the computers so the spectator can follow information routing within the network. The installation refers to the hypothesis introduced above as follows: it is assumed that, a) through interaction, the viewer will be able to get an idea of distributed computer networks that have the potential to share information similarly to social systems and b) being able to share information and to demonstrate a certain level of intelligence, computer networks have the potential to become an integral part of future societies.

The overall contribution of this research is twofold: aesthetic and technical. The art piece, made for a wider audience, highlights discourse on the impact of technology on society and questions the ethical values of future societies: Which entity ultimately should be granted the power to make the final decisions, human or machine? And if machine, then what is left at stake for the human race? The technical result emerges through open source plugins, wherein one of them is designed to track the Freenet network over time and the second operates as a bridge between the World Wide Web and the Freenet making the system sustainable. If self-organized processes in the Freenet network are tracked over time, the visualization could provide interesting results, e.g. they could demonstrate the swarm intelligence behavior of information flow within the network. The artwork, however, does not provide any answers to the hypothesis of clustering information proposed by Freenet developers and leaves it open.

In addition, development of the plugins for the purposes of the artwork could furthermore be fed back into the Freenet developers' community as raw material for other future technological and scientific endeavors.

Chapter I. Self-organization and the Post-digital

Aesthetics of the Post-digital

The Post-digital Domain

The questions outlined within the following thesis are viewed from the perspective of a posthuman, present-future state where the human merges with technology. In Katherine Hayles' terms, it is a state where the human seamlessly articulate with intelligent machines and approaches his or her body as a prosthesis (Hayles 1999). This perspective is also close to Rosi Braidotti's critical posthumanism and her awareness of being part of the Anthropocene (Braidotti 2013). Sometimes, especially when I describe my artistic work, this perspective merges an imagining of a cybernetic organism, that is, a hybrid of machine and organism defined by social and bodily reality (Haraway 1990).

Now, what contemporary arts are described as being hybrid, merging in themselves organic and non-organic matter? First of all, this includes interdisciplinary, multidisciplinary, and transdisciplinary arts. While these terms will be further discussed within the subsection “Approaching Transdisciplinarity” in the next section, it is worth listing more specific niches of contemporary arts. BioArt could be listed as hybrid, using various techniques and methods including organisms and biotechnologies (*GFP Bunny* by Eduardo Kac, *The Physarum Experiments* by Heather Barnett). Also hybrid is new media art, using computational techniques for aesthetic purposes (*Artificial Paradises* by Martin Howse, *Programmed Machines* by Maurizio Bolognini). Hybridity is also one of the main adjectives describing post-digital arts.

The positions describing the term post-digital differ, fluctuating between a hybridization of forms (Alexenberg), the introduction of failure to digital aesthetics (Cascone), and the importance of process in regard to the packaged product (Cramer). Nevertheless, digital arts and particularly software arts play a huge role in the post-digital age and are reflected while defining its domain. For artist and art educator Mel

Alexenberg, the post-digital (an adjective) is

> of or pertaining to art forms that address the humanization of digital technologies through interplay between digital, biological, cultural, and spiritual systems, between cyberspace and real space, between embodied media and mixed reality in social and physical communication, between high tech and high touch experiences, between visual, haptic, auditory, and kinesthetic media experiences, between virtual and augmented reality, between roots and globalization, between autoethnography and community narrative, and between web-enabled peer-produced wikiart and artworks created with alternative media through participation, interaction, and collaboration in which the role of the artist is redefined (Alexenberg 2011:10).

In other words, the “post-digital” is a hybrid of forms with a redefined role of the artist. “Digital” technologies for Alexenberg act as an extension of humanity (Alexenberg 1987), similar to what Marshal McLuhan calls extensions of a man helping one to reach his goals (McLuhan 1964). Moreover, the post-digital is rather the condition of everything, a Deleuzian *consistency* (for more details on Deleuzian consistency and other important terms for post-digital aesthetics, see the next section, “Post-digital Territory”). Although Alexenberg's definition suggests that the post-digital has a feature of hybridity, a balance of physical and virtual, form and action, the meaning he puts behind the post-digital is rather philosophical, imaginative, and spiritual. In other words, the post-digital for Alexenberg is an imaginative state where the digital becomes part of the analogue, and vice versa.

A different emphasis is put on the post-digital by researcher and media theorist Florian Cramer, who presented his ideas on post-digital research during a discussion that was part of the *transmediale* festival in Berlin in 2014. This position unfolds from two perspectives: on one hand, as a merging of digital and analogue and, on the other, through the everyday use of computers and digital information. In the reader of the discussion on the post-digital, Cramer writes that neither “old” nor “new” media are meaningful, as they merge in the post-digital (Cramer 2014). Different from Alexenberg, who defines the post-digital as an in-betweenness of forms and meanings, post-digital aesthetics for Cramer focus rather on “processual” DIY cultures and the application of “new media” practices onto “old media.” If, in the case of DIY cultures, the process itself has become aestheticized with the rebirth of “old media,” the conditional change made by digital technologies is already *de facto* and is no longer considered revolutionary.

Within such a domain, it is also worth bringing up the musician Kim Cascone, who introduced the term “post-digital” itself (Cascone 2000). While stating that the revolution of digital information is over, Cascone offers two features of the post-digital that distinguish the post-digital from the digital. First of all, he brings into the aesthetics of music a failure of the digital, the glitch. Secondly, he introduces the “tool” as the message instead of the medium being the message, an idea introduced much earlier by Marshal McLuhan (1964). If the “glitch” for Cascone speaks of the illusion of technological perfection and is the result of experimentation, the “message” is what one sees (or hears, in the case of sound) rather than reads. With the post-digital, Cascone defines a slight change in culture: on one hand, “failure” is introduced as a natural process for creativity, and, on the other hand, sound can be perceived by seeing how it is made. This position introduces the importance of the “background” or unseen medium in post-digital aesthetics.

To illustrate the post-digital as having a different approach to aesthetics, Cramer points to the generation born in the 1990s, who do not remember times without computers; the “digital” is a given for them, *per se*. Consequently, the youngest generation often uses different ways of interacting and have social lives influenced strongly by communication (see “Glossary” for the use of the term “communication” in this thesis) within virtual space. Even if the post-digital, according to Cramer, is a yet another “post” term, it is a term that is useful when talking about contemporary art. If new media artists use technologies explicitly to emphasize technologies themselves, post-digital artists focus on the message communicated through the use of technologies (compare, for example, *Biotricity*[1] by RIXC collective, *The Sequence Dress*[2] by Anna

1 http://www.renewable.rixc.lv/biotricity-dtw/, (Accessed 27 August 2015).

2 http://annadumitriu.tumblr.com/post/123672195554/the-sequence-dress-was-exhibited-as-part-of-eva, (Accessed 27 August 2015).

Dumitriu, *Bodymetries*[3] by Theresa Schubert and *Ear on Arm* by Stelarc[4] or artworks having less or no focus on biotechnologies, such as *Google Will Eat Itself*[5] by Uebermorgen and *Persecuting.US*[6] by Paolo Cirio).

Cramer's idea suggests that we are living during a time of significant cultural change similar to that marked by the appearance of the digital computer in the 1950s. On one hand, this change marks the end of the digital revolution, and, on the other hand, the digital world has become as natural as, to paraphrase, the air we breathe. This is, first of all, visible in the arts and mass culture, which have shifted to a stage wherein the tool(s) and the medium(s) used to produce an artwork are not necessarily central. While recent decades have often encountered the terms "performance art," "video art," "digital art," "software art," and the like, in the post-digital, the tool and the medium have changed their meaning, no longer generating content solely through their novel "nowness" as measurement, as genre.

Secondly, there is a transdisciplinary moment (for broader elaboration, see the second section "Approaching Transdisciplinarity") emerging through all practices, including scientific research, arts, and creativity at professional and non-professional levels. This position is already implicit in the definition proposed by Alexenberg. Moreover, it is clearly stated by Bolognini in his book *Postdigitale*, where he distinguishes three of the features of the approach of this new domain: the spread of digital technologies throughout artistic production, the spread of digital technologies at the non-professional level, and experimental research across disciplines (Bolognini 2008). The aforementioned features of the post-digital presuppose the wider collapse of subjects, a larger blur happening across not only media but also professional fields. Despite that, those fields might still be distinguished from each other if approaching the domain from different perspectives – for instance, the technical and artistic points of view (for example, see the description of my artwork "Annex I. Project: *0.30402944246776265*").

3 http://www.theresaschubert.com/bodymetries.html, (Accessed 27 August 2015).

4 http://stelarc.org/?catID=20242, (Accessed 27 August 2015).

5 http://www.gwei.org/, (Accessed: 19 March 2014).

6 http://persecuting.us/, (Accessed 27 August 2015).

As such, the post-digital domain becomes a layered whole, where people, tools, and media are used all together to express a thought, rather than to define a discrete product, as would be a case when approaching an object of discussion according to specific artistic genres or mediums. The post-digital domain brings to the forefront aesthetics extended into scientific, technical, political, social, or economic contexts, discourses, and processes which, in the end, make up a fundamental contemporary condition that we cannot step outside of.

Aesthetics of the Post-digital

When introducing post-digital aesthetics, it is worth mentioning the reason for the choice of this term and not, for example, "transdisciplinary," "postinternet," or "post-media" aesthetics. If transdisciplinarity is used for defining a layered and integrative approach (for broader discourse, refer to the second section and its subsection "Approaching Transdisciplinarity"), postinternet is used to define arts influenced by the Internet,[7] and post-media defines an installation which is not specific to any one medium,[8] post-digital, as introduced within the above subsection, unfolds as a layered whole through, first of all, technological lenses, which form specific aesthetics in comparison with post-media contexts.

The historical dimension of the post-digital is defined by Cramer as a merging of "old" and "new" media. Illustrating this merging, Cramer provides a meme depicting a "hipster" sitting on a bench with an old typewriter.[9] Ignoring the image as a "funny"

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7 For example, see the interview with Marisa Olson. Available at http://we-make-money-not-art.com/archives/2008/03/how-does-one-become-marisa.php Accessed 2015-04-25. Article "What's Postinternet Got to Do with Net Art?" by Michael Connor. Available at http://rhizome.org/editorial/2013/nov/1/postinternet/ Accessed 2015-04-25.

8 See Krauss, R. (2000). *A Voyage on the North Sea: Art in the Age of the Post-Medium Condition.* London: Thames & Hudson. Available at http://isites.harvard.edu/fs/docs/icb.topic837293.files/Krauss_Voyage%20on%20the%20North%20Sea.pdf Accessed 2015-04-25.

9 See online version of APRJA. Available at http://www.aprja.net/?p=1318 Accessed 2015-04-25.

meme or as a picture featuring a “strange” hipster, Cramer suggests analyzing it through the visible symbols. First of all, it is a play on opposite meanings: the “digital” image-board meme and “analogue” hipster with typewriter. Secondly, the “analogue” typewriter in the proposed environment expresses disenchantment with digital information systems, which can be seen as far too precise, too clean, and too discrete compared to generating “analogue” text, image, or sound. A deeper analysis of the image produces a story that leaves “new” media in the past and in so doing, defines what the aesthetics of post-digital could be within popular mass culture.

For the development of artistic expressions, the last decades have been important because of the new possibilities offered by the computer. The “digital” format of computer arts is represented using discrete computable values, unfolding in the end as zeros and ones. This is not the case in the use of traditional media like painting or sculpture, where everything is still physical matter. If “new media” applied to “old media” invokes the idea of the post-digital, then the term presupposes the use of computers or computation permeating the final result, at least as an outcome of research, a critical position, or a conceptual reference. As David Berry concludes, “In a post-digital age, whether something is digital or not will no longer be seen as the essential question … as all forms of media become themselves mediated, produced, accessed, distributed or consumed through digital devices and technologies” (Berry 2014). Therefore, within post-digital aesthetics, a mediation of social, political, economic, scientific, spiritual or environmental factors through and on top of new media becomes important.

What is so exciting about new media and the change defined by the post-digital? First of all, while focusing on new technological tools, new media art was soon explored. Secondly, the focus on computers and computer networks did not prove to be stable in the markets, including artistic contexts. Therefore, new media art soon lost its power of being novel and unique with the first technological crisis and the dotcom crash around 2000. This crisis, however, brought novel Web 2.0 tools, which offered the Internet user easier access to publishing content.[10] And finally, social activism, hacktivism, media

10 For example, see Olia Lialina's entry in 2013 on “Net Art Generations”. Available at: http://art.teleportacia.org/observation/net_art_generations/ (Accessed: 25 April 2015).

activism, and other net-isms opened up a discourse on “old” and “new” media; since then, new media art has extended into social space within the networks.

Within the post-digital art contexts, it is worth mentioning new media artists working in the domains of BioArt and net.art. In BioArt, ideas of evolution and emergence have their own niches, which were mainly explored in the context of A-life in the 1990s. Karl Sims' *Genetic Images* (Sims 1993), Christa Sommerer & Laurent Mignonneau's *Interactive Plant Growing* (Sommerer & Mignonneau 1992) and *A-Volve* (Sommerer & Mignonneau 1994-1995), Troy Innocent's *Iconica* (Troy Innocent 1998), and similar works focus on the simulation of biological organisms or the interaction among them. An extensive study of early A-life artworks has been done by Mitchell Whitelaw, who points out that emergence is central to A-life and A-life art (Whitelaw 2004). If examined more closely, the central task for the artists listed above has been to depict life-like situations and evolving processes using emerging aesthetic forms and technologies. For example, Sommerer & Mignognou simulated the growth of plants, or showed "breeding" forms by embedding them into a virtual context. Thus, the emergence of artificial life is only meant to be understood literally and not to be enmeshed in the hybrid context of post-digital art.

Net.art discourse and its focus on networks emerged in the late 1990s. Although its specificity is best described over analysis of technology and new tools such as HTML, Java Script, chat and mailing lists (see for example artworks by Alexey Schulgin, Olia Lialina, JODI), its importance for post-digital aesthetics is laid, first of all, on the reevaluation of social ties along technological achievements and the art market (RTMARK, The Yes Men, Uebermorgen). Being able to express him or herself over the Internet, the net.artist had less interest in traditional exhibitions (compare, for example, biographies of the late 1990s of d2b.org, JODI, Olia Lialina) and more interest in communication through various mailing lists (7-11, Nettime, Rhizome). This phenomenon brought about a series of artworks and discourses on the production of unsolicited digital information (or SPAM).

Among relevant artists who developed SPAM discourse in their projects, worth mentioning are Frederic Madre and his mailing list "Palais Tokyo,"[11] JODI's communication over email,[12] d2b's and my collaborative work *asco-o*[13] and the *Nato.0+55+3d* campaign from Antiorp, who is also known as Netochka Nezvanova.[14] Receiving tens and sometimes hundreds of hardly readable emails from Antiorp or useless communication over the Palais Tokyo mailing list, the reader was supposed to critically evaluate standards of communication over computer networks, as well as consider the annoyance (or power) of communication with machine-like systems. Bringing a critical position to a top-down-oriented society, capitalist economics, and neoliberal politics, net.art is very close to the aesthetics and discourses of the post-digital.

Nevertheless, it lacks a hybridity of forms, disciplines, discourses, and contexts. If the tools used in net.art were usually a combination of custom and modified or hacked software, and if the tendency of such art was in most cases limited to browser aesthetics,[15] post-digital aesthetics open art up to physical space and can refer to social networks and political or economic issues.

A classic example of post-digital artwork is GWEI (Google Will Eat Itself), a critical reflection on a Google advertising campaign by Uebermorgen (Uebermorgen, 2005), or a more recent work, Persecuting.US by Paolo Cirio, who used publicly available messages on Twitter pages for the analysis of users' political views (Cirio, 2012). Among the net.artists considered working within the post-digital domain are also net.artists who moved out of web space into physical space: Uebermorgen,[16] Jodi,[17] The

11 For further discourse, see interview between Josephine Bosma and Frederic Madre at http://www.josephinebosma.com/web/node/84 (Accessed: 25 April 2015).

12 For idea, see for example interview between Mark Allen and Jodi at http://www.theawl.com/2012/06/jodi-dot-org-net-artists (Accessed: 25 April 2015).

13 http://www.asco-o.com, (Accessed: 27 August 2015).

14 For example, see one of the Antiorp's emails to the Nettime mailing list at http://amsterdam.nettime.org/Lists-Archives/nettime-l-9902/msg00096.html (Accessed: 25 April 2015).

15 For example, consider *Form Art* by Alexei Shulgin, 1997 (available at http://www.c3.hu/collection/form/) or *OSS* by JODI from 2000 (available at http://oss.jodi.org).

16 http://www.ubermorgen.com/, (Accessed: 25 April 2015).

17 http://zyx-app.com/, http://folksomy.net/ (Accessed: 25 April 2015).

Yes Men,[18] Cory Arcangel,[19] Evan Roth,[20] and Aram Barthol,[21] among others. In addition, there are a large number of artists who came up from the BioArt contexts, including Theresa Schubert,[22] Anna Dimitriu,[23] Heather Dewey-Hagborg,[24] and Martin Howse,[25] among others. Interesting to mention are a series of projects by the Brooklyn-based artists who make up the collective Future Archeology and who bring digital artefacts like microchips into analogue space (Future Archeology 2014). Likewise, another example is Anna Flagg's *Cuddlebot*, a furry animal-like machine that intelligently recognizes "emotional touch gestures using machine learning methods"[26] (Flagg 2013). All these examples demonstrate the move of the "digital" into the "analogue" or the mix of "digital" and "analogue."

Therefore, it is clear that post-digital aesthetics do not conform to any defined forms, media, or genres, but are, in fact, ubiquitous; their relegation to genre is a superficial categorization that is not consistent with the contemporary (in)distinction of disciplines and media. Based on this assertion, I submit a discussion of three selected artworks: *Mailia*, the project I have developed (mi_ga 2006), *Artificial Paradises*, by Martin Howse and Jonathan Kemp (Howse & Kemp 2001-2008), and *Programmed Machines*, by Maurizio Bolognini (Bolognini 1988-present). Being not necessarily classic examples of post-digital art, these artworks define interaction, creativity, and emergence in a posthuman state (e.g. *Programmed Machines*) and are open for post-digital discourse, including critique of top-down social, political, and economic strategies (e.g. *Mailia*) and praise of bottom-up approaches to environmental issues (e.g. *Artificial Paradises*).

18 http://theyesmen.org/ (Accessed: 25 April 2015).

19 http://www.coryarcangel.com/ (Accessed: 25 April 2015).

20 http://www.evan-roth.com/ (Accessed: 25 April 2015).

21 http://www.datenform.de/ (Accessed: 25 April 2015).

22 http://www.theresaschubert.com, (Accessed: 26 August 2015).

23 http://www.normalflora.co.uk/, (Accessed: 26 August 2015).

24 http://deweyhagborg.com/, (Accessed: 25 April 2015).

25 http://www.1010.co.uk, (Accessed: 25 August 2015).

26 http://www.annaflagg.com/work/cuddlebot/, (Accessed: 25 April 2015).

Mailia

I developed the software piece *Mailia* in 2006, which carries aesthetics of the pure "digital," as the work is indistinguishable from the computer networks and screens displaying the result of computational activity. Nevertheless, this work could be considered within the post-digital domain or a broader posthuman discourse because it could evoke thoughts of artificial intelligence, or express disenchantment with digital information systems if considered from the perspective of digital waste. This artwork also served as the first inspiration for the extensive research that has followed on research in a posthuman state defined by Donna Haraway (1990), Katherine Hayles (1999), Catherine Malabou (2004), Rosi Braidotti (2013), and Nicholas G. Carr (2010).

Mailia could be considered a simple piece of software designed to answer emails. The encounter with *Mailia* is neither visual nor aural. It is rather a process, a life situation that only exists for the primary "audience" (i.e. the participants/actors). A sender/receiver of a given email and a machine are involved in the process. After sending an email to someone, the sender would expect some answer. If there is a *Mailia* machine involved, the answer would be generated by a machine. This answer is a sort of "out of office" reply.

Over the course of its existence, *Mailia* generated[27] replies from Google search results and, along with those results, included the original message in a standard reply form.

The machine was designed in such a way that keywords taken from the incoming email would be processed through the Google API in order to find related information on the World Wide Web and to generate a reply message from content available on the net. In an imagined framework where two *Mailia* machines are involved, the process would only be executed in a virtual environment. In the description of the software, I wrote that "if answers are publicly saved, search engines will index the answers again and utilize these as output for other similar replies" (mi_ga 2006). Consequently, databases

27 The *Mailia* machine used Google API to search for related information on Google servers. Since 2008, the API is no longer supported, and *Mailia* has therefore stopped functioning.

would grow over time with newly generated content and, henceforth, would evolve in terms of content-oriented or qualitative change (for more precise definition of the use of the term “evolution” within this thesis, see “Glossary”).

For testing purposes, *Mailia* was installed in my personal server with configured email services. The answers generated by the machine provoked people to continue interaction with the machine in different ways, including writing emails to various mailing lists to which my personal email address was subscribed. In such a way, every time people would write an email to a certain mailing list, the machine would immediately generate an answer in response to the email sent. A random "tester" sent an email to my mailbox with the Rhizome mailing list[28] address registered as being the sender's address. This resulted in an endless loop between the mailing list and the *Mailia* machine, which, in turn, generated some 5,000 reply emails back to the Rhizome mailing list, ending with a couple of million further emails in total sent to the subscribers.[29] If, say, there were a number of machines running the same software, those machines could have started exchanging messages among themselves, producing even more content while replying to each other's emails. It is easy to imagine that such stimuli-response behavior or communication (see “Glossary” for the use of this term in this thesis) between computers would rapidly flood and break networks with unsolicited data traffic, as happened with the Rhizome mailing list.[30] However, if the system were self-aware and self-reparable, the continuing discussion would probably lead us to yet another dimension – the possibility of a living machine or the possibility of a machine becoming as creative and as intelligent as a human being. This dimension is further explored in my other project, *0.30402944246776265*, which is part of this research and is introduced in the Annex of the thesis (for more details, see “Annex I. Project: *0.30402944246776265*”).

Having introduced the *Mailia* framework, the message behind the artwork leads to at

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28 For the Rhizome mailing list, see http://www.rhizome.org

29 According to Mark Tribe, one of the moderators of Rhizome Raw, the list in 2000 had about 400 subscribers, and it is assumed that, by 2006, the number had not changed dramatically. The reference is available at http://www.afsnitp.dk/onoff/Texts/tribearchivingne.html (Accessed: 24 March 2014).

30 Reported by Patrick May, Director of Technology at Rhizome.org. The report is available at http://rhizome.org/discuss/view/21166/ (Accessed: 24 March 2014).

least three threads which will be developed further: 1) shared work between machines and humans, 2) (un)controlled information exchange in artificial networks, and 3) the production of unsolicited digital information (or SPAM).

The first thread – a shared work between machines and humans – opens up a framework where tasks normally fulfilled by humans are outsourced to machines. Even if the proposed set-up has an ironic connotation and could be seen from the perspective of speculative design, in theory, a number of emails could be answered by a machine. For example, a machine analyses incoming email and determines that the request is for sharing personal moments in life; the machine then performs a search of the personal calendar, analyses recently produced content, and sends back a corresponding answer. Finally, the task is fulfilled by a machine. Let us take a more concrete example, a Mailman system designed to distribute emails to a list of email addresses. If the sender of the email is not supposed to send email directly to the list of emails configured in the Mailman system, the Mailman system would define it and would send a generated answer to the sender, indicating that he or she had to wait until the administrator of the list approved the email. Another option would be that the sender rejects the sent email by clicking on a link provided. In so doing, the email answering machine has a direct connotation of the post-human discourse introduced earlier in this subsection. It is also a reference to the scientific discipline of Artificial Intelligence, inquiring into the computer science that develops machines and software with human-like intelligence.

A straightforward analogy can also be made here with the ELIZA software built by Joseph Weizenbaum between 1964 and 1966 (Weizenbaum 1966). This software, which simulates a psychotherapist, illustrated the concept of the Turing Test (Turing 1950), demonstrating that, if a human communicating with a machine does not realize that he is communicating with a non-human, then that machine must be intelligent. The Turing Test is meant to be an intellectual or psychological test, showing that an artificial machine could be as intelligent as a human. In the proposed *Mailia* machine, the workload was intended to be shared between the machine and human, where the machine would take over some workload by replying to emails, thereby becoming relevant to artificial intelligence discourse.

A more poetic analogy to *Mailia* is one of the earliest software pieces, *LoveLetters*, a program written by software engineer Christopher Stranchey in the early 1950s (Stranchey 1952). The software generated letters from a collection of words allocated to different word pools, like databases of textual material. Parallel to its digital nature, *LoveLetters* was manifested in a relatively traditional format, in the form of letters that were scattered around Manchester University, where the software was developed. Such a manifestation was supposed to question the reader who was behind those letters. As is possible to imagine, the answer to that question was not evident, because neither were computers ubiquitous nor were the signed initials on the letters identifiable. Although the piece was not intended to be an artwork, discussing it from a post-digital art perspective reveals it as a potentially ideal example, in that it bears a performative nature, merging in itself virtual and physical forms, old and new media (as discussed within the post-digital frame by media theorist Florian Cramer), and is that it comes from an engineering approach within an artificial intelligence context. Although *Mailia* did not have any material output, the "collaboration" between machines and humans was expressed in such a way that *Mailia* replaced humans while answering emails, and humans contributed with initial databases of textual material – either writing an email or, as in this case, storing information on the Internet so that *Mailia* could perform searches and find relevant content for replies.

The second thread – (un)controlled information exchange in artificial networks – utilizes the idea of interaction between digital machines. For example, a random email is sent to a mailbox with the *Mailia* system installed in it; *Mailia* would analyse its content, search for related information on the Google search engine, and, in reply to the email, would include an additional couple of new lines found through the Google search engine. Providing replies for further searches, say through the Mailman archiving system, the newly generated reply would include information that might have been sent at the beginning of the thread.[31] To simplify, if an initial email message delivered to *Mailia* consists of a, b, and c, in reply, *Mailia* might generate ad, be, and cf, and the next answer could be dg, eh, and fi, and in a later reply could happen to be ga, hf, or ic. In such a setting, several *Mailia* machines could enter into continuous stimuli-response

31 For concrete examples, refer to http://triple-double-u.com/mailia/?s=feedback (Accessed: 25 April 2015).

behaviour, which, in turn, could be considered as communication between artificial machines, or, even further, as a setting for an artificially intelligent social system.

On the other hand, considering the *Mailia* setting from the quality of the replies delivered, the viewer should come up with the third thread introduced in the introduction – the production of unsolicited digital information (or SPAM). This thread refers to the critique of top-down social and political systems over questions such as etiquette within networked society, rapidly growing digital content, and, in a broader sense, technological development.

Considering *Mailia* in SPAM context, thousands of *Mailia* emails sent over the Rhizome mailing list, it was not intended that the reader be annoyed by spam-like emails; instead he or she was meant to consider the imperfection of the machine and worthless digital information. What happens with, for example, rapidly increasing digital content? Should it be stored, systematized, or maybe deleted? Being a strong example of SPAM art, *Mailia* does not answer such questions. Instead, it invites the viewer to consider the development of technology in parallel to humanity. Thus, *Mailia* becomes tightly linked to today's significant discourse on post-humanism.

Considering *Mailia* from the perspectives introduced above, an environment where a machine interacts with another machine and produces stimulus-response situations could be used in further simulating life-like behaviour and situations. If the first thread of *Mailia* leads to the acknowledgment of Artificial Intelligence discourse as referring to a top-down brain model, the second thread suggests operation within an artificial life territory, focussing on biological bottom-up processes that suggest self-organized frameworks. For instance, if I were to consider several *Mailia* machines communicating among themselves, the content of the reply messages would evolve over time into something new, considering the content of the reply messages. *Mailia* machines generating dg, eh, and fi or ga, hf, and ic messages tend to compile content reflecting previously given content and, in turn, generate a contextual discourse. Such a framework would be more explicit if additional methods were used to either systematize or visualize content. For example, the visualized routes of digital information sent within the computer networks would be more appealing if shown on monitors, as with the project *0.30402944246776265*, the description of which is provided in the Annex I. In other words, alongside interaction between machines, there would be a reference to the simulation of life-like and evolving processes. A life-like situation would bring an additional layer to the *Mailia* machine, which could be introduced within an A-Life context.

Now, even if it has been stated that one of the three threads of this section (listed above) describes the *Mailia* system as linked to SPAM, the emergence through interaction between machines might also generate valuable content. The following projects are examples of similar work: the *net.art generator* by Cornelia Solfrank (Solfrank 1999), a collaborative work of mine titled *asco-o* (mi_ga & d2b 1999), another work of mine called *carpet/?s* (mi_ga 2006), and Alan Sondheim's *Internet Text* series (Sondheim 1994-present). In the first example, the *net.art generator*, Solfrank offered software that generated personalized websites according to the names entered into the website form. In the case of *asco-o*, the content was often manually copied from existing websites, then triggered with the automated programmes and then sent back to the mailing list as a new ASCII image. The *carpet/?s* is a fully automated system producing ASCII patterns from the content found at the very moment the website is visited. In addition, the *Internet Text* series by Alan Sondheim is, in most cases, a triggered variation of computer terminal output.

All in all, the works are comprised of slightly changed or rearranged content that is reintroduced as new content created by an artist who shares creative work with or allocates some creative tasks to a machine. Having said this, the *Mailia* machine is in the position to create, or otherwise, to be a collaborator with the artist, or maybe even an artist itself.

Artificial Paradises (*ap*)

Initially entering the gallery space set for *Artificial Paradises* (Howse & Kemp 2001-2008), there is a feeling that the hardware stacked in the middle of the space is not a simple installation. Some time-based action must be absent: sound, visuals, people operating the devices. The hardware modules – computers, monitors, synthesizers, record decks, video projectors, printers, scanners, cables, connectors, a sound system, and custom devices – are attached to each other in a literal pile, so they form a sculptural installation worth attention from any contemporary artist, critic, computer freak, or dead media collector (Fig. 1).

The performance or, according to the authors, "software and situations," starts with the appearance of hipster-like[32] performers and the turning on of the machines. While the machines boot, it is clear that the machine-noise is part of the aesthetics of the performance. A variety of input signals, altered and controlled in real time by software and artists, unfold as a composition of part physical installation, part DJ-mix, part real-time audio input, and part generated sound and visuals. Although there is a feeling that not necessarily all the equipment within the installation is being used during the performance, a complex set of hardware devices, people, processes, sounds, and visuals shape an indivisible baroque-style ensemble, unfolding through variety of expressive forms, contrasting colors and computer-generated dynamics. Having a set up with mixed "old" and "new" media, "analogue" and "digital" sound and visuals, the performance opens up the space for a timeless feeling, becoming a good example of post-digital aesthetics.

An analogy to *ap* (*Artificial Paradises*), just under different circumstances and at a different scale, was the event titled "Art Hack Day" during the *Transmediale* 2014 festival in Berlin. The event united artists, audiences, workshops, performances, and presentations that unfolded DIY techniques, sophisticated mechanisms, and hipster performances. Post-digital aesthetics and self-organized activities recalled a sci-fi belief in technology and offered an anti-capitalist discourse. Kristoffer Gansing, one of the curators of the exhibition, described the event in one of the follow-up emails to the Rohrpost mailing list[33] as "a living entity … rather than a predefined collection of the

32 "Hipster," who in the context of this work is introduced as wearing new and vintage cloths and likes combining new and dead media, is seen as a post-digital archetype. Compare also the reference to a hipster with a typewriter described by Florian Cramer and introduced in the subsection "Aesthetics of the Post-digital."

33 Available at http://mikro-berlin.org/rohrpost/ (Accessed: 24 March 2014)

curators' best picks" (Gansing 2014). With performers keeping busy the whole time, *ap*, similarly to the "Art Hack Day" event, is less a collection of objects and more a living entity.

In such a context, *ap* (versions 01 and 02) was presented with a sophisticated description of the project:

> ap02 presents a promiscuous model of data generation and self-display, making use of a virtual machine architecture to develop and execute self-modifying instruction sets across networked nodes. Reconfigurable code is interwoven with and determined by network and environmental data. Nodes expand virally through diverse machine environments as they actively seek for data across any network. The body of the work is code (material) and in work this code is made evident, visible. The only functionality of *ap02* is in self-display; showing its own changing, performative code as it runs. *ap02* is expressed within three interwoven projects; as physical self display devices, as a freely available, distributed networked application and implemented within a performance structure; development of current *ap01* clustering and performance technology towards non-hierarchical models of client/server design and improved scalability. *ap02* performance technology will load custom-OS from floppy and communicate with range of devices + Internet. *ap02* performance technology implements promiscuous de-centralized data generation and self-display of operations resulting from cross-node-developing instruction sets (Howse & Kemp 2001-2008).

Altogether, the *Artificial Paradises* installation could be approached through at least four features relevant to posthuman as well as post-digital *strata* interpreted here as defined by Deleuze and Guattari (1980): a) interconnection and scalability, where nodes expand virally through diverse machine environments, b) self-modifying instruction sets across networked nodes, c) a distributed networked application implemented within a performative environment, and d) a self-display, showing its own changing, performative code as it runs.

The description proposes that the artwork's technical set-up plays an important role, mapping a non-hierarchical distribution of interconnected devices. Therefore, the number of devices attached to each other in the set-up is variable, and the final installation is kept open, depending on the equipment available at the time of the performance. This openness is conveyed to the viewer through ethernet switches, computers, and video projectors. Such a set-up provides a bottom-up perspective towards emergence, which, as will be shown in the next sections, is crucial for self-organized environments (for further details, see the section “Life Between Human and Machine”).

Self-modifying instruction sets across networked nodes are managed through the *ap* virtual machine, which is able to track data flows and metrics from peripheral hardware modules like scanners, printers, custom synthesizers, or record decks and output it to video projectors and a sound system. It also listens for the commands entered through the terminal and, depending on the available input data – whether it is tracked in real time, accessed from the memory of the computer, or elsewhere on the Internet – outputs processed data to the peripheral devices, resulting in sonic and visual forms.

The ability of *ap* to have interconnected devices along with the implemented virtual machine also enables “digital” network activity within an “analogue” performative environment, or, in other words, enables interaction between machines and performers. In so doing, the virtual machine becomes the “mediator” between the devices and performers, forming a connection between elements of different natures. Such a connection might be described as a rhizomatic, where, through the interaction, one element would mimic features of the other element (for a more detailed discourse on the rhizome, see the subsection “Rhizome” in the next section).

Finally, the *ap* technical set-up opens up a space for self-display and, upon that, self-reflectivity and reproduction. If, say, the video projector outputs some data traffic from the Internet, a webcam capturing the output may send the signal back into the virtual machine for further processing. The processed data might then be displayed on the screen again in a new form. This visuality further involves the viewer in the feedback cycle, able to intake and process the work him or herself.

To sum up, all features of the *ap* ensemble aim to provide a holistic view of a universe where all elements interact with each other. The elements of the performance – industrial noise, “dead-media” devices, computers, the projected plain green ASCII characters and images – refer back to the “old” or an early “new” media aesthetics and with that, to the post-digital discourse. Here, while turning on and booting up all the devices that are supposed to interact with each other, the software and the executable code is given a God-like role, responsible for the creation of a universe. Meanwhile, the performance unfolds as a rhizome exposing code as environment and environment as code and attempts to bring the virtual out of the machine and the environment back into the machine. Putting together an “analogue” environment with “digital” technology, the installation even strengthens the impression of being in a post-digital state.

As developed in this subsection, the interconnectedness of all the devices, the performing people, and the evolving content refers to the Deleuze and Guattari terms *rhizome*, *strata*, and *mapping*. These terms receive more attention in the next section “Post-digital Territory,” where I introduce the post-digital as bearing holistic features.

Programmed Machines

Hundreds of computers programmed by Maurizio Bolognini are left to run *ad infinitum* in his life-long project *Programmed Machines* (Bolognini 1988-present). If the computers are installed in an exhibition space, the viewer encounters them first as a classic installation, which – as opposed to the baroque style of *Artificial Paradises* – is very minimal, often featuring only machines and cables (Fig. 2). The standard-looking desktop computers as objects do not tell the viewer more without an additional story. This is especially true in Bolognini's *Sealed Computers* series,[34] where the monitor busses are “sealed” and are not supposed to be connected to monitors at any time. Other arrangements where computers are hooked up to monitors or video projections would re-direct the viewer towards moving-image aesthetics, and the installation of desktop computers would, in part, lose the author's initial idea of understanding the image without seeing it, as a non-visual abstraction. Moreover, the withholding of visuals in

34 http://www.bolognini.org/foto/ (Accessed: 28 April 2015).

digital arts does not necessarily fit into the usual context of time-based arts, which, in a conventional sense, arguably rely on the aesthetics of screen imagery. These are images that never stay the same; these are invisible images that self-shape *ad infinitum*.

Behind *Programmed Machines*, there are at least two messages important to the proposed research: a) the computer is introduced as a machine generating moving images, and b) the viewer having no visual to grab onto, is forced to think from the computer's perspective.

In the first case, the moving images are introduced through the endless generation of random imagery which, counter-intuitively, is not necessarily witnessed by the human eye. When imagining imagery, as in the unsealed *Programmed Machines*, the first question to ask is at what level are these images random, and would it be interesting if they were not random. In the case of random imagery, the image forms would not evolve and would stay as they were programmed by the artist. On the other hand, if random functions were used at the minimal level, the machine could be given a chance to perform some creativity, like, for example, in fractal or cellular automata patterns.

Less randomization, for example, is given in the case of the *Atlas 2* series (Fig. 3). Here, the image develops a certain level of complexity over time. Consequently, *Programmed Machines* could be programmed in such a way that endlessly moving images would produce a result similar to those generated by two-dimensional cellular automata or three dimensional fractals. Therefore, *Programmed Machines* could gain more attention from the viewer, as they could provoke him or her to analyze the work through evolutionary processes. Moreover, this would lead to even further discourse about who – the machine or the author of the algorithm – is more “creative.”

In the second case, the viewer is put into confrontation with a machine. Depending on the machine or the installation approached, it could be direct (as in interactive installations such as the *Collective Intelligence Machines* series) or indirect (as in, for example, the *Sealed Computers* series). The indirect confrontation would, however, require more imagination from the viewer. Reflecting on the *Sealed Computers* installation, which could also apply to any other installation of Bolognini's, Andreas Broeckmann “points us to an 'aesthetics of the machinic' whose aesthetic experiences are effected by such machinic structures in which neither artistic intention, nor formal or controllable generative structures, but an amalgamation of material conditions, human interaction, processual restrictions, and technical instabilities play the decisive role” (Broeckamann 2006). While separating machinic and human perspectives, Broeckmann suggests trying to understand the machine from its position. Here, the viewer again has to deal with the “digital” and “analogue” dichotomy, just under different circumstances, as described by Florian Crammer while introducing post-digital aesthetics (for further discourse, refer to the earlier subsection “Aesthetics of the Post-digital”).

Direct confrontation with machines is perceived in the later installation series from Bolognini titled *Collective Intelligence Machines.* In this piece, the viewer may modify the exhibited image by sending SMS containing numbers, say, from 0 to 100, to the computer, which then change the parameters that define some of the characteristics of the images, such as the thickness of the lines, radius, density, etc. This gives the viewer a chance to “think machinically” or to expect some reflection while starting interaction, or a “conversation” with it. While proposing structured communication techniques between user and machine (in this case, analogous to the delphi method,[35] where the user would expect certain moves from the machine), Bolognini refers to holistic ideas and collective intelligence scenarios where the individual is given a participatory task in a digitally analogue context.

To sum up, for Bolognini, *Programmed Machines* make up a sci-fi fantasy proposing that machines – similarly to humans – are living organisms. The only difference is that a machine is not able to reproduce itself and sooner or later will stop operating either because of technical failure or shortage of electricity. Metaphorically, *Programmed Machines* for Bolognini might appear as his own children, who, as soon as they are born (meaning programmed), are set free into the universe (meaning connected to electricity

35 Forecasting the method used in collective intelligence frameworks may involve communication techniques based on iteration, feedback, and statistical response in order to come up with common answers or results.

and left to run on their own).

Interaction and Emergence in the Post-digital

Describing the artworks above, I have contended that, in post-digital art, an important role is given to the interaction between different disciplines and elements, which provokes the emergence of new forms. This was demonstrated by bringing into the discussion *Artificial Paradises* by Martin Howse and Jonathan Kemp, *Programmed Machines* by Maurizio Bolognini, and my own project, *Mailia*. New forms have manifested through a) subjective method, in the case of *Artificial Paradises*, b) random method, in the case of *Programmed Machines*, and c) computed method, in the case of *Mailia*.

All the works introduced include a certain level of interaction and emergence. If, in *Programmed Machines*, the interaction between the machine and viewer was expressed indirectly as an act of introspection with a feel for machinic aesthetics, the interaction in *Artificial Paradises* was expressed as human-machine collaboration or, to be more precise, as stimulus-response behaviour within a hybrid digital and analogue environment. Since *Programmed Machines* and *Artificial Paradises* influence the viewer's decision-making indirectly, by comparison, one might say that there is no direct interaction in *Mailia* with the viewer, whose influence is determined exclusively by his or her history of interaction within the machinic environment.

While illustrating post-digital aesthetics with the *Artificial Paradises* performance, it was suggested that different elements – software, hardware, performers, and audience – while interacting with each other, function as a system wherein each of its elements is delegated a certain task. This idea is further analyzed with the support of Deleuze and Guattari's terms which should help in defining the discourse and the framework of the post-digital, in Deleuze and Guattari's terms, the territory.

Post-digital territory

Approaching Transdisciplinarity

As introduced in the first section, post-digital aesthetics defy borders between contexts, media, and formats old and new, digital and analogue. The aesthetics of the post-digital can have features of the natural and social sciences, engineering and the arts, theory and practice. The post-digital utilizes a variety of methods in the convergence of philosophy, science, and technology and tends to unfold in non-traditional aesthetic forms and concepts, including those developed with the help of computable machines (for example, see Paolo Cirio) or while experimenting with biological forms (for example, see Heather Dewey-Hagborg). Taking this into account, how do we approach post-digital aesthetics, and what methodology is applicable for artistic practices and analysis? If there is a variety of disciplines involved in the process, the answer must then fluctuate between multidisciplinary, interdisciplinary, and transdisciplinary perspectives.

If multidisciplinary research is “is approached from different angles, using different disciplinary perspectives” where “neither the theoretical perspectives nor the findings of the various disciplines are integrated in the end” (Besselaar & Gaston 2001), interdisciplinary research combines more than one discipline. In order to reach the goal of the subject, interdisciplinarity could be defined as a bridge between two or more disciplines or as an integration of two or more disciplines, an idea introduced by Julie Thompson Klein (Klein 1990). If, in the first case, while bridging disciplines, the disciplines remain discrete, the second case defines a new discipline that, according to Klein, overarches all disciplines to transcend towards the notion of transdiciplinarity (Klein 1990:66). In so doing, interdisciplinarity remains somewhere between multidisciplinarity and transdisciplinarity.

Within this notion, transdisciplinarity, as defined by Jean Piaget in 1970, tries to locate links between disciplines instead of separating them,[36] becoming in such a way a

36 This definition is borrowed from the article “Methodology of Transdisciplinarity–Levels of Reality, Logic of the Included Middle and Complexity” by Basarab Nicolescu, who introduces transdisciplinarity while quoting Jean Piaget's “L’épistémologie des relations interdisciplinaires”, in Léo Apostel et al. (1972).

layered structure, a *strata*, similar to what has been shown through the introduction of post-digital aesthetics. A different approach towards transdisciplinarity, which is meant to cover all disciplines, was proposed by Erich Jantsch while introducing the term for university reform (Jantsch 1970). For him, interdisciplinarity within universities is a methodology still awaited for coordinating activities, whereas “the entire education/innovation system may become coordinated as a multilevel, multi-goal hierarchical system through a transdisciplinary approach” (Jantsch 1970). If Piaget's definition has a non-hierarchical approach, the position introduced by Jantsch is closer to a holistic understanding of transdisciplinarity.

Understanding transdisciplinary is valid for cognitive sciences, complexity science, artificial intelligence, and artificial life, to name a few. New theories using transdisciplinary methodology to inquire into a research field – system theory, complexity theory, chaos theory – have become indivisible from any further scientific or philosophical inquiry. If the approach introduced by Ross Ashby to define cybernetics still has more of an interdisciplinary meaning (Ashby 1957), the General Systems Theory proposed by Ludvig von Bertalanffy (Bertalanffy 1950) and the definition of Living Systems offered by James Grier Miller (Miller 1978) both have features of transdisciplinarity as defined by Erich Jantsch. Systems discussed by Gille Deleuze and Felix Guattari (Deleuze & Guattari 1980) or those approached by Stephen Wolfram (Wolfram 2002) have features of transdisciplinarity as defined by Piaget. The same use of the term appeared at the Planetary Collegium led by artist Roy Ascott at Plymouth University, where he described the Collegium as “concerned with the advancement of emergent forms of art and architecture, in the context of telematic, interactive, and technoetic media, and their integration with science, technology, and consciousness research.”[37] This meaning appears to be closest to a layered post-digital transdisciplinarity as defined by Piaget, where no one discipline or genre appears to be more important than any other and transdisciplinarity itself is not positioned over all other disciplines.

Considering that transdisciplinarity and the inherent collision of views, forms, and formats in post-digital aesthetics seem to make up a natural methodology for the linkage

37 See http://www6.plymouth.ac.uk/researchcover/rcp.asp?pagetype=G&page=273 (Accessed: 29 April 2015).

of the digital and analog, old and new, theory and practice (for examples, see descriptions of artworks in the previous section), positioning post-digital aesthetics alongside contemporary metaphysical, ontological, and scientific theories that focus on the interaction of different disciplines, media, and heterogeneous elements becomes inevitable.

While the post-digital crosses many disciplinary boundaries, analysis of its borders would be insufficient from the more conventional disciplinary, interdisciplinary, or multidisciplinary perspective. Therefore, it could be interesting to approach post-digital boundaries from non-traditional perspectives, while using concepts of the *rhizome*, *mapping,* and *strata* as proposed by Deleuze and Guattari in order to define interaction between heterogeneous elements within a system (Deleuze & Guattari 1980). Within the following subsections, I make references to Deleuze and Guattari's terminology, including “territory,” which is abstract enough for opening up discussion. These references are relevant to artistic interpretation, and complement the concepts and terminology of the post-digital introduced above.

Strata

From the perspective of multilayered structures, two concepts will be introduced: the *chaosmos* of Deleuze and Guattari and the holistic theory of biologist Ludwig von Bertalanffy.

Bertalanffy's proposed theory aims at defining a unity of the sciences. General System Theory was outlined as a holistic theory, wherein the whole is equal to more than the sum of its parts and wherein interaction between heterogeneous elements plays a significant role (Bertallanffy 1950). With reference to Alfred North Whitehead, who defined every large organism as a unity of smaller organisms (Whitehead 1925:18,80,105,112), Bertallanffy's theory introduced the idea of *strata* as physical “wholes,” such as atoms, molecules, or crystals consisting of the union of other elements defining another *strata*. In so doing, Bertalanffy's holistic theory has features of hierarchical structure and, with that, a top-down approach (Bertalanffy 1950).

Although approached from a different perspective towards transdisciplinarity, the equivalent of Bertallanffy's “whole” for Deleuze and Guattari could be *chaosmos*, a complexity arising from chaotic structures through self-organizing processes. Chaosmos, similarly to Bertalanffy's “whole,” is an indivisible system[38] of interacting elements. The difference is only in its structure, which is described as a non-hierarchical or, using Deleuze and Guattari's term, a non-arborescent system having no structural elements around which all “things” can be discussed. However, Deleuze and Guattari introduce a definition of *strata* that is different from Bertallanffy's strata. Within this alternative definition, all the earlier concepts of Deleuze's ontology – difference, connection, heterogeneity, cartography, virtuality, multiplicity, becoming (individuation), etc. – are included. Deleuze and Guattari's *strata* is divided into three main layers – physico-chemical, organic, and anthropomorphic – wherein, differently from Bertalanffy's strata, all the levels are equal and each of them could be introduced as a substratum of another at any order of magnitude (Deleuze & Guattari 1980:40,69). Although Deleuze and Guattari's *strata* is “layered,” as opposed to Bertalanffy's onion-like reductionist structure, the division between layers happens in a horizontal “grassroots” structure, where none of the layers are wrapped up with a new layer and where dependency between layers varies depending on perspective.

Therefore, Deleuze and Guattari's holistic approach should not be confused with the reductionistic definitions given by Whitehead or Bertalanffy. Instead of defining a system as a unity of smaller organisms, Deleuze and Guattari's system draws an abstract map of linked processes and elements interacting with each other at a horizontal level, more like Piaget's transdisciplinary approach, finally shaping a complex system that resists any hierarchical structures.

When positioning the post-digital alongside transdisciplinarity, post-digital aesthetics can be more easily understood if approached via the meaning of strata as introduced by Deleuze and Guattari. Therefore, instead of approaching post-digital aesthetics from the top-down perspective of genres and disciplines, it is better to approach it through the

38 Deleuze's ontology rediscovers Spinoza's monism of the 17th century, where the characterization of God and nature is introduced as being the same and carried by the same characterizations, the univocity. For Deleuze, an important role in defining the universe is also played by Buddhist philosophy's notion of recurring events, which, while referring to Friedrich Nietzsche, he further develops through the “eternal return” concept, providing the basis for Deleuzian repetition.

bottom-up characteristics bearing a certain degree of action and process. These characteristics could be represented by mapping a territory. The *territory* – a place, person, context, or anything else – as defined in *A Thousand Plateaus* is introduced via mapping processes as a dynamic structure of reality (Deleuze 1980). In other words, mapping for Deleuze and Guattari is the method for defining the territory of the subject.

Mapping

Mapping, the process of drawing maps – or, in the contemporary sense, visualizing information, ideas, and connections – is used by artists and scientists to express themselves in a visual way. Mapping can be considered in terms of representation or analysis. In a map, a physical territory is typically represented by reduced and readable symbols and signs, making it easier to orientate in a physical space. Meanwhile, concepts and ideas can be depicted even more abstractly as graphs and networks, wherein every single element is connected to another element, forming vertices and edges. In this case, if connected by a line to each other, concepts and ideas would be represented via vertices and the lines connecting them would be edges.

Physicist Albert-László Barabási (1999, 2000) gives many examples of various systems being representable by a vertice-edge structure. The examples include living systems that form a genetic network wherein genes and proteins (vertices) interact; this interaction is an *edge*. The nervous system containing nerve cells (vertices), which are connected by nerve fibre axons (edges), shape the same vertice-edge structure. A similar vertice-edge example can be observed at the social level, where individuals or organizations (vertices) interact among themselves, forming relations. At the technical level (for example, the World Wide Web), HTML documents would represent vertices, and the links between them would be edges. This same vertice-edge structure is also apparent elsewhere, e.g. in maps representing travel from point A to point B, in biology representing relations between various species, or in direct computer networks where computers represent vertices and the cables connecting them represent edges. The same net structure is also used to represent differences between different network topologies, where, for example, a radial graph would represent a centralized network and a grid would depict a distributed network.

Connecting different systems representable by vertice-edge (for example, genes and individuals, forms and ideas, digital and analogue), we would arrive at the Deleuze and Guattari notion of mapping, the process that defines the meaning (or the territory) of the object discussed. Now, if I think of *Artificial Paradises* by Howse and Kemp (discussed above), the online documentation of the performance gives an idea of how the project evolved, why a large variety of devices was used for the installation, and what the intended meaning of the project was. The sometimes diary-like documentation linking or referring to the performance, symbols, and meanings complement the performance itself and defines the artwork through the process of mapping. Such a process – although not visualized in a graph-like form – finally arrives at the stage where the meaning of the artwork is defined.

Last but not least, through mapping processes, forms, and contexts, elements of a different nature could be connected. These connections would bring vertices to the point of either having similarities or would explain interactivity between them. In both cases, such a connection between the elements would be defined by Deleuze and Guattari's *rhizome*.

Rhizome

In the traditional use of the word, a *rhizome* is a botanical term defining a subterranean stem that is usually found underground connecting roots and sprouts; in other words, a rhizome is a part of a plant that is in between its root and its stem. Deleuze and Guattari define rhizome as a state in between things, situations, and concepts that is also a part of these things (Deleuze & Guattari 1980). Therefore, the concept becomes important for transdisciplinary methodology, linking and defining elements such as digital and analogue or process and form in a post-digital territory. Here, rhizome could appear as an edge connecting vertices.

As introduced in *A Thousand Plateaus*, a "rhizome has no beginning or end; it is always in the middle, between things, interbeing, intermezzo" (Deleuze & Guattari 1980:25). It is like a bridge between two elements that might be homogeneous and heterogeneous. This bridge, however, is not an endpoint of something, as it will always extend elsewhere within the territory. One famous example of the heterogeneous in nature, introduced in *A Thousand Plateaus*, is the interaction between a wasp and an orchid. Within this interaction, Deleuze and Guattari say that, by being heterogenous in nature while also being visually similar, an orchid becomes a wasp and vice versa, whereas traditional evolutionary biology would say that an orchid only imitates a wasp because of its propagation. Being such, these elements together map a rhizome.

In Bertallanfy's General Systems Theory, a rhizome could be described as open systems interacting with other systems, or one stratum interacting with another. Heterogeneity is explained here through the elements being from different strata (for example, plant and animal organization), and interaction is described through different elements (for example, the wasp that is part of the orchid's reproductive apparatus).

Considering rhizomes in post-digital arts, a biochemical experiment, for example, could become an artwork and an artwork could become a biochemical experiment. In *A Piece of 'Livable,'* I grew crystals that, on one hand, could be considered a pure biochemical experiment; on the other hand, this experiment could be considered an artwork if described or located in a specific environment (Fig. 4). Additionally, as introduced in the previous section, Bolognini's *Sealed Computers* artwork series shows that a rhizome could be formed, for example, between a computer and its environment – two heterogeneous elements in a space, constructing the installation. A rhizome could also be a thought emerging between the viewer and an image generated by a computer, bringing meaning to the artwork. As another example, in Howse and Kemp's *Artificial Paradises*, a rhizome could be formed between the input sound sensor and the output visual image, in this way forming an interaction between the sensor and image. A rhizome could also be found between the performer typing a computer command and the execution of binary code by a machine.

Considering rhizomes as mapping processes, they could be viewed as, for example, a labyrinth without beginning or end. From this perspective, Joseph Vogl, a professor of contemporary literature at Humboldt University in Berlin, explains that the Deleuze and Guattari rhizome has three properties: it has neither beginning nor end, it is without centre or periphery, and it is a structure of passages that consists of shortcuts and detours where an unforeseen encounter occurs (Vogl 2013). It is a part of a certain territory, wherein different random events, such as a traffic accident or a change in weather, may occur, ultimately provoking a set of unforeseen encounters. In such an interpretation of the rhizome, Martin Howse and Jonathan Kemp's *Artificial Paradises* would appear as an open performance for any input from devices, performers, or audience. The rhizome in such a way defines processes among and between different elements that are open to the unexpected.

Concluding Notes on Post-digital Territory

To sum up, the territory of the post-digital is best defined as a layered strata with a "grassroots," or from a bottom-up perspective, mapping processes and events into the Deleuze-Guattarian whole. Post-digital territory is about mapping instead of illustration. It conjures connections between heterogeneous elements, such as plant and animal, digital and analogue, human and machine.

Through the concepts of *strata*, *mapping*, and *rhizome*, it is possible to define the territory of the post-digital. However, the concepts introduced leave unanswered questions about the borders of this territory, as in the case of Deleuze and Guattari (for example, what is beyond chaosmos?), or the borders of the post-digital (for example, what is not post-digital?) and the relationships between a heterogeneous system's elements, thus complicating demarcation of the territory.

Life Between Human and Machine

A Human-Machine Rhizome

Having noted that the *post-digital* involves rhizomatic connections between heterogenous elements and that these connections are approached through posthuman lenses, the reader is brought closer to the interaction between organic and inorganic matter, through which new forms emerge. This interaction will be further developed through machinic, organic, and rhizomatic concepts in order to try defining borders of creative processes that are shaping new forms within the post-digital territory. While the emergence of new forms could be approached from different perspectives, including religion and the social, natural, and computer sciences, I propose limiting the discussion to creative processes emerging within interaction between the human and the machine, further defined as a human-machine rhizome. This includes but does not limit the understanding of living systems proposed by Gilles Deleuze, Félix Guattari, James Grier Miller, and Ludwig von Bertalanffy and self-organization as defined by William Ross Ashby, Humberto Maturana, and Francisco Varela. The philosophical and social context will be mapped with artworks by Karl Sims, Christa Sommerer, and Laurent Mignonneau among others.

According to Deleuze and Guattari's ontology, the materiality of the world emerges simultaneously, continuously shaping new multiplicities and rhizomes between heterogenous systems. All the materiality functions as an abstract machine, which is further comprised of smaller machines. Although not defined as digital or mechanical machines, these machines remain as a metaphor of the organism or the human-made machine having a set of functions to be executed. Similarly to an organism, these machines might have an anus, mouth, and so on, which function because of the desire to produce (Deleuze and Guattari describe this type of machines as *desiring machines*). On the other hand, the metaphor for the world is a human-made machine, where the processes unfold over a built-in code to execute certain functions. In this case, the world is similar to a digital machine, which, after execution of the function, interrupts and continues with the next function (Deleuze & Guattari 1972:38). This definition is close to that of Turing's machine, which, after executing some code, moves into another state in order to execute the next piece of code. Alternatively, Deleuze and Guattari's machine could be interpreted as an automaton constructed upon simple rules, which, depending upon given input, are supposed to provide some output. For example, if object *A* is in state *a*, let object *B* move to state *b*, or, if object *A* is in state *b*, let object *B* move to state *a,* and so on (for more detailed descriptions of the Turing machine and automata, see the next section).

Additionally, in “On Machines,” Guattari brings the machine closer to the notion of life, describing it as proto-subjective (Guattari 1995). This notion comes in while merging two other concepts, the *autopoiesis* of Umberto Maturana and Francisco Varella and the *hypertext* of Pierre Levy. While, according to Guattari, through Levy's *hypertext* the machine is conceived as an interface breaking down the “ontological iron curtain between being and things” (Guattari 1995), the Maturana and Varella's *autopoiesis* (translated from the Greek, means self-creation, self-production) adds to the machine the concept of self-reproduction (for more details on autopoiesis, see the later subsection “Self-reference and Autopoiesis”). In so doing, Guattari adds to the machine a feature of executing life-like functions.

Although Deleuze and Guattari (1972), and later Guattari (1995) again, do not introduce the human as machine[39] – which is the speculative purpose of the project developed in this thesis (for more details on the project, please refer to “Annex I. Project: *0.30402944246776265*”) – the importance within their work is two-fold. First, they bring heterogenous elements (for example, human and machine rhizome) into a single whole, which in the end functions similarly to a digital computer (Deleuze & Guattari 1972). On the other hand, Guattari's approach (1995) is reversed. While giving to the machine the life-like feature of proto-subjectivity, the machine is brought towards the human.[40]

39 Non-human animals were also reductively explained as automata by René Decartes in *The Treatise of Man* in 1662. The movements of man were intensively studied in Soviet Russia in the 1920s by Nikolai Bernstein. There are also a number of science fiction authors, including George Lucas (his 1971 film “THX 1138”) and Joseph Sargent (his 1970 film “Colossus: The Forbin Project”), who thematized artificial intelligence.

40 In other contexts, the man-machine relation is defined differently; for example, media theorist Marshall McLuhan considered the object as an extension of man (McLuhan 1964). In 1968, biologist Bertalanffy integrated man and machine into one "Big System", defining man as a "button-pusher" (Bartalanffy, 1968, p. 10). In addition, in 1983, philosopher Vilém Flusser considered man as an

Even if Guattari's machine is a step closer towards being human, it still has an earlier-defined rhizome mapped as the interaction between heterogenous elements. A step towards the “merge” between human and machine, or a gradual vanishing between heterogenous elements, is introduced with a posthuman perspective. As postmodern literary critic Katherine Hayles puts it, there are "no essential differences or absolute demarcations between bodily existence and computer simulation, cybernetic mechanism and biological organism, robot teleology and human goals" (Hayles 1999:2). While Deleuze and Guattari (1972) and later Guattari (1995) do not distinguish between living and nonliving and thus think in terms of ontology, Hayles brings the human-machine rhizome into the daily context, where the nonliving and inorganic machine merges with the living and organic body through direct interaction.

As the living and nonliving or organic and inorganic rhizomes seem to be important within the post-digital territory, I will approach the human-machine issue incorporating a biologist's and a cybernetician's perspectives, bringing next into the discussion a biologist James Grier Miller, who introduced his Living Systems Theory in the article “Living Systems: Basic Concepts” (Miller 1965) and later described in detail in his over 1,100-page magnum opus *Living Systems* (Miller 1978), biologists Humberto Maturana and Francisco Varela, who introduced the concept of Autopoiesis in their *Autopoiesis: the Organization of the Living* (1972) and a cybernetician Ross Ashby, who introduced self-organized processes of the machine in "Principles of the Self-Organizing Dynamic System" (1947) and later expanded it to reproduction in "The Laws of Mechanism" (1962).

James Grier Miller's Living Systems

Bringing living systems into the post-digital discussion, my intention is to juxtapose philosophical, artistic, and scientific issues. This, first of all, should pave the way for machinic creativeness, which is relevant for post-digital aesthetics, as has already been mentioned. Secondly, Deleuze and Guattari's philosophical propositions of human-

extension of an “apparatus” (Flusser, 1983, p. 30), which, in turn, shifted creative processes from man towards machine.

machine rhizome, introduced above, will take the ideas to a practical level. Bertalanffy characterized living systems as being open in the sense of interacting with the outside, being self-organized, and always being in a state of thermodynamic equilibrium (Bertalanffy 1968:39). In contrast, for Miller, the living system means an element of organic nature (Miller 1965, 1978). If the living systems in Miller's systems theory are defined by levels of hierarchy while nonliving systems are defined by nonliving molecules and multi-molecular complexes, the mixed systems could also include human-made machines and ecological systems, such as Earth. According to Miller, the fundamental difference between living and nonliving systems is that all living systems have nucleic acids (DNA, RNA) and cytoplasmic components enabling matter-energy processes (Miller 1978:203-204). Such classification is standard in contemporary biology, although some other scientists, such as Edward Rybicki, suggest changing the classification of living systems and propose considering viruses (which do not have cytoplasmic components enabling matter-energy processes) as living organisms because of their organic nature (Rybicki 1990:182-186). In both approaches, a silicon computer does not fit into the definition of a living system.

Aside from organic nature, Miller also suggests that living systems are open, interact with the environment, and are self-organized. Self-organization is driven by matter and energy, where matter is anything that has mass and occupies physical space and energy is defined in physics as the ability to work. These processes exist in time and space and are organized as information (Miller 1978:11). Although information could also be processed in inorganic systems like digital computers, they are still classified as being rather models or simulations to analyze the structure and processes of living systems (Miller 1978:83). Therefore, Miller excludes the possibility of any prostheses, such as artificial legs and plastic aorta replacements (as would be natural in the posthuman), to become “living.” These would only be considered components that form the living system (Miller 1982).

Despite Miller's definition of living systems, their hierarchization might appear interesting at the levels introduced, which include atoms, organizations, and supranational systems. The definition also proposes that there is a non-living system on both sides of the hierarchy. On one side, there are inorganic molecules and, on the other side, inorganic planets and galaxies that demonstrate self-organized processes. It is also worth mentioning that, in the sciences, while defining living and non-living systems, a distinction between chemical elements and their compounds appears. For example, carbon itself, in the form of a crystal, is considered to be inorganic, but carbon as one element of some compound, wherein part of it is, for example, water, is considered necessary element for forming organic matter (consider alcohol, C_2H_6O, or methane, CH_4). The complexity of defining living systems suggests that, even in the sciences, the border between the living and non-living varies depending on the context, and, therefore, it might be that the concept of life in the context of the human-machine distinction should be approached differently. Moreover, it would be compelling to take a look at other features usually attributed to living organisms from the perspective of non-living systems.

Life-like Processes in Inorganic Systems

According to Miller's definition, self-organization emerging from interaction between matter and energy is a natural feature within living systems that lets them survive and continue to propagate. However, if only matter and energy were considered, self-organization would not be an exception in inorganic systems. On the contrary, growing crystals, including snowflakes, diamonds, and table salt, demonstrate life-like and self-organized processes. Life-like processes might be observed in turbulent flows, such as cigarette smoke, streams of moving vehicles, or oceanic currents. Biological evolution also suggests that organic forms evolved from inorganic forms, so, self-organized processes driven by matter and energy, as introduced by Miller, should not be considered a feature of organic nature alone.

The idea of the internal, self-organized processes of the machine was first introduced in a paper written by a psychiatrist, and one of the pioneers of cybernetics, William Ross Ashby. His theorem stated that a determinate mechanistic system, like the one proposed by Turing, can demonstrate self-organization, given that it has all the possible variables of the nervous system as inputs and that all those variables can be represented numerically (Ashby 1947). The definition suggests that, processed by some function, input will finally result in some output. In addition, if there were two interacting organizations within the system, they would be able to change spontaneously according to the predefined rules. It follows that, even in a machinic environment, there is a chance for life-like processes.

The last statement reminds one of *Mailia*, a project introduced in the first section on post-digital aesthetics. There, it was mentioned that if several machines were connected into the network and continuously generated new text upon incoming text, the databases of generated content would grow over time and, henceforth, would evolve. If the newly generated content is always referred to previously generated content, the framework would become similar to something self-organized, or to be more precise, life-like. It follows that a similar system has the potential to self-organize over exchange of digital content. On the other hand, self-organization within the computer environment is defined by the human and is hardly self-reparable if there is an unsolvable task, as the one defined by Alan Turing as a “halting problem,” making the digital computer stop or continue to run forever (Turing 1936). A good example of a machine not being able to identify an error was introduced while describing the *Mailia* project ending with a loop between the Rhizome mailing list and the *Mailia* machine (for details, see the subsection “*Mailia*” in the first section).

Ross Ashby's Reproduction

Self-organization in a machinic environment might seem irrelevant compared to self-organized processes in living systems; therefore, Ashby also discusses the idea of reproduction, asking and positively answering (Ashby 1962:75) whether the organism can reproduce itself. As for conditions, in order for an individual "offspring" organism to be produced from its "parents," Ashby introduces four components: an environment called a *matrix* (for example, a womb), a *form* (or element, like an ovum) introduced to said *matrix*, an *interaction* between two elements, and a process generating *new forms*. Such characteristics suggest a division between organic and inorganic forms and propose that reproduction in an inorganic environment is impossible. Now, considering an inorganic system in the same terms as an organism, including its properties, patterns, and qualities, Ashby suggests that reproduction in inorganic systems could be possible (Ashby 1962:76). Let's take a closer look at the suggestion.

Giving a set of examples, Ashby states, first of all, that reproduction occurs over a process of adaptation, which is necessary in order for systems change and evolve. Reproduction is not merely a replication of the parent, but an altered version of it. For example, in a community, according to Ashby, the act of one person taking up a particular hobby is likely to be followed by that hobby being taken up by another person. As another example, a change in color would probably occur in a group of chameleons watching each other (Ashby 1962:79-80). While these processes occur because of interaction with environmental disturbances, reproduction does not mean an exact replica of the parent. In the case of dynamic complex systems composed of parts, such as a brain or a computer, reproduction would occur because of their inner logic, wherein a set of states is mapped onto itself, causing some sort of repetition. In a computer, viruses could reproduce themselves while copying themselves and propagating within the same or another computer.

In such a way, Ashby's idea of life within systems as introduced via adaptation through reproduction corresponds to the Deleuzian idea of “becoming” caused by difference through repetition (Deleuze 1968). Corresponding similarly, the Deleuze and Guattari machine concept, introduced earlier in this section, sums up the processes into additional, continuous production. Here, however, the emphasis is given not to the reproduction of an element, as was proposed by Ashby, but to the desire to produce for the sake of producing – the drive of the machine (whether human or human-made) to fulfill its primary function of production (Deleuze & Guattari 1972). The end perspective is also different in both cases. If Ashby talks about a machine-like nervous system and the possibility of artificial intelligence, Deleuze and Guattari pack “reproduction” within the relationships between machines that tend to replicate themselves through the processes of repetition (Deleuze 1968).

Self-reference and Autopoiesis

Alongside “self-organization” and “reproduction,” an important role defining the human-machine rhizome could be given to yet another term – “self-reference” – which reflects the self and is projected onto the past in order to evolve. For example, a plant produces seeds from itself in order to, during the next vegetative period, produce another plant similar to itself. Therefore, self-reference is a good term to be used in creative contexts where certain repetition is involved. Aside from organic nature, this could also include mechanical machines or software looping in a digital environment, which, of course, have multiple potentialities in generating creative processes (see the *Mailia* example introduced in the first section).

Built upon the term *self-reference* is the term *autopoesis,* which, translated from the Greek, means self-creation, self-production. This term is used by the biologist and philosopher duo Humberto Maturana and Francisco Varela, who bring living systems closer to an inorganic life context. The term extends Maturana's previously-used term “self-reference”, which was used in contrast to “self-organization” as proposed by Ashby. The first and probably most important difference between previously evaluated conceptions and *autopoesis* is the approaches to the object under consideration. While speaking of autopoietic systems, Maturana and Varela put an emphasis on the cyclic process of interaction and production. On one hand, Maturana and Varela's machine is similar to Deleuze and Guattari's idea of a machine desiring to produce via repetitive processes. On the other hand, it is similar to Ashby's self-reproducing system, which operates within a network of processes in order to regenerate parts and to therefore stay continuous:

> An autopoietic machine is a machine organized (defined as a unity) as a network of processes of production (transformation and destruction) of components which: (i) through their interactions and transformations continuously regenerate and realize the network of processes (relations) that produced them and (ii) constitute it (the machine) as a concrete unity in space in which they (the components) exist by specifying the topological domain of its realization as such a network (Maturana & Varela 1972:78).

Now, since it sounds like an autopoietic machine could be a network of computable machines, further insight into Maturana and Varela's living system is necessary. Maturana and Varela see it as a self-referring, circular organization which is, first of all, defined by units of interactions that exist in an ambience (Maturana & Varela 1972:9-11). This feature is comparable to the self-organization contexts introduced above. On the other hand, Maturana and Varela doubt self-organized systems and argue that organization of the thing would mean changing that thing, as in the organization of a chair, which, disassembled, would lose its identity as a chair (Maturana 1987:71). Therefore, they prefer using the term “autopoiesis” instead of “self-organization.” Among other features of a living system is the possibility of participating in interactions relevant to bigger systems that constitute higher order *autopoietic* unities. This feature is comparable to Whitehead's idea that a larger organism is defined as a unity of smaller organisms (Whitehead 1925:18, 80, 105, 112). This is also similar to Bertalanffy's holistic approach to the universe, where inter-relationships between elements, including atoms, all together form the whole (Bertalanffy 1950). The possibility of participating in interactions relevant to bigger systems is also clearly defined in Miller's hierarchical living systems, mentioned above (Miller 1965, 1978).

Although Maturana and Varela talk about machines as living organisms and organizations, they never discuss these machines as human-made creatures. Maturana and Varela give a car as an example of a non-autopoietic machine, a human-made machine that in itself is not a unity and whose components are produced via other processes. A crystal would not fit into the definition of a autopoietic machine either, because it is constituted of components that are specified by a lattice organization. The authors call that kind of organization *static* (Maturana & Varela 1972:79-81). Additionally, non-material elements, such as the coding or transmission of information, are not in the domain of the autopoietic machine (Maturana & Varela 1972:90). Consequently, the robot or software simulating living organisms are never conceived as living organisms. However, autopoiesis is a widely used metaphor for describing autonomous robotic systems within artistic contexts. It is often referred to in the discipline of artificial intelligence, as well as engineering contexts, to describe autonomous mechanisms wherein certain activity is allocated to a human-made machine. If discussed within the artistic context, *Programmed Machines* by Maurizio Bolognini, which was introduced in the first section on post-digital aesthetics, might be referred to as the autopoietic machine, because of its endless processes of production, through which new forms emerge. On the other hand, Bolognini's work is a human-made machine, so it would not be considered autopoietic according to Maturana and Varela's definition. Analogous to robotic machines are creatures that demonstrate life-like processes. These usually, as in the case of Bolognini's *Programmed Machines*, unfold within a virtual context and are thus described within an A-life context (Whitelaw 2004).

Aesthetics of Artificial Life and Artificial Intelligence

While *artificial intelligence* often is not separated from *artificial life* (A-life), scholars working in the field (e.g. Francisco J. Varela, Margaret Boden) consider artificial life and artificial intelligence as two different disciplines and make a distinction in the use of both terms. While artificial intelligence,[41] a term introduced decades before artificial life,[42] traditionally focusses on simulating human abilities, e.g. motor actions, thinking, and speaking, A-life is used in evolutionary contexts or for defining life-like processes. To define A-life, computer scientist Christopher Langton puts an emphasis on artificial behavior as "systems that behave like living organisms," the "study of man-made systems that exhibit behaviors characteristic of natural living systems," "life made by man rather than by nature," and the "attempt to put together systems that behave like living organisms," whereas AI focuses primarily on the "production of intelligent solutions" (Langton 1988:1-47). A researcher of computer science and philosopher, Margaret Boden, describes AI as a discipline set "to build computer systems that are useful in some way," while A-life is set "to use software and/or robotics to help us understand human and animal minds (or life), or even all possible minds (or life)" (Boden 2006:15). Media theorist Mitchell Whitelaw adds that A-life “proposes [...] an abstract distillation of aliveness, life itself, reembodied in voltage and silicon” (Whitelaw 2004:5).

The term *artificial life* is also often met in art projects, conceptualizing life while using computers, robots, and other electronic devices. The artwork *Genetic Images* (1993) by Karl Sims is one of the early examples of artificial life in artistic practice. Images shown in the interactive installation reproduce new images "chosen" by the viewer. To bring the project closer to the concepts of evolving processes, Sims describes the execution of the algorithm as code (genotype), thereby producing images (phenotype) (Sims 1993).

In their installation *A-Volve* (1994-97), the artist duo Christa Sommerer and Laurent

41 Coined in 1955 by John McCarthy

42 Coined in 1987 by Christopher Langton

Mignonneau show a small pool filled up with water into which video imagery of virtual creatures is projected. The visitors to the installation are invited to touch the surface of the water and to interact with the creatures while “catching” them. In their other work, *Life Spaces*, visitors to the installation are invited to “touch” artificial plants or insects. If two visitors touched a creature at the same time, that creature would produce an offspring, and, furthermore, if the predefined rules in the territory allowed, that offspring would later produce yet another offspring. Another well-known artwork, *Autopoiesis* (2000), by Kenneth E. Rinaldo, is composed of fifteen musical and robotic sculptures. Visitors to the installation interact with the robotic sculptures by walking around the space. The *autopoietic* could also be described in the self-contained works of yet another robotics artist, Simon Penny. In his work *Petit Mal* (1993), a robot on wheels interacts with visitors using a built-in camera, while tracking moving objects and reflecting the objects by approaching them. A more recent project within A-life territory is introduced in the first section of this paper: *Artificial Paradises* (2001-2008) was developed by Martin Howse and Jonathan Kemp. In this work, artificial life is meant as the execution of self-modifying instruction sets across networked devices and the generation of new sonic and visual forms. In the same vein, the sound artist Derek Holzer built *SoundBoxes* (2010-2013), autonomous drones generating sound through a closed electrical circuit that includes a microphone and speaker.

There are also software platforms and scientific research projects that could be introduced within the artificial life context. One of the best known artificial systems representing life-like behavior is Conway's *Game of Life*, a software program that shows the interaction and evolution of depicted elements on a grid (Gardner 1970), which is introduced in detail in the next section. The complex environment *Tierra* (1991-2004), developed by biologist Thomas S. Ray, is an ideal example representing life-like behavior while simulating the environment. This project is also introduced in more detail below. An indirect example of widely implemented software packages bearing A-life features is the anti-spam and anti-virus software *SpamAssassin,*[43] which is able to "learn" while filtering emails from spam. All of these examples demonstrate some level of intelligence and thus could also be introduced and described within the artificial intelligence context.

43 http://spamassassin.apache.org/ (Accessed: 28 August 2015).

Artificial intelligence, in contrast to artificial life, is used more in the scientific domain than in art. However, some of these scientific projects could also be introduced alongside artworks, because they bear clean concepts that naturally resemble artistic concepts and can have strong visual forms that could be interpreted aesthetically. These works are also intentionally placed in creative contexts, such as art exhibitions. A good example of an artificially intelligent "artwork"[44] is the software platform ELIZA, realized by Joseph Weizenbaum based on the Turing test concept, which was proposed in 1950 by Alan Turing (Weizenbaum 1966:36-45). The ELIZA software simulated a psychotherapist reacting to questions or comments that were written in a chat room by a user. Another, more sophisticated and more recent industrially produced example comparable to artificially intelligent machines was manufactured by Sony between 1998 and 2006: Robotic machines with intelligent features were implemented as the robotic pets AIBO and QRIO, which were able to "remember" and "learn" certain behavioral traits while recording spoken commands or tracking video of the environment. A more recent example of an autopoietic machine is Geminoid HI1, a robot that was created by Hiroshi Ishiguro and introduced at Ars Electronica festival in Linz in 2009. The robot would interact with the audience while speaking or moving its silicon body in response to its environment. Even though the robot looked identical to the scientist himself, the interaction was simulated while controlling the robot remotely from a back office.

Artworks that were briefly introduced within the artificial life and artificial intelligence contexts above demonstrate technical solutions and representative forms, which, from an artistic perspective, might seem less interesting than more rigorously developed, conceptually-oriented art projects. Nevertheless, creativity in A-life has the potential for developing social, economic, and political contexts from a perspective of post-digital aesthetics, because its territory inquiries into transdisciplinary fields. Furthermore, early artistic experiments in life-like processes, from a historical perspective, are important for the understanding of post-digital art aesthetics.

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44 Joseph Weizenbaum never called his chat simulators "artwork". His concept of the Chat Bot, however, was often used later by programmers and artists within artistic contexts.

Artificial Life Territory

From the perspective of scientific disciplines, A-life could be split into three branches: hard, wet, and soft. While the hard artificial life branch is practically identical to the artificial intelligence territory, some more specificity could be pinpointed within wet and soft A-life. In contrast to robotics, hard artificial life aims to synthesize behaviors characteristic of organisms that are simpler than humans (Bedau 2003). The field has a focus on autonomous adaptive and intelligent systems, usually referred to as having “swarm intelligence” behavior. There has been quite a lot of success in the field of synthesizing insect-like robots in the war industry, which has produced unmanned vehicles to trace and spy in hostile environments (e.g. the Black Hornet Nano produced by Prox Dynamics or the Nano Hummingbird developed by AeroVironment). A more scientific approach was developed at the Laboratory of Intelligent Systems by a Swiss team that developed flying robots in a self-coordinated flock using flocking rules proposed by Craig W. Reynolds (Reinolds 1987). The flying drones demonstrated a formation while following a leader or regrouping themselves while flying. This performance was achieved using a Global Positioning System (GPS) with implemented, distributed routing protocols without any central control (Hauert et al 2011). Yet another project demonstrating a flying flock was developed for artistic purposes at the Futurelab in Linz in 2012. Spaxels, an Ars Electronica Quadcopter Swarm project, was designed to form varying light compositions in the sky. Although, in this case, each of the drones were coordinated separately with software, it is still one of the most visible projects of its kind (Futurelab 2012).

The soft A-life branch, unlike hard A-life, focuses on algorithms and software and investigates life-like properties within computer simulations. According to philosopher Mark A. Bedau, software is "one of the most practical and constructive ways to explore any evolutionary explanations" (Bedau 2003). A classic example of the life-like is John von Neumann's concept of a self-reproducing artificial cellular automaton from 1948 (von Neumann 1966:81). Within life-like computer simulations, significant results were achieved by biologist Thomas Ray, who, between 1991 and 2004, developed a project called *Tierra,* which was briefly mentioned in the previous subsection. The purpose of the software that was developed was to investigate evolving processes in a manner faster than that which occurs in nature. The simulation was constructed (and conceptualized) in the following parts: the Darwinian Operating System, Soup (RAM), CPU Structure, Instruction Set, and the Genetic Operations or "creatures" included within the Darwinian Operating System. Using an analogy to cells, molecules, and animals of living systems, Ray programmed evolving and self-replicating virtual forms (Ray 1991-2004). In order to create a self-evolving model in *Tierra*, Ray used a virtual machine that was designed to run on a personal computer. With the architecture chosen for the software, Ray was able to distance the outcome from: a) potential threats from evolved codes, b) aging technology, and c) languages used system-wide and operating systems that might not support significant evolution. The chosen virtual machine architecture allowed the implementation of the project within the networked computer context, which, as a consequence, reduced the vulnerability of a single physical machine, which could immediately be replaced by another one if necessary. In this case, a more important role is given to the interaction among several machines and routing protocols, which is given more focus in the next chapter.

The branch that is closer to organic forms and biology – wet artificial life – inquires into the field of biology while merging electronic and organic forms and analyzing the processes of artificial cells. Two approaches exist: top-down and bottom-up. In the sciences, within the top-down strategy, the idea is to simplify the genome of the simplest existing cell with the smallest genome – *Mycoplasma genitalium* – while the bottom-up strategy is anticipated to inquire into more and more complex physiochemical systems, incorporating more and more life-like properties. According to Bedau (2003), the latter approach is challenging, because there are no known ways to synthesize DNA or RNA capable of encoding minimal molecular functions. Nevertheless, this approach is used in environments simulating swarm intelligence behavior, as in, for example, the aforementioned flying robots project by the Swiss team or Sommerer and Mignonneau's *A-Volve* project. Despite those two approaches, there is a traditional way of working with organic matter, especially in merging organic and inorganic forms. These experiments have recently become more popular within the art world, especially in BioArt, where artists experiment in merging biological forms with electronics.

One of the most well-known artists working in the field merging electronic and biological forms is Stelarc, who, for example, in his *Ear on Arm* (2007), had an extra ear implanted into his arm. As the ear's functionality was not established biologically, the artist solved the problem by attaching a microphone to it, so at least an electronic signal would be captured. While Stelark was developing the posthuman context, an environmental problematic was being analyzed by a media artist group from RIXC, which has recently been working on *Biotricity* (since 2012), a series of workshops on how to make energy from wastewater. The workshops resulted in an art installation where the activity of bacteria enclosed in water tanks was used as a biological battery for transforming the electrons produced into sound (RIXC 2013). This artwork generated interesting results from the behavior of bacteria, which, in the nighttime, showed less activity and, during the daytime, more activity. Since the activity of the bacteria was transformed into electrical signals, which, in turn, were converted into sound, the final product – a real-time sound piece – had a biological rhythm.

A-life, as I have tried to demonstrate, occupies a territory between the sciences and the arts and could be best described with Deleuze and Guattari's *rhizome* term, which links two heterogenous layers. In the A-life context, it is, first of all, biology and technology, living and non-living, science and arts.

Discussion

While inquiring into the context of life, I have tried to define the territory for evolving processes and how these processes might contribute to creativity. By approaching life from a creative perspective, as well as using various examples from different disciplines, I have tried to define a rhizome between the organic and inorganic, human and machine. The artworks introduced and mentioned above, including *Autopoiesis* by Kenneth E. Rinaldo and *Petit Mal* by Simon Penny (wherein visitors to the installation interact with robotic sculptures), demonstrate properties of living systems which share, or balance on the edge of, the following features:

a) human-machine systems are dynamic systems and evolve over time;
b) human-machine systems adapt to the environment via self-reference, self-reproduction, and self-organization processes;

c) human-machine systems are interconnected;

d) despite differing natures, human-machine systems are determined apparatuses.

It follows that, if simplified, both human and machine contexts could be defined or characterized by the same stimuli-response behavior. If, for example, two people in Sommerer and Mignonneau's *Life Spaces* touch a creature, that creature produces another creature. Even in nature, a new creature would be “reproduced” in other circumstances, and the simplified behavior would look like a simple rule, a conditional if-then statement. Or, if within a flying robot flock one drone approaches another one too closely, one receives a command to keep a greater distance from the other. Even if in a natural environment the organization of a flock of birds looks much more complex, the idea of logical rules remains.

Now, the similarity between the living and non-living could be mapped on a two-dimensional sheet of paper or a computer screen. If the example were put into matrix and figures were reduced to black and white squares acting upon either a true or false value, the pattern would become similar to that of cellular automata. Therefore, within the next section, I will concentrate on simple rules that could be expressed in a manner of (cellular) automata. Based on simple rules, an option for computable creativity will be introduced, which, as we will see, sometimes produce complex patterns.

Simple Rules and Computable Creativity

Automata are Everywhere

In the sections above, I introduced the territory of the post-digital; in Deleuze and Guattari's terms, this could be defined through a mapping process, and, in artistic terms, it could be defined through a creative process. Highlighting that the post-digital territory tries to define ideas and concepts while connecting elements of different natures (e.g. biology and technology, living and non-living, science and arts) and, through this connection, modeling new discourses and shaping new forms, we have arrived at the point of defining creative processes generated by simple rules.

As has been stressed, these creative processes – that is, not as specific as in the sense of human processes in creative practice – involve organic and inorganic elements that shape rhizomes through their interaction. Moreover, different kinds of systems shape self-organized environments, including the entire universe, which, for James Grier Miller, would mean the totality of all systems, including planets, galaxies, and not yet discovered systems. For Ludwig von Bertalanffy, this would mean the *whole*, and, for Deleuze and Guattari, this would mean the *chaosmos*. A reduced machine might be a certain type of automaton, the concept of which has been developed by a number of scholars, including the creator of the first digital computer, Konrad Zuse, the polymath John von Neumann, and the mathematician Stephen Wolfram.

The concept of finite automata is rather simple: it is a self-operating machine defined by a simple rule for processing information. Zuse describes it as an output state of an initial state and input corresponding to an algorithm built into it (Zuse 1969:6). In other words, the simple rule relies on input information with only two possible output values: true or false. If, say, I need light in a room, I change the position of a switch, which then allows an electrical current to travel through wires, thereby lighting up an electric lamp. If I do not need light anymore, I change the position of the switch into its previous state. A slightly more complex rule applied to the opening of a door would depend on the person approaching or departing from it and on whether the person is in front of or behind it. If there is one more person involved in the situation, the rule becomes even more complex.

From that analogy, let's move on to the problem of the interaction of elements. Imagining that the universe has all possible variables as inputs and all variables are represented numerically, as in William Ross Ashby's introduction of the theory of self-organizing processes (Ashby 1947), the universe could be generated by a computer. The idea of the universe being a large computer first shows up in Zuse's article “Rechnender Raum” (Calculating Space) and his book of the same title (Zuse 1967, 1969). In the book, Zuse introduces the universe as a computing machine, functioning on the principles of automata. This idea is later developed by Edward Fredkin in his research dedicated to digital physics and digital philosophy (Fredkin 2013) and Stephen Wolfram in his book *A New Kind of Science* (Wolfram 2002). While Fredkin assumes that any discrete physics model is equivalent to a cellular automaton (Fredkin 2000), Wolfram builds a further case for it, proposing that the natural world and, by extension, all of the universe, could be described by simple computer programs and mathematical rules unfolding in evolved cellular automaton patterns.

In order to come closer to the idea of computation capable of creative output, I will introduce machines acting upon simple rules: the Turing machine and finite-state cellular automaton.

Computable Discrete Elements in the Turing Machine

In a 1936 paper by Turing, the concept of the machine is proposed as the simple idea of an apparatus which is able to compute discrete values – zeros and ones. In the same paper, Turing introduces a computing machine with an infinite length of tape and a tape head acting upon seven commands: a) read the tape, b) move the tape left, c) move tape right, d) write “zero” on the tape, e) write “one” on the tape, f) jump to another command, and g) halt. The idea of these commands is to show that output B could be processed having an initial state and some input A. The position of the tape head on the proposed apparatus processing the information is dependent on the information stored on the tape: If the input information is defined, so is the output. The problem in such a computational model is any numerically undefined variable which would cause the machine to stop processing information, or to "halt." The halting state or, according to Turing, the “decision problem" (*Enscheidungsproblem*) is the problem of digital computation being defined by numerical variables. Thus, the Turing machine is limited to computing all input information and to solving all given problems (Turing 1936).

Although Turing showed limitations of digital computability, at the same time, he proposed that his machine could be capable of universal computation if it were able to emulate any other machine including itself and if it were able to process information from that machine. In theory, the universal computing machine would have no “halting” problem if used in accordance with another type of machine able to endlessly produce some output. Such a framework is considered in Ross Ashby's environment, wherein all variables are represented numerically (Ashby 1962:75). Here, the “decision problem” could be avoided, while calculating all possible values. Such a machine could be represented by cellular automata acting upon predefined rules (for further details, refer to the subsection “Emergence of Creative Forms in Cellular Automata” in the same section). In a non-discrete environment, that could encompass all cosmological concepts, including those taken from ancient Greek philosophy[45] and a variety of religions.

Applied Computation and *Game of Life*

A classical cellular automaton is represented in a two-dimensional square grid of cells having two states (positive and negative or black and white). The original idea behind the cellular automaton comes from von Neumann's research on living organisms being able to self-reproduce and self-organize and using the cellular automaton as a model. In von Neumann's automaton, the target cell is transformed into one of the possible 28 states, depending on the states of neighboring cells and the predefined rules (or algorithms) applied to the target cell (von Neumann 1966). Von Neumann's cellular automaton has since been applied by British mathematician John Horton Conway in his

45 The exception might only be the idea of the universe based on simple rules and computation proposed by Anaxagoras (500–428 BC) and later developed by Epicurus, who introduced cosmology through interacting atoms made of the same substance but differing in size and shape.

cellular automaton *Game of Life*. According to the given rules, at each step in time, the following transitions occur:

a) Any active cell with fewer than two active neighbor cells dies, as if caused by under-population.
b) Any active cell with two or three active neighbor cells stays unchanged in the next generation.
c) Any active cell with more than three active neighbor cells becomes inactive, as if due to overcrowding.
d) Any inactive cell with exactly three active neighbor cells becomes an active cell, as if through reproduction (Gardner 1970).

The rules applied to the grid allow the number of active cells to increase or decrease depending on the mode of the neighbor cell, which could be active or inactive. To make things easier and to procure the results of the rules applied to the two-dimensional grid faster than one would on paper, a computer application may be used. In the application *Golly*[46], a number of different rules can be applied and tested over the numerous generations. For example, if tested, the rules of *Game of Life*, while evolving over generations, would look like a real fight for survival (Fig. 5.). Other rules, including the one-dimensional, cellular automaton rules further introduced by Stephen Wolfram, may also be tested.

Emergence of Creative Forms in Cellular Automata

In the research he did between 1982 and 2002, Wolfram introduced the idea that organic and inorganic patterns and systems derive from simple repetitive rules and interaction between elements. In organic nature, symmetrical forms are not exceptions: animals, leaves, and insects are usually symmetrical. There are also more complex structures visible in inorganic structures, like snowflakes or crystals. If applied in a certain manner, simple rules, over time, could generate patterns similar to those found in nature.

46 The name of the application refers to the practice of Kabbalah, where the creative process ends in the creation of a "*golem*" (literally, “shapeless or lifeless matter”), a hypothetical human given life by means of the magical invocation of Divine names.

For example, simple rules for binary, one-dimensional cellular automata over a number of generations could produce a pattern similar to the one seen in a cone shell's pigmentation. If more complex rules are applied to a two-dimensional grid, this might produce a pattern similar to that of a snowflake.

If the Universal Turing machine described above can compute anything (hence the term “universal”), a cellular automaton could be considered limited because of its limits in producing an end result, which often appears to be homogeneous, or the process is stymied and ends in no result at all (Langton 1988, Wolfram 2002). While working with one-dimensional, or elementary, cellular automata, Wolfram came up with some results in 1983 that can be summed up in a few statements: a) one-dimensional cellular automata may have 2^8=256 possible rules, ending up with 256 different patterns; b) cellular automata may evolve into four different structures: stable with a homogeneous state, stable producing periodic structures, chaotic though not completely random, and complex structures; c) only rules falling into the category of complex structures may be proven to be capable of universal computation (Wolfram 2002).

The first statement is a reference to one-dimensional cellular automata being capable of producing creative patterns. All of the patterns are computed via a binary method applied to an active cell and an inactive cell. So, if, for example, an active cell has an inactive cell to its left and has another active cell to its right, the next generation would turn out to be active or inactive depending on which rule is applied. Each case might have a maximum of eight rules, which, in turn, would produce 256 different patterns. Rule number 126, for example, would produce an image similar to what Wolfram compares to that of a cone shell (Fig. 6. and Fig. 7.).

The second and last statements are described by Wolfram as offering a variety of repeating and non-repeating elements in a pattern produced via simple, defined rules of cellular automata or any other pattern that accepts the cellular automata construct – for example, the Turing machine or a sequence of numbers of a specified sort, such as prime numbers. If, after a number of generations, the evolved patterns start to demonstrate some complexity in their structures, the rules can be considered as capable of universal computation.

To prove it, Wolfram used the interaction of two cellular-automaton-like elements, rule number 110, and a hypothetical Turing machine, which, through the process, was embedded into the structure of rule number 110. Combining this interaction with a cyclic tag system, which is defined by yet another kind of simple rule, he was able to demonstrate a pattern emerging from the interaction with a hypothetical Turing machine pattern. The interaction resulted in the emulation of other elements within the 110th rule of cellular automata, proving it to be capable of emulating a Turing-machine-type element (compare Fig. 8. and Fig. 9.). A similar proof has been shown constructing a seven-state and four-colour Turing Machine based on the cellular automaton principle. The result Wolfram came up with is evidence that complex cellular automata bear a feature of universal computability.

On the other hand, Wolfram's proof provides the idea that two heterogeneous elements – a cellular automaton and a Turing machine – can interact with each other, which brings us back to the position that heterogeneous elements interact among themselves, together shaping a kind of rhizome.

Computation Within Larger Interactive Systems

In the previous section, it was pointed that, in the ontology of Deleuze and Guattari, the universe consists of elements that continuously interact in shared time and space, together shaping a single indivisible system. In Miller's theory, the universe sits at the top of his hierarchical system consisting of elements.[47] A solution somewhere between those two is brought forth by Whitehead and Bertalanffy, who argue that the entire universe functions as a system of smaller interacting systems, which then interact with even smaller systems. In all these cases, the universe is introduced as consisting of interacting elements. If one considers applying Whitehead's and Bertalanffy's discreteness to Wolfram's idea of the universe explained by simple mathematical rules,

47 Defining living systems, Miller distinguishes seven (in 1978) or eight (in 1990) hierarchical levels: cell, organ, organism, group, organization, community (added in 1990), society, and supranational system. Along the main levels, there are a number of sub-levels interacting with each other in order to continue the propagation of their species beyond themselves (Miller, 1978, p. 1; Miller and Miller, 1990).

then, possibly, larger computer systems could in principle simulate creative processes through which new forms could emerge.

Features such as the interactivity and infinity of operations in computing systems have also been studied intensely by Jan van Leeuwen and Jirı Wiedermann (van Leeuwen & Wiedermann 2001). Despite the simplicity of automata, in contrast to Wolfram, they do not consider automata as having universal computing power, although they agree on the fact that automata may interact and process infinitely when considered as operating in complex environments such as computer networks. In so doing, they, in theory, agree to Wolfram's proposed idea that, if an automaton embeds in itself a Turing machine, it becomes universal.

Applying automata to computer networks and, in such a way, gaining the automaton's feature of interactivity, Jan van Leeuwen and Jirı Wiedermann propose more powerful computational machines than the single computer described by the Turing machine. Computer networks as interactive finite automata (IFA) could serve as a basis for the investigation of evolving interactive computing systems or as a model of a “living organism.” The interactivity and infinity of their operation was more widely developed as Interactive Turing machines with Advice (ITM / A) in their papers “The Turing Machine Paradigm in Contemporary Computing” (Leeuwen & Wiedermann 2000) and “How We Think of Computing Today” (Leeuwen & Wiedermann 2008). Within the latter paper, the authors argue that evolving automata and Turing machines are both defined using the same formal language; they propose two new models of computation: a) every classical Turing machine, or even an interactive Turing machine (ITM), can be simulated by an evolving automaton, and b) evolving automata can simulate interactive Turing machines with advice and vice versa.

Despite the fact that the Universal Turing Machine and finite cellular automata are of different natures (one is designed for computing and the other for modelling patterns), both are constructed upon a grid with stored information, both act upon input and produce output, both are able to compute, and both are able to simulate each other. The "halting" state is problematic within the Turing machine, but not within Wolfram's proposed cellular automaton type, which is capable of interaction with the environment, nor within Leeuwen's and Wiedermann's Interactive Turing machine with Advice. At the same time that he proposes cellular automata as being capable of universality, Wolfram overcomes the halting problem of the Turing machine, because, in automata, some decision is always made depending on the given rules and interaction between elements.

Assuming that more complex computational environments, such as computer networks, could, in principle, have creative power provokes further thoughts on how such networks could interact with or without humans and what rhizomes could emerge.

Conclusion

Describing the post-digital domain (see the subsection “The Post-digital Domain” in the first section “Aesthetics of the Post-Digital”), I started with communication that emerges in computer networks. Therefore, all the analysis that has followed has raised questions from the perspective of networks, or, to be more precise, from the perspective of interaction between elements, which together form a system. Considering post-digital territory, it has been pointed out that there is a certain level of hybridity there, or at least we humans have to deal with machines, and therefore this territory is comprised of physical and virtual realities, real and imaginary territories, organic and inorganic domains. Furthermore, the analysis of three artworks – *Mailia*, *Artificial Paradises*, and *Programmed Machines* – has brought us to the point that, within post-digital art, an important role has been given to the interaction between different disciplines and elements, which provokes the emergence of new forms.

Examination of Deleuze's term “rhizome,” which describes the interaction between different kinds of elements within an ensemble, suggested that, within post-digital territory, the border between living and non-living elements might not exist. Following that thread, I tried to provoke consideration of a sort of life between living and non-living systems, or between one non-living system and another non-living system. Let's consider a few examples. For instance, a synthetic gene integrated into organic cell makes it react to given information and thus forces the whole cell to mutate and evolve. Might such an interaction be called a living organism? Or, for example, is the whole universe, with all its interacting stars and planets, a living organism? A traditional biologist would probably answer that a living organism is bound to organic structures, and therefore such a system is not a living system. On the other hand, an expert operating from a different, more holistic scientific point of view would probably argue that inorganic structures could be alive (compare, for example, the concepts of Miller, and Maturana introduced in the section “Life Between Human and Machine”). Who is right? The analysis of living and non-living organisms in that chapter proposed considering such a system as indivisible, which became the starting point for looking at the principles of the emergence of complexity.

The emergence of complexity as such happens to unfold through a number of interacting elements within a system, which apparently self-organizes through the processes. If, in the physical world, self-organization is taken for granted (compare, for example, the concepts of Deleuze and Guattari, Miller, and Ashby found in the section "Life Between Human and Machine"), self-organization in the artificial world is not as obvious and is proposed to be defined by, for example, the simulation of life-like processes (for more details, refer to the subsection "Aesthetics of Artificial Life and Artificial Intelligence" in the aforementioned section). The analysis of such simulation brought me a step further towards simple computable rules, which are at the core of the computing machine introduced by Alan Turing or the idea of cellular automata as conceptualized by John von Neumann. By observing simple elements interacting with each other by a defined set of rules, one can recognize emerging forms similar to those found in nature (for more details, refer to the subsection "Emergence of Creative Forms in Cellular Automata" in the aforementioned section). The idea of applying simple rules to computer networks – which is described in more detail in the subsection "Computation Within Larger Interactive Systems" – proposes that a certain level of intelligence within human-made machines has its logic.

This conclusion suggests that, while being able to self-organize within complex networks, forming a rhizome together with humans and thus becoming human-like, computable machines not only might demonstrate interactivity or be a supplemental element in a human-machine rhizome, but also might have the potential to become independent creative elements demonstrating emergence and, along with it, a certain level of intelligence. This idea became a driving force for conceptualizing my new artwork, developed in parallel to the considerations above (for more details on the artwork, see "Annex I. Project: *0.30402944246776265*").

Chapter II. The Territory of P2P Networks

Networks and Their Specifics

Computer Networks and Routing Systems

Considering the fact that digital information and communication technologies have strongly influenced our lives, and that it is not possible to discuss post-digital art and the information society without understanding what the information is and how it is distributed among us, I will attempt to bring the reader closer to technical questions. What are computer networks and how are they constructed? Is it possible to build up a system that could self-organize independently from human input?

The section "Simple Rules and Computable Creativity," of the "Self-organization and the Post-digital" chapter and in particular its subsections "Emergence of Creative Forms in Cellular Automata" and "Computation Within Larger Interactive Systems," briefly introduced the idea of network systems operating as interactive finite automata and evolving networks being able to demonstrate emergence within non-living systems. As a consequence, it was suggested that such systems have the potential to demonstrate a certain degree of vitality and intelligence over self-organized processes. Now, there are a few concepts behind the idea of such systems that need to be highlighted: a) processes changing over time within the system and b) elements interacting among each other within the system. If the first concept is bound to vitality and evolving processes, then the second concept is about the integrity of structures within the systems. These concepts are important for the future development of technologies and human relations to technologies (or vice versa), including such questions as ethics and etiquette.

Considering that interaction, creativity, and emergence in human-machine environments are very important,[48] the interaction of elements within the physical environment requires some technical in-depth analysis. This will provide a more substantial conceptual background for the artistic project, *0.30402944246776265*, which is

48 Consider, for example, John Cage's piece *4'33"* composed in 1952 or Tehching Hsieh's *One Year Performance* from 1980-1981.

supposed to communicate to the audience the idea of self-organization in non-uniform networks and artificial systems being able to demonstrate a certain level of vitality and intelligence.

Physically, computer networks are connected to each other non-hierarchically and do not necessarily depend on intermediaries, e.g. servers routing digital information to the end computer.

Nevertheless, computers within the computer networks are usually connected over the network switch or wireless router, in such a way forming a decentralized (and at the same time semi-hierarchical) network. In order for the computers to interact with each other, the networks are based on certain rules set across the different protocols. The Internet Protocol Suite (TCP/IP) is one of the most widely used set of protocols forming a network of interconnected computers. One of its abstraction layers, the Internet Layer, facilitates the interconnection of networks, enabling digital data flow among computers. Its Internet Protocol (IP) defines the fundamental address spaces that are then controlled by Domain Name Servers (DNS). In other words, the Internet is defined by TCP/IP and DNS (Braden 1989).

Now, in order to be able to consider dynamics in computer networks, it is important to mention that the physical network is distributed, meaning that computers are connected over switches and how they “communicate” among themselves is a matter of implemented software. The connectivity of the prevailing Internet is achieved over a routing process and information forwarding on the basis of predefined routes to various network destinations making the network decentralized (Braden 1989). In contrast to a decentralized network (such as the Internet), distributed data routing is also possible (Boehm & Baran 1964) (Fig. 10). Keeping these network architectures in mind, the further analysis will consider possibilities for self-organization within the Internet.

Being the most prevailing, the Internet is also seen as a layer for other networks that can be constructed in order to permit the routing of digital data in predefined lower level networks. For example, the Local Area Network (LAN) is usually used for small-scale networks and is defined by physical space, like a room or house. A Wide Area Network (WAN) or Virtual Private Network (VPN) can overarch a much broader geographical area but are still used in a defined network by businesses or governments. Those networks are usually constructed upon hierarchical routing rules using intermediary servers, and self-organization within those networks could only be possible with a set of predefined exceptions, such as elements a, b, and c, which may become self-organized if all of them are connected to an element d.

In contrast to the network systems mentioned above, other network concepts are based on Peer-to-Peer (P2P) or computer-to-computer connections, which may have a decentralized or distributed character better suited to self-organized systems. However, as was mentioned earlier, they would still be dependent on the Internet layer organized upon a semi-hierarchical DNS system, which is controlled by the Internet Corporation for Assigned Names and Numbers (ICANN). This corporation is responsible for managing all IP addresses, and it therefore makes the Internet centralized from the perspective of IP addresses provided.

As the artistic installation developed in parallel to this research includes a computer network, it is important to mention the DNS service, the Top Level Domain (TLD), which provides easier readability of the computer addresses. The first-level set of domain names, the top-level domains (such as the prominent domains .com, .net and .org), and the country code top-level domains (such as .uk, .de, or .lt) are installed in a DNS server root zone controlled by the ICANN branch company called the Internet Assigned Numbers Authority (IANA). This company then further distributes the Internet addresses. For example, in the United Kingdom, "Nominet" is responsible for all domain names ending with ".uk". It has sub-delegated all domain names ending with ".ac.uk" to the Joint Academic network (JANet). In turn, JANet has delegated all domains ending with ".gold.ac.uk" to Goldsmiths University, which then assigns the lower-level domains to different departments or projects, e.g. the sub-domain "libra.gold.ac.uk" is assigned to the library. Each organization has to either handle the administration of their sub-domains or further sub-delegate them to another organization in such a way that the management becomes completely dependent on higher level organization. From the perspective of self-organization, such hierarchy is hardly helpful. On the other hand, seeing the readable address of a computer, the user can better understand the location of one or another computer in the network in relation to his own location. Therefore, the possibility of creating an alternative service to DNS is not yet excluded from further consideration. A similar service could be configured upon the afore-mentioned LAN, WAN, VPA, or P2P.[49]

Besides the hierarchical TLDs' approach to control, a significant deficiency in ICANN-controlled IP addresses might also be observed in the scalability and flexibility of the growing Internet. This is seen, for example, in the most widely implemented fourth IP version (IPv4), which is no longer sufficient. The upcoming sixth IP version (IPv6) does not necessarily solve the problem of IPv4, as it continues to be dependent on the one single organization controlling domains. In addition, it might soon become as insufficient as the IPv4, because of the rapidly growing need for unique IP addresses. Last but not least, another problem of the IP system currently in use is its dependency on commercial and governmental power structures, issuing more problems such as the vulnerability of private data and freedom of speech. Even though these latest shortcomings might not seem obviously important for the artistic installation, the work's dependencies on certain tools, which are inevitably tied to certain issues (such as the encryption of data) make up another valuable conceptual layer. Therefore, the issue is introduced in the next subsection.

The Vulnerability of Prevailing Networks and the Need for a Self-organized Network

The previous subsection introducing the architecture of the Internet proposed that it suffers from many shortcomings, which, overall, do not allow nodes within the system to self-organize. First of all, the approach to ownership in terms of registering the domain name at ICANN is not necessarily a good one. The deficiency of scalability introduced may also harm the Internet as it develops. Thirdly, the dependency on commercial and governmental power structures creates further problems, such as the

49 One example of non-existent alternative network is AlterNIC. AlterNIC started operating their registries even though their name servers were not included in the Internet's official root zone. As a result, only users of manually reconfigured name servers were able to resolve AlterNIC names. AlterNIC offered alternative TLDs like .alt, .free, .usa, .eur, and others even based on company names. For example, Wired magazine has reserved .wired, and IDG's affiliate in Europe has reserved .idg (Lawton 1996).

vulnerability of private data and freedom of speech. Although vulnerability of private data and freedom of speech might not necessarily be central to the artwork developed alongside this research, as soon as the discussion concerns post-digital territory, the external control of the system might strongly influence the narrative of the artwork in terms of self-organization.

Laws such as the USA PATRIOT Act, which allows the U.S. to use a variety of surveillance methods (e.g. implementation of Carnivore software in networks) in order to trace, for example, terrorist attacks (GPO 2001), or much more complex surveillance systems like China's state-wide firewall, the *Golden Shield Project,*[50] or systematic monitoring of world wide networks by the National Security Agency (NSA)[51] are always targets for criticism by the P2P community or advocates of free speech who point out pre-existing laws (e.g. in the U.S., the First Amendment to the United States Constitution). As a reaction to the Telecommunication Act of 1996, among other passages regulating obscene programming on cable television and the communication of obscene materials in cyberspace, John Perry Barlow published a manifesto criticizing the government's repudiation of the Constitution and freedom of speech, wherein he invited the government to keep cyberspace separate from the “real” world (Barlow 1996:29). Barlow suggested that virtual space has different social architecture and therefore should not be influenced by any external control.

Recently leaked documents about mass surveillance systems like PRISM, XKeyscore, and Tempora[52] have prompted long discussions on privacy and the vulnerability of digital information within society. On central servers, recorded metadata, including senders' and receivers' IP numbers (the route and time of data packets sent from node to node) have proven that a hierarchically organized Internet is transparent regarding

50 In 2003, China's Ministry of Public Security implemented a firewall, filtering accessibility to public websites and content.

51 See, for example, *Der Spiegel*, “Partner and Target: NSA Snoops on 500 Million German Data Connections.” Available at: http://www.spiegel.de/international/germany/nsa-spies-on-500-million-german-data-connections-a-908648.html (Accessed: 27 May 2015).

52 In 2013, Edward Snowden, who worked for the Central Intelligence Agency (CIA) and the National Security Agency (NSA), leaked details of several top-secret United States and British government mass surveillance programs to the press. The documents introduced PRISM (used by the NSA), which was supposed to collect the metadata of encrypted content, and Tempora (used by the UK), which was said to collect recordings of telephone calls, email message content, Facebook entries, and the personal Internet history of users.

information sent over computer networks. The ability to track information in the networks has both positive and negative sides. On one hand, traffic analysis could help protect authors from having their intellectual property infringed upon (e.g. ACTA, SOPA agreements) or stop, for example, child pornography. On the other hand, traffic analysis could build barriers against the freedom of speech (as mentioned earlier, China's Golden Shield, Syria in 2013, or Egypt in 2011 being cut off from Internet access[53]) and serve businesses to foresee the needs of customers (allocation of Google or Facebook ads on websites[54]). Being exposed to further information analysis, Internet users are not protected with regard to their individual points of view towards others.[55]

Alongside social vulnerability, hierarchically organized networks are also technically vulnerable. If, say, a company that takes care of providing Internet access to a number of users has electrical shortages or errors in its technical setup, users can be left without Internet access. Or, if, for example, a provider is under attack by hackers, a number of users can be left with interrupted access to the Internet.

Following the problematics detailed above, the social and technical vulnerabilities of a hierarchically organized Internet suggests that a non-hierarchically structured Internet might have more potentiality regarding control of personal information or technical independence. Therefore, most P2P systems (e.g. Tor, I2P, Freenet), except for those designed for file sharing (e.g. BitTorrent, Gnutella) take a position in favor of freedom of speech, anonymity, surveillance, and control and use encryption to protect networks from information analysis sent over computer networks (for details, see the section "Related P2P Computer Networks"). Meanwhile, P2P systems are designed to reduce dependency on a hierarchically built Internet.

53 See for example *Al Jazeera*, "Syria Cut off from Global Internet." Available at: http://www.aljazeera.com/news/middleeast/2013/05/20135813917138958.html (Accessed: 27 May 2015).

54 See for example enerica.com, "Online Advertising Case Study: Facebook Ads vs. Google AdWords vs. LinkedIn." Available at: http://www.enerica.com/online-advertising-case-study-facebook-ads-vs-google-adwords-vs-linkedin/ (Accessed: 27 May 2015).

55 See for example Telekommunisten, "The Internet is not a Surveillance State…" Available at: http://telekommunisten.net/2013/03/27/the-internet-is-not-a-surveillance-state/ (Accessed: 27 May 2015).

Self-organization Within P2P Networks

As introduced in the “Computer Networks and Routing Systems” subsection, physically, the Internet layer bears a lattice structure and has no hierarchically predefined architecture. It has been noted that, on top of the physical layer, the TCP/IP protocol implemented for the prevailing Internet is organized upon a hierarchically organized IP address system, and the capacity for self-organized processes within computer networks is therefore limited. Nevertheless, self-organizing processes are not an exception and are often in use in, for example, local networks computers are usually allocated dynamic IP addresses in order to connect to the Internet. Self-organizing processes are also important in P2P networks in order to localize other computers within the network and to avoid the server-client hierarchy of the prevailing Internet architecture.

Given that the hierarchically organized Internet is vulnerable for technical and social reasons, P2P networks often focus on the security of the information transmitted. Aside from security purposes and reasons of communication (Tor, I2P), P2P networks also focus on capacity in file-sharing networks (Bittorrent, Gnutella), decentralized searches (YaCy), and storage (Freenet), or, for experimental environments, they are set up for analyzing life-like processes (DREAM).

Related P2P Computer Networks

BitTorrent File-sharing Network

Bram Cohen designed and released BitTorrent in 2001 as a file distribution system. It is the most popular P2P protocol used for file exchange, which counts over 150 million active monthly users worldwide.[56] The protocol is defined by nodes that seek files to be downloaded and trackers that contain information about the files and coordinate their distribution (Cohen 2003). All of the clients (e.g. µTorrent, Vuze, BitComet, etc.) have the same or a similar purpose: to download, store, and share files for users connected to the BitTorrent system. Despite the variety of clients and the fact that they are developed in different programming languages, the architecture of the protocol is limited to sharing files. Thus, the protocol is not considered of high interest and will be introduced within the next section only for comparative purposes.

The Distributed Search Engine YaCy

Most of the code and libraries of the distributed search engine YaCy are copyrighted by Michael Peter Christen, who has developed and coordinated the development of the network since 2003.[57]

According to developers, the philosophy behind the YaCy network is linked to the open source software movement, which allows the code to be freely accessible, modifiable, and further distributable,[58] enabling the freedom to speak freely without censorship, as well as the right to anonymity and privacy (YaCY 2013). Along with free speech and

56 BitTorrent (2012) Prensa – Company – BitTorrent – Ofrecemos acceso a todo el contenido del mundo. Available at: http://www.bittorrent.com/intl/es/company/about/ces_2012_150m_users (Accessed: 04 November 2013).

57 In 2003, Gnutella, Kazaa, Soulseek, and other file-sharing programs were widely used; Internet Archives, Google, Altavista, Yahoo, and other search engines and companies were indexing the Internet. Cohen B. (2003).

58 The YaCy code is licensed under the General Public License (GNU) Lesser license, version 2.1 or any later version of the license.

free access to knowledge, YaCy developers identify themselves with the hacker ethics of Chaos Computer Club, who support freedom of information, promote decentralization, protect private data, and encourage use of public data. According to their website, they also work jointly with the Pirate Party, who has similar goals: informational self-determination, transparency, and open access (ibid.).

YaCy developers describe monopolistic search engines such as Google or Yahoo as centralized and limited to discovering free content. In order to not let monopoly holders decide what information is visible on the Internet, YaCy developers have proposed coming back to the original, decentralized world-wide-web philosophy where the user controls the information (Christen 2005) and building not only transmitter-receiver connections, but also connections that are equal between the participants in the network. Hence, YaCy builds up a decentralized search engine that stores indexes of information accessible worldwide on local nodes. Such a technique opens up the means for a philosophy of free speech and free access to knowledge (YaCY 2013).

Being a distributed network of computers with an ability to search for remote information and store local indexes that include this information, YaCy is a good candidate for continuing to work with the evolving automata or interactive Turing machine concepts. These concepts, as discussed in the "Simple Rules and Computable Creativity" section of the first chapter, could bring the reader closer to understanding the potential of creativity in human-machine systems via self-organizing processes. Therefore, the YaCy search engine will be analyzed from a technical perspective (for details, refer to the "YaCy Architecture" subsection in the next section).

Freenet Storage System

The roots of Freenet could be a prevailing DNS system, which bears semi-distributed features (for more details, see the subsection "Computer Networks and Routing Systems") and wherein domain name servers are set up to frequently update domain entries from a targeted DNS server. The DNS system, however, is not completely distributed, because the servers within the system are linked to the root DNS servers, which complete the hierarchical structure in relation to the databases of available and registered IP numbers and domain names. In his related 1999 paper, Ian Clarke, an initiator of the project, mentions *Usenet* newsgroups and Internet Relay Chat (IRC) channels as the most well-known distributed systems (Clarke 1999). Lack of security, lack of required bandwidth, and the huge quantities of Usenet data were the reasons why Clarke came up with a new kind of routing system.

In order to come up with a distributed model for the project, Clarke proposed using an "adaptive networks" idea from social networks, where "routing" was performed by asking people for a direction: "By starting at a location, asking for advice of where another place is, and following that advice, you are likely to find yourself somewhere closer to your destination" (Clarke 1999:16). This idea led to later implementation of the Freenet storage system to conceptualize the system upon Milgram's "small-world" social experiment, wherein only friends and friends of friends could take part. It was expected that such implementation would reduce the vulnerability of the node and ensure privacy for all participants (Clarke et al. 2010:17).

When Clarke was working on his paper "A Distributed Decentralised Information Storage and Retrieval System," most of his research was focused on decentralized networks and improvements to the Internet that would enable a non-hierarchical exchange of information. Instead of interconnecting network nodes over user-friendly and readable domain names, Clarke suggested storing and retrieving information from nodes on an encrypted key base. Such a system had to guarantee a distributed, decentralized, and easily scalable system for information that was accessible worldwide. Thus, according to Clarke, the philosophy behind Freenet is focused around the free flow of information, which results in freedom, the right to anonymity, and privacy (Clarke 1999).

All together, the Freenet storage and retrieval system proves to be a real candidate for developing a project based upon evolving automata and interactive Turing machine concepts. First of all, besides the distributed nature of the network, the Freenet project is able to store information in the computers connected to the network. Secondly, being able to store data within the network, Freenet is able to search for and retrieve it. Thirdly, routing algorithm enabling search within the system is developed as a reference to the social system based upon small-world phenomena (Milgram 1967, Watts 1999), which is a direct reference to a self-organized society as well as to life-like situations, which as was shown earlier, are considered important in A-life concepts (for more details, refer to the “Life Between Man and Machine” section in the first chapter). Finally, the Freenet network has an encryption system implemented, allowing one to hide information from parties that are not supposed to have access to such information. Such a feature could correspond to dialogue situations, where particular information is shared between the parties participating in the dialogue, leaving unrelated information out of the conversation. In short, dialogue is introduced here as an ability to access information while “decrypting” it.

Tor Communication Network

Similarly to the Freenet project, *The Onion Routing* project, or Tor, lets people securely access Internet websites, communicate over IRC channels, share files over third party software (for example, the P2P Bittorent client Vuze), and publish their own websites without a need to reveal the location of the node. This development started back in 1995, when it was funded by the Office of Naval Research.[59] The idea behind developing the project was to limit the network's vulnerability to traffic analysis while building an encrypted system. This system was designed as a layered structure where files and data packets would be encrypted several times. Hence, the metaphor of an onion having a layered structure.

An interesting detail is that the development of Tor was supported, among other things, by the Electronic Frontier Foundation (2004-2005) and one of its founders, John Perry Barlow, who is a well-known writer, politician, cyber activist, and fighter for freedom of speech and free access to information.

An I2P Network for Communication

Yet another distributed anonymous routing system, the *Invisible Internet Project* (I2P)

59 Onion-router (2005). Onion Routing: History. Available at: http://www.onion-router.net/History.html (Accessed: 08 November 2013).

was formed in 2003 to offer the community an uncensorable, anonymous, and secure communication system. The developers state that it is a "fully distributed, autonomous, scalable, anonymous, resilient, and secure network.”[60] These features place the I2P network next to the Freenet project and the Tor network introduced above and might be as interesting while developing a human-machine system that demonstrates a certain level of intelligence.

Evolving Information Systems in DREAM

A machine-to-machine type of communication system, a *Distributed Resource Evolutionary Algorithm Machine* (DREAM) was first described by Ben Paechter et al. (2000). The project was funded by the European Commission and was supposed to become an infrastructure for distributed data mining, distributed scheduling, and the modeling of economic and social behavior. The project was described as based on two components, one physical and one virtual, wherein the virtual would become a mirror of the physical world via *infoworld* and *infohabitants*, a software acting on behalf of individuals and organizations. Among the core objectives, the authors distinguished evolving virtual worlds with infohabitants and facilitation of economic and social systems while simulating them. The authors imagined an evolving infohabitant society as embodying collective intelligence that would have an intrinsically distributed, adaptive, and self-organizing nature. It should have been possible to globally disseminate the results of individual and collective learning processes through migrating and recombining digital information. The evolutionary components were defined by standard real-valued vector representations (evolution strategies), binary- or discrete-valued vectors (genetic algorithms), permutations of integers (order-based genetic algorithms), and computer programs in LISP-like genetic programming languages (Paechter et al. 2000).

The core of DREAM is the *Distributed Resource Machine* (DRM), an equivalent to *infoworld* that was a virtual machine developed to function in a P2P network, forming an autonomous agent environment. Able to demonstrate life-like features and able to

60 I2P Anonymous Network – I2P. Available at: http://www.i2p2.de (Accessed: 08 November 2013).

simulate social systems (Jelasity et al. 2002), DREAM is a good candidate for developing concepts similar to those of evolving automata or an interactive Turing machine. On the other hand, this virtual machine is developed for modeling economic and social behavior, which are features that exist in the physical world and are not directly interactive or influenceable in the rhizomatic way described above. As such, the machine is also similar to the *Tierra* environment (Ray 1991-2004), or to the *A-Volve* and *Life Spaces* art projects (Sommerer, K., Mignonneau 1994-1995) (for more detailed descriptions, see the subsections “Artificial Life Territory” and “Aesthetics of Artificial Life and Artificial Intelligence” in the “Life Between Man and Machine” section in the first chapter). Being a simulation of real environments, the system is considered less interesting for the project being developed here, which, instead of simulating, is thought to become itself a system demonstrating a certain level of intelligence. Therefore, DREAM will not be considered further as a potential model for developing the art work.

Search and Storage Methods of Distributed P2P Systems

Architecture of Decentralized and Distributed Networks

In the first section of this chapter, the Internet was introduced as a base layer for different protocols enabling communication among interconnected computers, including P2P networks, WWW, or VPN. Therefore, the P2P architectures discussed below use the infrastructure of the Internet as organized upon the DNS system, which carries hierarchical interdependence. As related work, the decentralized and distributed networks of computers acting both as servers and as clients were considered as non-hierarchical, since they provide client-to-client dependence through implemented routing protocols. Further analyzed P2P architectures will refer to software-specific storage and routing algorithms.

Nodes connected in decentralized and distributed networks have the same or compatible software, enabling access to digital information across the network. In such systems, information is saved and the routing system is managed with a variety of algorithms using Distributed Hashed Tables (DHT) schemes that allocate the information's meta data or data packets to key and value identifiers. Such organization of information storage and routing schemes enables nodes within the decentralized networks to register meta data such as the "arrivals," "departures," or "failures" of other nodes. Processed data is then shared with other nodes within the system.

Bassam Zantout and Ramzi A. Haraty from the Lebanese-American University in Beirut distinguish three architectures for DHT technology and P2P networks: centralized indexed system, flooded query system, and heuristic key-based routing (Zantout & Haraty 2011). The centralized indexed system has a central node in the network that shares with connected nodes meta data about the nodes themselves connected within the network, and thus it becomes a decentralized system with a hierarchical properties. Napster is one of the most well-known P2P systems using such a method. The flooded query system has a requirement of distributing each query to all participating nodes in the system in such a way that it demonstrates improbable scalability and self-organization of the system. Zantout and Haraty give Gnutella as an example of such a system. Within heuristic key-based routing, the query is directed to a set of nodes with similar keys instead of being broadcasted to all nodes or the central server. Such a system is implemented in the Freenet project (ibid.). Such classifications give an overview of P2P systems and an image of how P2P networks might be built, as well as how they organize themselves. For example, Napster functions like most of the Web 2.0 type social networks, including Facebook and Twitter, which keep their users connected through a central server. If the central server is switched off in the network, the whole system also goes down. The other types – the flooded query system and the heuristic key-based routing system – are more interesting, as they are not dependent on one server or one company and would continue functioning even if part of the servers were switched off. If the flooded query system is designed to share information from the connected computers while continuously sending information on connectivity and stored information between computers, the heuristic key-based routing system functions by using the comparison of encryption keys between the directly-connected computers, which, in turn, compare keys with other computers. The two latter types of P2P networks appear to be more easily scalable, may function independently from other networked machines, and are therefore more interesting for deeper analysis related to self-organized concepts.

Bittorent, YaCy, and Tor architectures introduced further are classified as being flooded query systems, while the Freenet network, as already mentioned, is a good example of the heuristic key-based routing system, and I2P has features of both systems. These P2P networks are chosen in order to compare technical features in systems with a different focus; for example, the focus of BitTorrent is on file-sharing, and YaCy is a distributed search engine. The anonymous systems Tor and I2P focus on communication, and Freenet is the distributed storage system.

BitTorrent Architecture

In order to initiate use of the BitTorrent system, a file with the extension *.torrent* is required. The *.torrent* file contains meta information about the actual file, its length, name, and hashing structure. The classic version of BitTorrent protocol uses a decentralized architecture with a central server called a “tracker,” which registers the addresses of nodes containing information about stored files. Thus, the architecture of a classic BitTorrent system is not fully decentralized. The later BitTorrent generations also support a fully decentralized tracker system based on the *Kademlia* algorithm, enabling distribution of meta information to a number of nodes (Crosby & Wallach 2007, Cohen 2003). As the same algorithm is used by I2P network, it will be overviewed further within the subsection “I2P Architecture.”

Within the BitTorrent network, nodes use a *tit-for-tat* communication method, which assures equal file sharing; nodes send information about the downloaded file, the port number of the node, and similar information. Other nodes use this information to connect to each other. In order to keep track of the file information contained, BitTorrent cuts them into data pieces of a fixed size, typically a quarter megabyte, which is then encrypted with a secure hash algorithm (SHA-1) in order to verify data integrity between nodes. Nodes continuously download and upload pieces of data from all the nodes they can and then record updated information for later reference. When selecting which piece to start downloading next, nodes refer to either the least widespread piece or a random piece if the file has not yet started downloading. This is done in order to assure a replication of the least widespread pieces of the files (Cohen 2003).

Although BitTorrent is very limited in terms of communication, it has an interesting concept of distributed data packets, which, over sharing algorithms, is meant to come together into one file. If thought of as living organisms, such a feature could be compared to, for example, swarming behavior or self-organized mechanisms.

YaCy Architecture

While file-sharing architectures of P2P networks are relatively simple, networks with a focus on communication and information storage bare much more complex architectures. Within YaCy search engine architecture, each node includes, for example, a web server, an indexer (crawler), a DHT database, and a local DNS for accessing nodes in the network.

While the web server is used for storing indexed information from different networks (including public Internet), indexing, which is used for recording information available on the network, has a complex implementation. Within YaCy, indexing is performed after initiating a search within the network and by telling the local crawler to download information available within the network. The indexing system of YaCy is divided into seven different methods: Remote Crawl Receipts, Result of Search Queries, Index Transfer, Proxy Indexing, Local Crawling, Global Crawling, and surrogates import. These methods assure that downloaded information is well structured within the DHT tables. For example, Remote Crawl Receipts are responsible for the downloads of websites that were told to crawl by a host node and have not yet been crawled by other nodes, as well as Global Crawling methods that are responsible for downloads of websites that have been indexed by the local node but for which the crawl has been initiated by a remote node. Having, for every different case, a particular model for indexing websites from the Internet, YaCy is able to build a distributed search engine, which functions relatively reliably compared to centralized search systems. The final result, however, is much poorer compared to, for example, Google's search engine (for more details, refer to the subsection “Routing” in the section “Non-uniform networks and post-digital territory”).

The DHT of YaCy are organized so that indexed information is kept dynamic in a "walking concept," wherein older results are replaced with newer ones. The “walking concept” is implemented through the Reverse Word Index (RWI) associated with unique random keys.[61] RWI associates each word that is extracted from the indexed documents with a list of web references (e.g. URLs, uniform resource locators) for the documents, including websites where a given word occurs. At the end of every crawling process, the index is finally distributed over the nodes within the network. The use of such a method is fair because, in such a way, a system of the single computer does not get overloaded by secondary data. In so doing, the system is also kept up to date, which altogether builds an optimal index of information available on the Internet. On the other hand, a computer might not include indexes of information that is not considered popular or that

61 The random key "String key = crypt.randomSalt();" is generated, which is first changed into the SeedString and later saved in the SeedDB, yacyCore.seedDB.mySeed.genSeedStr(key).

would have less references, and so the information would be out of reach.

The local DNS system, which is yet another feature enabling YaCy to become distributed, assigns each node a unique domain name with the address extension *.yacy* in order to reach other nodes within the network. These domains, similarly to indexes, are stored in local DHT in order to keep it available for the next time, if the node is restarted (Rebei 2007, Demidova & Nejdl 2006). In such a way, YaCy nodes are able to provide an alternative navigation to the one used within the prevailing DNS, which uses common domain address extensions like *.com*, *.org*, or *.net* (for more information on the prevailing Internet structure and its DNS system, please refer to the subsection “Computer networks and routing systems” in the same chapter). Although the domain extensions are designed for easier readability, the use of a local DNS system might be important for mapping the post-digital territory as it, along with the routing protocol, might propose different connectivity between networked computers.

Freenet Architecture

If storage of the YaCy system was only created for keeping indexes and for local architecture purposes, the Freenet storage system is designed to function for the information provided by the users of the network. The Freenet storage system operates as a self-organizing P2P network that uses allocated free space of personal computers to create a collaborative virtual file system and therefore becomes a most intriguing feature in terms of shared information within the distributed networks.

The computer running Freenet software, or the Freenet node, consists of an implemented unique routing algorithm, web server databases, and the Freenet Client Protocol (FCP). While the FCP functionality is defined by interacting with third party software, such as jSite[62] designed for uploading documents on the Freenet network or Freemail as an alternative email system, the Freenet routing algorithm and its web server are part of local structure bearing specifics that are described in further detail.

62 https://freenetproject.org/jsite.html (Accessed: 28 August 2015).

Freenet Routing Algorithm

As introduced in the “Architecture of decentralized and distributed networks” subsection earlier in this chapter, the Freenet algorithm is based on heuristic key-routing, which makes the system different from other networks using the DNS systems introduced above. The very first Freenet routing algorithm was very close to the idea of adaptive networks formed in order to adapt to the changing environment: a place or a node where the information request is originated, recorded, and sent to another node in the network that makes a note of the requested key and sends it further into the network until the requested data is found.

Such a design was achieved by sending the following request messages: *data request*, *data reply*, *request failed*, and *data insert*. Within the designed structure, the initiator node of the request allocates the unique ID, based on encrypted key, to the requested message and a value number – *time to live* (TTL) – defining how many more times the message may be passed. The message is then sent to a neighbor node that is more likely to possess the requested information. When some node receives a query, it first checks its own store, and, if it finds the requested information, it generates a *data reply* message and returns it with a tag identifying itself as the information holder. If the information is not found, the node forwards the request to the node in its table with the closest key to the one requested. That node then checks its data store, and so on. If the request is successful, each node in the chain passes the *data reply* message back upstream and creates a new entry in its routing table, associating the data holder with the requested key. If the requested information is not found within the allocated TTL number, the last node in the chain generates a *request failed* message and replies to the previous sender of the request (Clarke et al. 2002, Clarke 1999) (Fig. 10.). Besides having a completely different concept for routing search requests, such a system is unique in such a way that it could function without intermediary servers such as DNS servers.

Even if the results of such a design were "surprisingly effective,” the routing algorithm was not able to distinguish between the slow Freenet node located at the end of a slow modem line in Australia or the powerful node connected to broadband Internet access in

Los Angeles (Clarke 2003). A solution to the problem was offered by Oskar Sandberg, who proposed using a *greedy routing* algorithm introduced by Jon Kleinberg. The algorithm, which was designed to calculate the proportion of shortcut edges of different lengths between the nodes in the network with respect to coordinates in the distributed network, allowed the request message to reach the destination faster (Kleinberg 2000). In addition, Sandberg then proposed using the *Metropolis-Hastings* algorithm, which chooses random nodes and uses the method of swapping between the nodes independently from their physical locations. When brought into the Freenet routing mechanism, the swapping method introduced some dynamics to the statically organized Kleinberg algorithm (Sandberg 2005).

New dynamics of the algorithm, gained while merging the swapping mechanism and the greedy algorithm of the nodes, brought the developers of Freenet to the idea that such a network should "begin to cluster with data items whose keys [...] are similar."[63] As this idea has not been further developed by the developers themselves, it remains unclear if the network has been programmed in order to start clustering. The swapping method and self-organization of the information while clustering therefore becomes intriguing, as it might result in features similar to those found in nature – for example, swarm intelligence demonstrated by flock of birds or by people living in communities.

Such a design caused Freenet to be further conceptualized in terms of social behavior and was followed by implementation of *DarkNet*, excluding the randomness of Metropolis-Hastings algorithm and including connection to the nodes on a confirmed basis (Clarke et al. 2010:1). In so doing, Darknet Freenet made a direct reference to Milgram's "small-world" social experiment (Milgram 1967), wherein only friends and friends of friends were able to connect to the network. In this model, the information requested within the network is first compared with information available on the node in the neighborhood on a trust-basis.

In order to retrieve and to store files, Freenet nodes communicate over User Datagram Protocol (UDP) and Transmission Control Protocol (TCP) protocols, enabling information exchange within computer networks. Both a newly integrated Darknet

63 Available at: https://freenetproject.org/understand.html (Accessed: 29 May 2015).

Freenet Node Protocol (FNP), used to connect to trusted nodes, and an older Opennet FNP, based on Kleinberg's algorithm, use UDP protocol to transmit messages over the network (The Freenet Project, 2013). The Freenet proxy (FProxy) was built in order to access information with a usual Internet browser, and third party clients such as *Frost*, *jSite,* and *Thaw* use TCP protocol.

To enable communication with third party applications, Freenet uses its Freenet Client Protocol (FCP). The second version of the protocol (FCPv2) that is currently implemented in the Freenet network uses the UTF-8 character set encoding. Among other tasks, FCP controls the insertion of information into the Freenet system, its retrieval from the network, the querying status of Freenet, and the management of other Freenet nodes that are interconnected. These tasks are processed with the help of a built-in web server. All the components together make the Freenet system, first of all, much more user friendly, and, secondly, it becomes less dependent on specific computer architectures. Finally, the system invites further development and implementations.

Freenet Web Server

Yet another feature designed for users and their content is a web server. It is built as a proxy server, Fproxy, between the web browser and the Freenet node. The proxy translates HTTP requests from the browser into website requests that the Freenet node can understand (Minihowto 2013). The websites in the Freenet (*Freesites*) support static HTML standards and style sheets introduced by the W3C consortium,[64] whereas dynamic content such as *JavaScript* or *PHP* is not supported. The websites are also supposed to be stored in one main directory, with optional subdirectories in order to navigate using the HTML standard. Having such a structure, the web server proxy gives Freenet users the chance to design their websites similarly to those usually accessed via the traditional Internet. Although the Freenet web server does not include as many features as a traditional website, having implemented an HTML standard, it is able to provide the same content as the traditional website.

64 W3C. Available at: http://www.w3.org/ (Accessed: 14 May 2014).

Technically, the Freenet stores information in data pieces of 32KB that are encrypted and saved in the nodes connected in the Freenet network. In order to retrieve the data piece, a node needs to know its encryption code, which is logged in the address location. After the required pieces of the file are downloaded, the software decrypts them with the decryption key encoded in the file address. To enable such a system, the software maintains a routing table that lists the addresses of other nodes among the keys once they have been registered.

Differently from traditional DNS systems providing user-friendly website addresses, Freesites are determined by their content and by the secret key held by the Freesite owner in order to be able to decrypt transferred data pieces. Therefore, Freesite addresses are long strings – containing about 100 random-looking characters – known as "keys." Although not as user-friendly as traditional DNS systems addresses, being a long string of random keys, the Freenet addresses become independent from intermediaries providing the "readable" addresses of the websites. Having a long random string of keys allocated for the addresses, Freenet becomes independent from the scalability of the network. Such accessibility design is implemented through the three main kinds of keys: Content Hash Keys (CHK), Signed Subspace Keys (SSK), and Updateable Subspace Keys (USK), allowing data to be accessed and updated by users responsible for that particular content. This information is embedded in the address itself: one part of the key identifies where in the network the encrypted file is stored, and another part of the key, separated by a comma, decrypts the file once it is retrieved.

For more preciseness, Freenet keys are calculated using SHA1 secure hashes. The CHK are used for primary data storage and are always unique to an identical file, independently from whoever uploaded it into the system. The SSK are intended for personal namespace that anyone can read, but only its owner can write to it. The USK are almost identical to SSKs – they point to exactly the same data. The difference is that, when one requests a website or a file using a USK, it starts a process for looking for the most recent version within the Freenet node. CHK is then generated by hashing the contents of the file to be stored, while SSK is generated from combining the public half of the subspace key and the descriptive string of the content (ibid., Clarke et al. 2002).

There are different techniques for keeping Freenet sites accessible in a reasonable timeframe or giving them higher rankings so they are not pushed out of the storage system too soon. Within Freenet websites, using links to anchor sites to each other is suggested. For that reason, images called "activelinks" are used. While, on a regular website, this kind of behavior would be called leeching, Freenet considers it very useful, because it gives a higher ranking to the Freesite and does not push the site out of the system too quickly. This feature might also be very helpful for the automated plugin developed alongside the artistic project in order to keep less random information within the system (see “Annex I. Project: *0.30402944246776265*” for details).

Tor Architecture

Tor, a P2P network for communication, provides an anonymous socket connection through a proxy server, enabling indirect network connections (Fig. 11.). For communication between nodes, the software uses standard HTTP protocols. Differently to YaCy P2P search engine and Freenet storage system, its core is written in C language (Tor Project 2014). There is also an experimental version of the client written in *Java* programming language, the *JTor*, although this has not been developed since 2011.[65]

Tor's network is comprised of different levels of nodes responsible for different tasks within the network: Tor client, Tor server (or routing node, onion, middleman node), directory node, and exit node. While the Tor client is only used for accessing information on the network, the Tor server is responsible for routing information within the server, the directory node provides a platform for hidden services, and the exit node opens the gate for information to be decrypted and provided to the end user.

An important role in Tor is played by hidden services, which let users use web servers for information storage or IRC servers for communication. The hidden services also provide the DNS system for accessing Tor's websites. Similarly to the YaCy search engine, Tor provides its own extension for domain addresses, *.onion*.

65 GitHub (2013). brl/JTor – GitHub. Available at: https://github.com/brl/JTor (Accessed: 08 November 2013).

As Tor focuses on routing information, it does not influence the variety of software installed on the end node. In this way, the web server could also be any Internet server (for example, Apache, khttpd, or Boa).

Having a very complex system of different levels of nodes and clients, Tor thus maintains a certain level of hierarchy. If, for example, the directory nodes controlling Tor's DNS system were shut down, the hidden services including websites would not be accessible. It follows that, on one hand, DNS systems similar to those implemented for the prevailing Internet, YaCy search engine, Tor, and I2P communication networks (for details on I2P, refer to the next subsection) are more user-friendly, but, on the other hand, such DNS systems limit the distribution and scalability of P2P networks. Considering routing mechanisms as more important for creative purposes in human-machine systems, user-friendly DNS addressing will be given less importance while conceptualizing a non-uniform network.

Now, differently from the BitTorrent, YaCy, and Freenet routing mechanisms introduced above, Tor's routing mechanism, introduced as “Onion routing,” is defined by the first node initiating a request wherein the digital information stream follows a path through several nodes to its destination (Goldschlag et al. 1996). Similarly to the routing in the prevailing Internet, this route may vary each time data packets are sent. However, the route will be hidden by encrypting or decrypting data packets several times upon arrival at the final destination. This is accomplished over a mix-net, a technique based on public key cryptography that allows the hiding of a route path traveled by data pieces. This technique was introduced by David L. Chaum in "Untraceable electronic mail, return addresses, and digital pseudonyms," where both the originating message M and its address A are encrypted with a key K within the layered structure: K1(R1, Ax), Kx(R0, M) -> Ax, R1(Kx(R0, M)) (Chaum 1981). In this way, Tor's node incrementally builds a chain or circuit of encrypted connections through other nodes in the network. The circuit is extended one hop at a time, and each node knows only the address of the previous node and the next node to which it is routing information. Thus, it is similar to the structure of an onion, which has a layered structure.

Although the routing mechanism of Tor is interesting, it was designed in order to hide information from surveillance and from unwanted destinations instead of looking for similar communication formats and patterns in nature. Therefore, comparing the routing mechanism of Tor and the Freenet network, Freenet becomes more attractive for conceptualizing artwork. First of all, Freenet, differently from Tor, does not have intermediary servers, and secondly, the routing mechanism in Freenet has a straightforward reference to a small world phenomenon, which, in this case, is considered a pattern in nature.

I2P Architecture

Yet another network for anonymous communication, I2P, shares many similarities with the Tor project, as it is designed for communication, implements hidden services, and uses encryption layers driven by proxy servers. Differently from Tor but similarly to Freenet, I2P was developed in Java and not C language as in the case of Tor. Parts of its code are released under different licenses (e.g. GPL, BSD, Cryptix, MIT), but most of it is assigned under the public domain, which refers to works whose intellectual property rights have expired or are not applicable (I2P 2013).

I2P also shares a terminology similar to Tor, introducing the file encryption system and its routing as "garlic routing" (ibid.). However, I2P has some differences as well; for example, Tor provides a centralized directory of the network and gathers and reports statistics, while I2P prefers a distributed node selection.

For routing purposes, I2P, like later BitTorrent architectures, has the implemented P2P storage and lookup system *Kademlia*, developed by Petar Maymounkov and David Mazieres (Maymounkov & Mazieres 2002). It routes queries and locates nodes using a XOR (exclusive or) lookup algorithm in order to define distances between the nodes. I2P nodes store reference information (IP address, UDP port, and Node ID) about each other to route query messages. When an I2P node receives a message (*ping, store, find node,* or *find value*) from another node, it updates contact information for the sender's node. For node lookups and searches, I2P nodes use a recursive algorithm which allows the result value to choose the closest node. In so doing, the routing system becomes similar to the Freenet algorithm and is considered interesting in building an evolving automata like project.

The I2P network is composed of I2P routers (client and server software) that relay encrypted garlic cloves and I2P users that transmit and receive such cloves to each other. It uses bundled encryption over a multi-proxy server and has a list of reliable host IPs, like Tor. The packets are bounced all over the network for everyone using I2P. Encryption bundled end-to-end allows a packet to only decrypt in the next hop as it passes through various nodes on its path. Nothing else is decrypted along its path, including the sender and recipient. Each I2P node or router in the network has an inbound and outbound tunnel or tunnels established and connected to other I2P gateway(s). Senders have no information about the path the message will take except for the gateway the senders have used to release the message. Differently from Tor, I2P does not have any entry or exit nodes, and data is encrypted end-to-end among nodes in the system (Fig. 12.).

Now, although sharing a similar routing mechanism as in Freenet, e. g. data packets recording distances between the nodes or recording only information about the next connection, I2P is still considered fragile in terms of self-organization, because it uses a DNS system similar to Tor and the other P2P systems introduced above. I2P, differently from Freenet, does not search for information using the encryption key, which was considered an interesting feature in machinic environments, where meaning is not necessarily known (compare, for example, the meaning of an unknown phrase as it is understood by a human and the meaning of an encrypted key as it is interpreted by a machine). In addition, the main I2P features, that is, scalability, routing, and storage, are not defined as precisely as they are defined in other similar systems – for example, Tor or Freenet.

Discussion

Scalability in P2P Networks

The analysis of the various P2P architectures above focused on historical notes alongside conceptual backgrounds and technical solutions including scalability, routing, storage, and encryption. All the systems were developed around 2000, and some of them, such as Tor, Freenet and YaCy, still continue to be developed.

Analysis of P2P systems has shown that those systems, which are built upon semi-hierarchical architecture (Tor, YaCy), are less scalable than the systems built upon non-hierarchical architectures (Freenet, I2P). The routing algorithms could also influence the accessibility of information stored in P2P networks.

My experiments have been mostly executed and compared using the YaCy search engine, Freenet storage system, and Tor communication environment. It has come up that, for example, YaCy is not designed to fully function over the IPv4 Internet layer that is currently implemented. While testing the system, the YaCy node with standard Network Address Translation (NAT) configuration was not reachable with a router that had a standard configuration provided by an Internet provider (Fig. 13.).

In contrast to YaCy, Freenet did not demonstrate shortages with standard firewall configuration and was easily scalable within the distributed network. Freenet, in contrast to the other networks analyzed, is non-hierarchical, whereas the other networks, including YaCy, Tor, and I2P, are better described as heterarchical while having features of layered hierarchical architecture. Thus, within the context of this research, Freenet is considered to have the most reliable architecture, possessing desirable features of scalability and self-organized processes within the non-uniform networks, which might demonstrate a certain level of creativity and still be attractive from an artistic point of view.

Notes on Routing Algorithms in P2P Systems

The quality of search results is most likely a major problem in all decentralized systems. Assuming that, within a post-digital territory, any system requires information exchange and implementation of search algorithms, different search results were compared between the hierarchical Google search engine and the decentralized P2P environments of the YaCy search engine, the Freenet storage system, and the Tor communication system, having a search feature among other features.

Freenet architecture, with its greedy routing algorithm, has shown a high level of scalability within its network. Despite its potential for self-organization, the system appears to have some deficiencies in architecture. First of all, it does not cover available information on the Internet and has a closed architecture within its own network. While executing a search command, the following results have been recorded: For the word “Microsoft” as of March 20th, 2011, Freenet provided 603 results, for the word “Apple,” 209 results, and for “Mindaugas,” just 1 result. Meanwhile, on April 9th, 2011, Google found about 3,920,000 results for “Mindaugas” and, for “Apple,” about 1,190,000,000 results. Secondly, Freenet has been shown to be very slow compared to Google. Freenet took up to five minutes to get results for the words “Microsoft,” “Apple,” and “Mindaugas,” while Google delivered results immediately.

Compared to Freenet, much better results were delivered by YaCy search engine in terms of speed and content. However, these results were incomparable to Google's results. For example, on April 9th, 2011, for the word “porn,” YaCy came up with 56,304 results, while its search for the word “Apple” resulted in 27,522. On the same day, Google output about 737,000,000 results for the word "porn," and, for the word “Apple,” gave about 1,190,000,000 results. Despite the huge differences, YaCy developers have optimistically assumed that "only one installation per 1000 users would probably be sufficient to completely replace centralized search portals" (YaCy 2013). Then again, despite increasing the number of users, the quality of searches would most likely remain incomparable.

P2P systems have also demonstrated weakness in uploading information. For example, on September 22nd, 2011, upload commands executed on Freenet required a few minutes from starting the upload, and the speed only reached 0.2 kb/s for uploading of one single file, whereas, when using file transfer protocol (FTP) for uploading files on WWW, the upload speed depends only on the provider's given upload rate and can be hundreds or even thousands of times faster compared to Freenet.

Even if the speed of various routing systems are not satisfying in relation to the prevailing Internet speed, the Freenet is considered to have more potential in routing information than, for example, Tor or I2P systems, because of several different advantages. First of all, the design of the Freenet's routing system is borrowed from nature, e.g. routing information as it would be routed in real life (see Milgram's concept of six degrees of separation as introduced in “The Small World Problem” (1967)). Secondly, Freenet does not have any traditional DNS system implemented, which might cause interruptions or a complete disfunction of the whole network. And finally, Freenet does not differentiate between its nodes like the other systems introduced, e.g. YaCy and Tor, which have different types of “middleman” machines building semi-hierarchical networks in such a way.

Storage in P2P Networks

Aside from weaknesses in routing information in P2P networks, storage of information is yet another weakness within P2P networks. If P2P engines based on file sharing (BitTorrent) solve this problem while not taking much care regarding the integrity of information within the overall system (separate files stored in separate folders in private computers), then P2P engines based on communication use distribute data across the network (e.g. Freenet, Tor, I2P). The only difference is the method of distribution. If, for example, Freenet stores and distributes files independently from the number of connected nodes, the Tor system would distribute files only across nodes set specifically for that purpose. Those nodes are configured in a way similar to most pervasive web servers, except that they mirror the stored data automatically instead of using “back-up” or “mirror” technology.

In addition, Tor may function more similarly to the usual and most pervasive servers/nodes, as it can integrate all possible software, including php scripting language and mysql relational databases, which, in the end, might be tunneled through encryption processes. Freenet instead uses its own storage architecture and simple html commands and is completely independent from usual software packages.

Despite the highlighted weaknesses in storage in P2P networks (slow access to data, lack of storage capacity), the networks still share an interesting feature, namely the use of NoSQL object-oriented databases allowing storage and the linking of objects to each other without altering the structure of the database, as would be in the case of relational databases such as MySQL. Furthermore, object-oriented databases are more suitable for storing objects with time-based characteristics such as audio, video, and graphs (think of, for example, MySQL databases used for storing huge binary files). Referring back to the post-digital territory described in the first chapter of this thesis, object-oriented databases in P2P networks could be more easily defined and described by using Deleuze and Guattari's terms *strata*, *rhizome*, and *mapping*. Moreover, the object-oriented approach is navigational, marked by pointers to the objects, whereas the relational approach is declarative and described by statements such as “join” or “select.” According to Katherine Hayles, object-oriented databases encourage a holistic and behavioral view of the world, whereas relational databases see the world as made up of atomized bits (Hayles 2012:193).

Databases based on DHTs might also have a hybrid shape. For example, Tor might use its hidden service database in accord with traditional MySQL databases and pervasive web servers, like Apache or Microsoft's IIS, which are usually installed to use databases with pointers to the locations of the binary files with different characteristics, including those that are time-based. Moreover, the traditional relational databases are able to store binary files in themselves, though, in this case, they become only digital data with no characteristics. Therefore, object-oriented databases such as DHT are considered within this research as having more potential to demonstrate storage capacity with life-like processes. And the noted weaknesses are seen merely as due to a lack of technical development.

Notes on Encryption Use in Computer Networks

As was pointed out in “Networks and Their Specifics” section, information encryption can be two-fold. On one hand, it may allow one to avoid surveillance (think of China's state-wide firewall or mass surveillance systems like PRISM), and, on the other hand, it may trace infringement on author's rights or foresee illegal activities (think of downloading copyrighted data or child pornography).

Encrypted information and distributed storage systems like Tor or Freenet have resulted in criticism and claims that they raise anarchy, suffer from a lack of accountability, and violate state laws. Although some scholars doubt the ability to be totally anonymous in P2P networks (Biddle et al. 2002), encrypting any kind of transferred information – whether a personal message or the source location of a message – usually leaves the author of the message unidentified and untraced. In polemics with people who inquire about child pornography, offensive content, or terrorism, Freenet's developers argue that “[w]hile most people wish that child pornography and terrorism did not exist, humanity should not be deprived of their freedom to communicate just because of how a very small number of people might use that freedom” (Freenet project 2013). Therefore, self-organized processes such as those demonstrated in P2P networks might come up with solutions which do not harm their environment. For example, authors' rights could be protected by using open-source strategies while society could control illegal activities.

In 1995, Timothy C. May argued that being able to encrypt messages in computer networks produces a different state of laws, an “absence of government”: “First, the 'anarchy' here is not the anarchy of popular conception: lawlessness, disorder, chaos, and 'anarchy.' […] Rather, the anarchy being spoken of here is the anarchy of 'absence of government'” (May 1994). In such a way, May proposes governance which is redirected to a self-organized society rather than a hierarchically structured government, even if elected democratically.

Leaving aside accountability and law issues, I should also note here that cryptographic methods could be highly valuable for authenticity purposes. Berners-Lee (1996) mentions the importance of encrypted and signed documents, as they might prove their own authenticity: “For machine reasoning over a global domain to be effective, machines must be able to verify the authenticity of assertions found on the web" (Berners-Lee 1996). The authenticity is done through the assignment of encrypted keys, which, if compared, could either prove or disprove assertions. Also, for example, Dorothy E. Denning (1996) argues that "cryptographic techniques, including methods of authentication and digital signatures, can protect against spoofing and message forgeries." Thus, it is important for machine driven non-uniform networks to become less vulnerable, as the machines could trace more highly valuable content in the networks or leave untouched encrypted information that does not belong to them.

Notes on Visualizing P2P Networks

Traditionally, network visualizations have hierarchical or semi-hierarchical representations that use tree-like graphs (Chen 2006). However, visualizing complex networks and self-organized systems such as P2P networks becomes more complicated because of their architecture and philosophy.

There are two criteria for visualizing complex networks: a) one based on topological or geographical properties and b) one based on dynamic properties. If topological properties are traced over IP addresses, within the dynamic properties, features such as transmitted packet size, time, and connections to other nodes are used. While the Internet and its unencrypted layers are based on the IP system, and while the physical network might be easily represented geographically, the visualization of encrypted and distributed networks remains complicated. Depending on the encryption structure, the use of geographical topology for networks like Tor, I2P, or Freenet would be limited, because of the methods used for the encryption. While, in these networks, the node behind the next node is not detectable to the first node, the visualized networks would be able to show only one neighbor node. On the other hand, knowing the physical location of a defined neighbor node, the possibility of mapping its physical location could be helpful for understanding the intensity of information flow in the network, the number of connections to and from the node, or the "swarming" of nodes.

Referring back to post-digital territory, visualization of P2P networks would be best done by using mapping methods as described by Deleuze and Guattari. In this case, through mapping, P2P networks could be better defined while connecting properties or elements of different natures, such as nodes and time, information flow, and routes within the network.

Potential for Creativity in P2P Networks

In the first chapter "Self-organization and the Post-digital," I introduced aesthetics of the post-digital territory, which marks the aesthetics of the posthuman era. The reader has been directed through the concepts of self-organization and non-hierarchical systems, which, in turn, appear to be a steering wheel for creative processes. It is assumed that evolving automata and interactive Turing machines might be creative and demonstrate a certain level of intelligence. Therefore, I have arrived at distributed networks, which, of the existing networks, have the least hierarchical features and have the potential to be creative.

Analysis of P2P systems in the second chapter brought me to the point where the Freenet storage system appeared to be the most interesting for further use within the artistic project developed alongside this research. Seeing Freenet's deficiencies and potential for improvement, I decided to develop a plugin system, which, alongside the installation of computers and visitors to the installation, would shape a non-uniform network wherein the human and machine in concert could become a Deleuzian rhizome, defining post-digital aesthetics.

Therefore, for the project, I propose using the Freenet storage and retrieval system as is, so the core software keeps up to date on the computers. In addition, I propose using Freenet Client Protocol, which bridges third party plugins with the core software. One of the third party plugins will integrate open source *jSite*, a software piece for uploading websites in the Freenet (*Freesites*). This plugin will need an additionally crafted software piece for downloading information from the Internet, which will enable rhizomatic connections between information packets of different natures. The second plugin will be crafted from scratch according to the visualization notes.

Annex I. Project: 0.30402944246776265

Description

The Installation titled *0.30402944246776265* was developed during 2013 and 2014 as an artistic project extending theoretical research on self-organization in non-uniform computer networks. It unfolds as a set of computers showing an interaction of elements between each other.

The installation uses *n* number of computers (or nodes) and software that enables data exchange among them. The viewer of the installation is allowed to move around and interact with computers, thus becoming part of the overall ensemble. The computers are located next to each other so the viewer can compare the animated graphs visible on the monitors.

In order to emphasize the diversity of the surrounding elements, a wide range of older and newer computers are used for the installation. The variety of computers encourages the viewer to consider the technology in our environment. Why does the installation use outdated computers? How outdated are the computers? And why computers and not, for example, TV screens? The use of older computers, first of all, can suggest rapidly aging technology and technical evolution, which should further raise questions as to what is next and where is technology leading us. Secondly, when these decades-old computers are compared to up-to-date tablets and smart phones, one could think, well, technology has become much smaller, much more user-friendly, more streamlined and therefore less accessible in terms of computer architecture. It follows that the near future suggests even more direct, seamless interaction with computers, and humanity will possibly merge with computers or even become computers, as predicted by futurist Ray Kurzweil in his book *The Singularity is Near* (2005). Thirdly, one usually interacts with computers directly. Although interaction with the computers is not precluded in this installation, the configuration suggests that the computers do not require further human input and they are operating independently.

The virtual environment shown on the computer screens suggests that something is happening between the installed machines. The animated graph on each screen is a visualization of the activity within the computer network. The graphics show, in real time, neighbor nodes and data traffic between them. As the location of each node in the graph is marked by a distinct color, it is possible to trace which node is represented on the graph and how data chunks are sent between the nodes. The graphics are simple, animated geometric forms that, on one hand, might deliver a message of computation concepts emerging from simple rules and, on the other hand, might indicate emerging creativity via simplified interactions between the different elements. The simplified computer screen animation might also refer to early computer graphics or science fiction aesthetics, when such aesthetics were relatively sophisticated to the cultural eye and proposed that, in the near future, we would exist in an environment where computers were as intelligent as humans.[66] In this respect, the viewer of the installation might consider comparing such aesthetics to contemporary 3D graphics, or otherwise the spacial representation of physical things,[67] and similarly to hardware aesthetics to try to shift him or herself back and forth in space-time.

66 Consider, for example, the Spacewar computer game from early 60s or George Lucas' “THX 1138” or “Star Wars” from early 70s.

67 Consider, for example, Steven Spielberg's “Minority Report” from the early 2000s.

Development

Conceptual and Technical Mappings

The practical part of the project was developed simultaneously with theoretical and technical aspects of the overall project. The initial idea for the project – to open up a space for the rethinking of the current integration of society and technology – has gone through different stages of the research including current discussions in media theory, aesthetic developments in post-digital arts, and self-organized concepts in computer networks. While presenting a self-organized, a non-uniform network of humans and computers that mediate the integration of society and technology, I aim to refer to A-life concepts (for a more detailed discourse, please refer to subsections “Aesthetics of Artificial Life and Artificial Intelligence” and “Artificial Life Territory” in the first chapter) and attempt to put together artificial systems that behave in concert with living organisms.

The construction of such environment was still an abstraction that had to unfold as a clean idea and a simple form able to mediate the idea. The starting point was comprised of a number of artistic, theoretical, scientific, and technical works that stimulated the emergence of the new artwork.

Among the artistic artworks were *Mailia* (2006), my own artwork, *Artificial Paradises* by Martin Howse and Jonathan Kemp (2001-2008), and *Programmed Machines* by Maurizio Bolognini (1988-present), all of which were introduced in detail in the first section of the first chapter of this paper. All of these works embody a certain level of artificial creativity in and of themselves.

The theoretical part mainly unfolded through Deleuze's and Guattari's (1980) concepts of the rhizome, strata, and mapping, as introduced in the second section of the first chapter, “Post-digital territory.” Additionally, this work was influenced strongly by Katherine Hayles' (1999, 2012) posthumanist ideas. The scientific input came through Ludwig von Bertalanffy's (1968) systems thinking, the heterarchical constructs of

Warren McCulloch (1945), the analysis of self-organization in the works of Ross Ashby (1947, 1957), and the idea of artificial life constructed by Christopher Langton (1988). My considerations of these scientific ideas are laid out in the section “Life between man and machine.” The technical stimulus was the fundamental idea of computer networks, particularly the Freenet storage system and its search algorithm, which comes from the idea of Milgram's (1967) six degrees of separation. A detailed analysis of technical architectures is provided in the second chapter of this paper.

During the initial phase of this research, the intersection of the inspirations above generated a number of ideas, ranging from computer generated content to life-like simulations, computable universes, society as networks, artificial neural structures, singularity constructs, etc. All of these ideas were supposed to be revealed through a self-organized, non-uniform artificial network, where they were to be laid out like *rhizomes* or *strata* in the final version of *0.30402944246776265*. Here, every rhizome or stratum could be taken as a starting point for deconstructing the artwork.

The self-organized, non-uniform artificial network had to take a physical form, which was imagined as a computer network operating as an indivisible evolving automata. Having plenty of options to proceed with computer networks and routing systems (for further details, see the first section of the second chapter, “Computer networks and routing systems”), open source products where considered as most suitable for experimentation. First of all, open source products are more easily accessible and secondly, by creating a new and free product, one can make a contribution to society. This is assumed to create a broader spread of the creative ideas proposed in this research.

On the technical side, the idea was grounded in software that demonstrated a certain level of creativity, functioning within the computer networks – especially those without hierarchical architecture (or server-client dependences) – and independent from computer operating systems. The challenges were laid out with the following criteria, which had to define an imaginable, indivisible system:

- distributed storage system with scalability feature;
- distributed search engine with access to information available worldwide;
- system downloading and storing information for further use.

The proposed framework is comprised of anonymous and decentralized systems and networks that use an open source philosophy and products built with the Java programming language. The newly crafted software architecture was intended to become independent from commercial and power structures. The proposed open source software was imagined to be built upon a decentralized Internet, including distributed search engine and distributed databases that update themselves in real time. A distributed structure for the software was needed in order for it to adapt itself within the dynamic networked architectures. Such a model was meant to pave the way for a self-organized, non-uniform artificial system, which was, in turn, meant to embody something that could be described as intelligent; this is what the artwork was supposed to communicate to the audience. Such a system was to have something that could be described as demiurgic, which, in Platonic schools of philosophy, is defined as a figure responsible for the maintenance of the physical universe. Similar concepts are introduced in the aforementioned work by Martin Howse and Jonathan Kemp, *Artificial Paradises,* and in Deleuze's and Guattari's term *chaosmos*.

The search for available open source systems, their comparison, and their analysis (see Chapter Two) has shown that P2P network systems reflect similar philosophical aspects. These systems are mainly built with Java programming language and are used for communication-oriented applications, such as maintaining discussion groups or distributing information within the networks. The Freenet storage system and the YaCy search engine showed enough features to start with, although these systems alone did not complete the imagined software architecture. More research revealed that the Freenet uses a routing algorithm that is built upon the small-world concept introduced by Milgram (see “Freenet Routing Algorithm” subsection in “Search and Storage Methods of Distributed P2P Systems” of the second chapter) and could be a good example for approaching computer networks as social networks. On the other hand, the YaCy search algorithm was found to be useful for its ability to locate information in different network systems. Therefore, in the initial phase of the work, the decision was made to merge systems using a self-crafted software. The Freenet storage system and the YaCy search engine, when integrated into a single architecture, were intended to result in an unexpected non-uniform network model, providing further research material for cultural activists, open source developers, and P2P experts.

The Freenet storage system was taken as a basis for proposed software architecture because it had the required storage function and an integrated routing algorithm that are able to distribute, store, and retrieve information. As mentioned above, the Freenet storage system also has an interface, called the Freenet Client Protocol, which enables Freenet interaction with third-party software. This interface was imagined to be suitable for the input content in order to trigger automated computer functions and had to be used for the full integration of both P2P systems described: the Freenet had to be used to store and distribute search results provided by the YaCy system.

Every node running the proposed software was defined as having unique databases, updated in real time according to the data transmitted through the network. Every computer was supposed to be able to categorize and share chunks of data with neighboring computers. Such architecture had the potential to be interesting for emerging new shapes within a virtual environment, as well as for the conceptual part of the artwork unfolding metaphorically as, for example, an artificial neural network or a dynamic social system. If one believes the Freenet developers (see “Freenet routing algorithm” subsection within the second chapter), these new shapes in Freenet databases, over a certain period of time, would start to be distinguished by certain information clusters (e.g. education, science, leisure, sports). It was foreseen that these shapes within the installation would form into independent clusters of similar nodes analogous to social communities or the brain structures responsible for different actions (e.g. vision, motor control, emotions). Further experiments and analysis of information flow within computer networks could be instrumentalized for comparison to living systems or self-organizing environments in non living systems (e.g. snowflakes, turbulence). Along such a framework, my hypotheses for possible self-organization in non-uniform networks emerged. This was followed by the idea that such a system could provoke the viewer of the installation to consider an artificial environment intelligent and creative.

During the first phase of the art installation, the Freenet storage system and the YaCy search engine were merged in order to test the functionality of the software architecture. These merged softwares opened up space for further development of the artistic work, on one hand, comprised of the up-to-date search results provided by the YaCy search system and, on the other hand, reshaping databases on the Freenet side. However, the technical side of the software architecture seemed a bit clumsy, so YaCy was eliminated from the future developments of the artistic installation.

Defining the Visual Framework

The second phase of the development focused on the visualization of the merged Freenet storage system. While testing the visual part, various concepts of artificial life were analyzed, which naturally suggested that the proposed software architecture bear some features of life. The software developed and the physical installation showing interacting computers was introduced for the first time in the group exhibition "In the Graveyards of Interdisciplinarity," which took place in the spaces of JMVAC and Vilnius Gates in Vilnius in 2013. The computers were arranged in a circle together with chairs that were supposed to be used by the audience (Fig. 15).

While working on data-routing mechanisms within the networks, two solutions for visualizing the imaginary system architecture came up: a) the use of sniffing tools such as *Jpcap* and visualization of information based on packet descriptions[68] and b) the use of the Freenet search algorithm. The latter option appeared more challenging, as it suggested hacking into the code. On the other hand, it was potentially useful for Freenet developers, who did not yet have a visual tool for following data flow within the Freenet network. It was also interesting to test the assumed clustering of information, as introduced above in the second chapter (see "Freenet Routing Algorithm" subsection). The clustering of the information was meant to bring the artwork a step further towards artificial, self-organized environments – a key concept for the developed artwork.

In the "Mapping P2P networks" subsection of the second chapter, it has already been noted that the graphic representation of P2P networks is a very complicated task because of the use of data encryption and hidden data routes within networks. Furthermore, representation of interactions between different types of elements, such as computers, audiences, and data-flow mechanisms in non-uniform networks, raise

68 This method was used by Alex Galloway in *CarnivoreP5*.

questions as to how much and what information should be provided to the viewer. Therefore, a set of visualization techniques, including those described by Chaomei Chen, have been analyzed.[69] Although they often include diverse, interconnected elements, such as those found in citation graphs (e.g. interconnected geographical places, authors, topics), those systems end up in tree-like hierarchical representation and do not seem to suit the distributed and dynamic context of the Freenet storage system or YaCy search engine software architectures. This inadequacy necessitated further research into the representation of the interactions between elements of different natures in the artistic installation.

Concerning the visual part of the installation, two further visualization methods were analyzed: mapping technique and graphs. Mapping technique seemed to be appropriate for non-uniform environments, first of all because of the non-representative conceptual framework that often intersects with the ideas of Deleuze and Guattari (for more details, see the “Mapping” subsection of the first chapter). On the other hand, graphs are used to represent simple activities between interacting elements and could be considered within different environments for real-time mapping purposes. Graphs were also considered useful for developing the visual part of the installation because of their simplified graphical representation unfolding as edges and vertices, or in other words, lines and dots (for more details, see the same “Mapping” subsection). Having a simplified element and a line connecting it to some other element opens up a space for real-time mapping either by hand or by computer. Hand-rendered graphs as, for example, those by Mark Lombardi, could be transferred to the computer and vice versa.

The simplified graphics also dictate the aesthetics of the forms. One could also consider

69 Forms and techniques for visualizing information, as described by Katy Börner, Chaomei Chen et al., were proposed as being divided into: hyperbolic trees depicting hierarchical structures such as file directories or websites; fisheye views emphasizing focus at the center and shrinking objects in relation to their distance to the center of focus; fractal views used for depicting huge hierarchical systems; semantic zoom used for visualizing large quantities of independently authored pieces of information; zoomable user interfaces that place documents at absolute positions within a large zoomable space (Börner, Chen et al. 2003). Additionally, Chaomei Chen (2006) distinguished information-visualization systems in a simplified manner: cone trees, hyperbolic views, tree maps, and fisheye views. Along with the visualization systems, Chen also distinguished possible applications for techniques: trees (or hierarchies; cone tree, a cluster-based visualization cat-a-cone, botanical tree), networks, spatial information exploration, focus + context, visualizing search results, web and online communities, and commercial systems (2006). A slightly different split of information-visualization types appears in the analysis of Jeffrey Heer et al.: tree maps, cone trees, perspective walls, star field displays, hyperbolic trees, DOI trees, space trees (Heer 2005).

Mark Lombardi's graphs as visually similar to the graphs of Oscar Sandberg (2005) that were used to represent the topology of the Freenet. Moreover, *US Corporate Interlock (Banks, Oil, and Aircraft)* by Mark Lombardi, for example, is very similar to the topology of the Freenet (compare Fig. 16. top and bottom), while Lombardi's *Ben Barnes* is very similar to the Freenet routing sketch (compare Fig. 17. top and bottom). While the physical distance between the corporations in the US or nodes in a Freenet storage system does not necessarily play a big role, it could be represented simply by connections between them. Lombardi also composes his corporations on a sheet of paper, whereas the chosen representation of Freenet nodes around a circle has its logics hidden behind the location of Freenet nodes in the network (Fig. 16 bottom).[70]

The visual setup of the installation and placement of computers in the space, as in Lombardi's compositions, guides the logic of the physical set up within the space. For virtual representation, an additional square was added in order to distinguish the location of each node within the rest of the network. All together, these three virtual elements – circle, dot, and line – seemed to be enough to map the proposed network virtually, and to metaphorically start mapping the territory as in Deleuze's and Guattari's chaosmos, where, for example, a circle might mean strata, and the dots – machines and lines – might mean rhizomes. While the audience is mixed up among the computers in the physical space, the simultaneous self-organization of nodes happens in the virtual space.

The title of the installation is yet another component of the visual framework. While launching the Freenet for the first time, it generated the initial location of the first node, an "address" – in this case, the number 0.30402944246776265.[71] This number, even if

70 The designers of the Freenet chose a different concept to "locate" a node in the network. Instead of using IP numbers, they conceptualized the network, allocating to the computers in the network a decimal number from 0 to 1, where 1 is the same location as 0, thus suggesting in such a way visualizing the network as a circle. For data packets to travel from one node to the other, a major role is played by the speed of the Internet connection and the number of the node data packets needed to pass in order to reach the target node. The designers of the Freenet came up with the solution of using a greedy algorithm (for a more detailed description, see the Chapter Two section "Freenet storage system") in order to access the target node faster while using the swapping method with the other node.

71 The figure 0.30402944246776265 is a unique number and the address of one computer within the network. If the computer is used in the traditional Opennet Freenet network, this number and the computer's virtual location is not supposed to change. Therefore, the square on the screen representing the computer will not move to another location on the circle representing the network. Freenet, however, also works in the Darknet Freenet mode, operating via social rules comprised of connected known computers, which, in turn, link to other known computers exactly as acquaintances

no longer used practically in the installations, became a symbolic number representing *the beginning*. At the same time, this number represents something inaccessible, a number with a quality of randomness that only a computer would generate. The use of a number likened to an “irrational number” also suggests that it is not natural to normal human counting. Along the lines of a machine operating independently of humans, this number is symbolically charged with information incomprehensible to human thinking but natural for computing machines. Proposing such a visual representation, the viewer of the installation is invited to look for “his/her” topological coordinate in the network. And yet, the virtual relocation of the computers in the installation subverts this location-based number at the same time.

connect within a social network. In this mode, the computer's location and number will therein change in response to its interaction with other computers in the system. Therefore, the square representing the computer will move across the circle similarly to a person moving within a social network.

Concept

The installation *0.30402944246776265* offers an imagined social network where computers (nodes) represent people (other kinds of nodes), and network cables represent the ties connecting them. Within the visual component brought to the monitor screens, the bubbles represent active nodes, while the lines represent activity among them. The square represents the node itself.

The installation suggests the possible creativity of the machine and the notion that humanity is approaching a state of artificial intelligence or post-humanity. The viewer is provoked to consider the place of the machine in society, as well as the ways and strategies in which a computing machine is developed. These issues lead to further questions of transparency in merged computer and human environments, surveillance mechanisms used in artificial networks, and the decision-making and ethics of the machine.

Installations

As mentioned within the “Defining the Visual Framework” subsection, the installation was shown for the first time in the group exhibition “In the Graveyards of Interdisciplinarity” in the spaces of JMVAC and Vilnius Gates in Vilnius in 2013. The installation was comprised of three chairs and three computers with Freenet and its visualization plugin installed. The leading text introduced differences between Freenet Opennet and Freenet Darknet modes, proposing that in Darknet mode, the number used to name the installation and the figure representing the self-location would change over the duration of interaction between the nodes. Keeping in mind Milgram's concept of six degrees of separation, the installation in Vilnius proposed the possibility of nodes interacting in a way similar to that in social behavior. Therefore, the installation itself was introduced and conceptualized as a social environment and proposed a life-like situation (Fig. 15).

Solo installations at OKK/Raum 29 in Berlin (Fig. 18) and Malonioji 6 (Fig. 19) in Vilnius in 2014, for the first time, fully implemented Darknet Freenet mode and was arranged on twelve computers while eliminating the chairs provided in the first installation. The computers installed within the space claimed less importance and were placed in order to fill up physical space. At the same time, focus was placed on monitors showing the interaction between the computers (nodes). The Darknet Freenet mode, which here was installed for the first time, enabled the virtual relocation of computers, thus reducing the importance of the computer location registered in the title of the installation, except as the previously mentioned starting point of the mapping territory and its non-human nature.

The first development of the installation and the proposed life-like environment was not convincing because the installation did not simulate life directly. Therefore, a further concept extending to distributed neural networks was considered and introduced.

The study anticipated that the Darknet Freenet would potentially function as a neural network, triggering neighborhood neurons to move chunks of information back and forth. It was assumed that, within the time *t*, the nodes connected and sharing similar information in the Darknet Freenet would get closer to each other, forming clusters of information similar to those stored in the cortices of the brain. The expected outcome was the proposition that the movement of digital information in the Darknet Freenet be likened to information spread throughout the brain.

Such a framework enabled the installation to be accelerated with yet another plugin that would be able to collect information from the outside. A new Automaton plugin was designed in order to collect information from the Internet and to upload it to the Freenet. Although the Automaton made automated functions, the question remained how and what information would be selected, if that information could be randomized in such a setting, and, if yes, at what level. The bid was made for human interaction. In order to trigger automated functionality (in a neural network this would mean "firing" neuron), a manual search would need to be performed. Therefore, all this software architecture brought yet another aspect to the installation: the idea of an artificially intelligent system.

The two individual exhibitions were followed by an installation at the international festival for new media, Pixxelpoint in 2014 in Nova Gorica, Slovenia. Although the installation only used three computers, the work was finally complete with fully functional Visualization and Automaton plugins, which do not require human input.

The conceptual part was slightly changed once again because the artificial neural network used to describe the installation was too ambitious and not obvious enough. The conceptual part was simplified to the "communication" between computers, proposing a post-human state. Having only the reference to a social environment and interaction among people, the concept brought the viewer closer to the idea of a system and the interactivity of elements within it. Although simplified, the installation included all elements defined at the beginning of the research, including the updating of information based on the previously available information in the databases, the interaction with the external world (in this case, the Internet), and the exchange of information with other similar elements (in this case, computers charged with similar software architecture).

Installation instructions

Instructions for the Physical Space

There are no particular requirements for the space where the installation of the artwork has to be presented, except that the monitors displaying the visualization of the software have to be traced by the viewers to the installation. The minimal requirements for the installation are three computers, say A, B, and C, so they show connectivity dynamics within the ensemble: A -> B -> C -> B -> C -> B -> A, etc. These dynamics may already demonstrate a feature of (social) self-organization or simply map transferred data chunks within the virtual environment. It is suggested that the computers installed in the space are visually different, so the idea of the specificity or uniqueness of interaction between elements is present.

Technical Requirements for the Computers

There are no specific requirements for the computers, and the software architecture should run on computers ready to install Freenet software. The Freenet software is designed to run on Windows, Linux, or Mac OS X. The designed plugins were tested on Windows XP, Linux Ubuntu 10, and Mac OS X 10.7 with the latest version of the Java Runtime Environment additionally installed. The processor speed of the tested computers ranged from 800 MHz to 3GHz, and the RAM ranged from 256MB to 4GB. Slow computers took time and patience to configure, while faster computers were quick to configure.

The minimum disk space used for installing and running the software architecture was 4GB. All the computers were connected to the same local network either through a LAN cable or wireless connection. The end performance shown was similar, except that the slower computers crashed more often.

Software Installation and Configuration

The installation of the software is supposed to have a Darknet Freenet mode. In order to install it, the software has to be installed in several steps. First, the computers have to be connected to the local network, ideally with a DHCP mode, so the computers choose their IP numbers from the given range of IPs. Secondly, all the computers have to run Freenet software, and thirdly, the two plugins provided – the Visualization and the Automaton plugins – have to be loaded.

The default configuration of the Freenet will work in Opennet Freenet mode, thus showing the dynamics of connected nodes at a certain level: the self-node, depicted as a square, will not change its location. In order to switch the Freenet nodes to Darknet Freenet mode, the neighborhood nodes have to be added to every single node. This is done through the menu option “add friends” (Fig. 20). If there are more than three computers within the installation, it is not necessary to add all the neighborhood nodes to each node.

As soon as the Freenet knows the neighborhood computers, it is necessary to switch the security mode of the Freenet to "high" (Fig. 21). This would mean that the Freenet is entering “Darknet” mode. Within this mode, the visualization should start to demonstrate a jumping square along the circle.

Loading of the Freenet plugins is done through the same Freenet interface, following the options “Configuration” and then “Plugins” (Fig. 22). The Visualization and Automaton plugins can be downloaded from the project's website at http://www.triple-double-u.com/0.30402944246776265.

Technical Description

The computers within the installation run different operational systems, thus becoming as independent from corporations providing different computing platforms as possible.

The Freenet storage system is used as a basis for the software architecture. Additionally, two plugins – the Visualization and Automaton plugins – were developed in order to give the viewer the possibility of a self-organized environment within a virtual environment. These two plugins are separated by their functionality and, in concert with the Freenet, build a non-uniform network system. The plugins, as is the Freenet itself, are developed in a Java virtual environment and are installable via the Freenet user interface. Although not a necessity, it is supposed that the Freenet storage system is configured to run in a Darknet Freenet mode.

The Visualization plugin shows a simple graph depicting the Freenet storage system. The graph consists of a circle upon which bubbles and a square are placed. The square represents the computer itself, which, if the network is configured and running the Freenet, is linked to appearing and disappearing bubbles on the circle. The appearance and disappearance of the bubbles on the circle represent active connections to the computer through which data packets are sent or received. Within the Darknet Freenet mode, the location of the computer changes, and so changes the location of the square on the circle. The changing mechanism introduces the Darknet Freenet swapping mode, which shows that a computer has found information on the neighbor computer and has relocated (for more details on the functionality of the Freenet, refer to Chapter Two).

In addition to the Freenet network visualization concept, a spectrum color scheme was used in order to distinguish depicted nodes more easily while viewing the installation. The spectrum used also adds more variety to the installation than if the nodes were depicted in monochrome.

The Automaton plugin enables the software to run independently from direct human interaction, thus excluding the human factor from the installation. The Automaton is built upon *jSite*, an open source software package for uploading information onto the Freenet storage system. *jSite* was tweaked in such a way that it would upload given information with no additional human interaction with the program. In addition, it was tuned up with functions that supply the software with content uploaded without interruption. The Automaton plugin uses the Bing search engine as an initial world wide web source for input information and provides the Freenet storage system with that information. The interaction between the world wide web and the Freenet extends the functionality of the Freenet, thus suggesting interaction between different elements within a non-uniform network.

Visualization Plugin Classes and Functions

Source code and plugin are available at https://github.com/mi-ga/visualization

Sample code

Example #1: Initiate plugin and draw the graph (vPlugin.java)

[...]

Constructor

```
public class vPlugin extends JFrame implements FredPlugin {
```

// Set up the visualization frame so that it extends from a JFrame; every Freenet plugin needs FredPlugin class to get the PluginRespirator

[...]

“vPlugin” Class methods

```
public void terminate()
```

// The method called in order to break the loop and terminate the plugin

```
public void runPlugin(PluginRespirator pr)
```

// Event Handler.

```
public void paint(Graphics g)
```

// Method for handler update while drawing graph

```
private void drawBack()
```

// Method to check if there is a graphic context

```
private void drawPoint(Graphics graphics, PeerNode peerNode)
```

// Method to draw nodes based on the information and activity

```
public void line(int x, int y, int x2, int y2, Color color)
```

// Method to draw connection of the nodes based on the information and activity

[...]

“vPlugin” Class members

```
this.setAlwaysOnTop(true);
```

// This member keeps the image always above other programs. Options are: "true" or "false."

```
this.setSize(new Dimension(320, 240));
```

// This member defines the dimensions of the initial window.

```
setVisible(true);
```

// This member defines the visibility of the window.

```
while (goon)
```

// This statement is automatically called each time a new packet arrives.

```
System.err.println("---->: " + (new Date()));
```

// Member to mark a control timer in the console

```
Node node = pr.getNode();
```

// Variable to get the node information from Freenet over the plugin respirator

```
LocationManager ln = node.getLocationManager();
```

// Variable to get a location object (see Freenet documentation)

```
if (ln != null)
```

// Statement to check if there is information

```
String s = ln.toString();
```

// Member to transform to readable information

```
s += "_loc:_" + ln.getLocation();
```

// Creates information string for output when it is in use

```
this.myLoc = ln.getLocation();
```

// Gets the location of the node

```
PeerNode[] p = node.getConnectedPeers();
```

// Gets the connected nodes

```
if (p != null)
```

// Statement to check if there is a connection

```
if (p.length > 0)
```

// Statement to check if there is information in that connection

```
drawBack();
```

// Member to draw/overpaint with a little transparency

```
int offset = 3;
```

// Location, inBytes, outBytes

```
for (int i = 0; i < p.length; i++)
```

// This statement is automatically called until there is a connection between nodes

```
drawPoint(buf.getGraphics(), p[i]);
```

// Member for drawing the points and information

```
paint(this.getGraphics());
```

// Member for displaying graphics

```
Thread.sleep(1000);
```

// Set the scan of new connections to 1 second

```
if(this.buf == null || oldS != getSize().width)
```

// Statement for graphic context updater on dragging and refreshing the graph

```
Color clearColor = new Color(220, 0, 0);
```

// Slowly fade out of the graph

```
g2.fillRect(0, 0, this.buf.getWidth(), this.buf.getHeight());
```

// Overpaint graph

```
graphics.fillRect(mLocx - 3, mLocy - 3, 8, 8);
```

// Draws a position of the node

Automaton Plugin Classes and Functions

Source code and plugin are available at https://github.com/mi-ga/automaton

The plugin is based on *jSite*. Its main class, the Main.java, is manipulated in order to automate its own functionality and implement new automaton functions. Additional classes: automate.java, CopyDirectory.java, findNewUrls.java, and aPlugin.java. The automaton searches for the words in bing.com, downloads the result, stores them in the jSiteSites folder in the home directory of the node, and uploads to the Freenet. After uploading to the Freenet, the process starts anew.

Sample code

Example #2: Initiate plugin and implement jSite file manager (aPlugin.java)

[...]

Constructor

```
public class aPlugin implements FredPlugin
```

//Start class for the Freenet Automaton plugin

[...]

"aPlugin" Class methods

```
public void runPlugin(PluginRespirator pr)
```

//Implements the *jSite* file manager into the Freenet storage system.

```
public void terminate()
```

//The method called in order to break the loop and terminate the plugin

```
public static void main(String[] args)
```

//Main method of the class in order to start executing the plugin

[...]

Example #3: Manipulate files (CopyDirectory.java)

[...]

"CopyDirectory" Class methods

```
public static void main(String[] args)
```

//Main method of the class

```
public static void copyFolder(File src, File dest)
```

//Copies temporary directory with content from the downloaded website to a new location

```
public static boolean deleteDirectory(File directory)
```

//Deletes temporary directory

[...]

Example #4: Searches for content at bing.com and stores info on the node (findNewUrls.java)

[...]

"findNewUrls" Class methods

```
static void createNewSearch() throws IOException
```

//Searches bing.com for locally saved words; if words do not exist, creates a string of five random characters, then creates wordBuffer.txt while, where stores new words

```
public static void searchHtml(String toSearch) throws IOException
```

//Searches for the new websites that match the word searched at bing.com

```
private static void downloadHtml_and_createFolder() throws
UnsupportedEncodingException, IOException
```

//Downloads the website and stores it in newly created temporary folder

```
public static void writeToFile(String Words)
```

//Saves random words in wordBuffer.txt for future searches

```
private static void createFolder(String urlStr, String content) throws
IOException
```

//Creates temporary folder in which to store files

```
private static String createRandomString(int I)
```

//Creates random string of characters to be searched at bing.com

[...]

“findNewUrls” Class members

```
static Vector<String> urls = new Vector<String>();
```

//Creates a vector for newly existing urls

```
static Vector<String> usedW = new Vector<String>();
```

//Function to avoid some word conflict

```
reader = new BufferedReader(new FileReader(home + "/jSiteSites/" +
"wordBuffer.txt"));
```

//Opens wordBuffer.txt file to read words; if words do not exist, creates the file in the home directory

```
while ((line = reader.readLine()) != null)
```

//Reading the wordBuffer.txt

```
System.out.println(ww);
```

//Outputs on the console the words that exist in the file wordBuffer.txt

```
if ("".equals(ww))
```

//If the string is empty, creates a string of five random characters

```
String[] parts = ww.split("\\s");
```

//Splits the string with spaces

```
String str = parts[(int) (parts.length * Math.random())];
```

//Takes one word to be searched at bing.com

```
for (int i = 0; i < parts.length; i++)
```

//Writes used words in an array to avoid multiple uploads

```
catch (FileNotFoundException ex)
```

//If there are any problems, creates a new string and starts a search anew

```
reader = new BufferedReader(new InputStreamReader(url.openStream(),
"UTF-8"));
```

//Reads content of the remote URL

```
Logger.getLogger(findNewUrls.class.getName()).log(Level.SEVERE, null,
ex);
```

//Downloads the content

```
Pattern p = Pattern.compile("<ol id=\"b_results\">(.*?)</ol>");
p = Pattern.compile("<li class=\"b_algo\"><h2>(.*?)</h2>");
p = Pattern.compile("<a (.*?)</a>");
```

[...]

//bing.com site specific parsing to get the urls

```
for (int i = 0; i < splitArray.length; i++)
```

//Statement to filter the words from existing words

```
while (urls.size() > 0)
```

//Statement to pick the url from the url collection and to see if its content is long enough to store in the Freenet

```
if (content.length() >= 100)
```

//Statement to proceed with updating manipulated jSite folder structure

```
urlStr = urlStr.replaceAll("[^a-zA-Z]+", "");
```

//The URLs must be sanitized to use them as folder names

```
FileWriter fstream = new FileWriter(home + "/jSiteSites/uploadFiles/"
+ urlStr + "/index.html", true);
```

//Writes downloaded content to a new index.html file

Conclusion

The artistic installation *0.30402944246776265* has gone through different phases of development, the software architecture and concept behind it changing slightly as it progressed. Over time, the inspiration for the installation oscillated between several ideas: the idea of life-like situations, the possibility of an artificially intelligent system with reference to neural networks, and the artificial social network. The main idea – to open up a space for the rethinking of the current integration of society and technology – has been preserved. While presenting a self-organized, intelligent system that suggests a state of post-humanity, I refer to the current discussions in media theory that focus on the impact of technology on society.

In the installation, the viewer enters and is excluded from the exchange between the computers. Yet, the setup allows the viewer to project their own place in the social network onto this configuration. It is not just hypothetical participation, but is also activated by walking into the room and experiencing the piece. Although the artwork has many complex layers of ideas and strata behind it, the final simplified concept of *0.30402944246776265* leads the viewer to potentially read the installation as an artificial social environment. From this perspective, I argue that, if developed similarly to social networks, computer networks would have more potential for merging with society.

At the technical level, the installation provides a visualization of the Freenet storage system that functions in accordance with the social system defined by Milgram as the six degrees of separation between people. In the Freenet, a given node cannot trace any node that is behind the next node (see the Chapter Two section "Freenet Storage System" for details). Moreover, within a social system, one person does not normally know the friends of an anonymous person. Thus, the parallel of computer networks to social networks is made. Seeing obsolete computers installed in a space and being confronted with the notion of rapidly aging technologies, the viewer of the installation could engage with ideas about the future. By following the movement of data chunks, the viewer is expected to get at least the idea of an artificial system being able to demonstrate a certain level of intelligence within the computer network.

Overall, the art piece highlights discourse on the impact of technology on society and questions the ethical values of future societies. Although my combined artistic and written work does not provide an explicit solution to be integrated into future societies, it questions situations that are currently being discussed among futurologists, technicians, artists, and media theoreticians, thus making a contribution to and augmenting the larger discussion of post-digital creativity in human-machine systems.

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Glossary

Data. Data within this thesis is referred to as piece of unorganized information that has yet to be processed in order to become organized information.

Information. The term information in this work is used as defined by Ronaldo Vigo (2013), i.e. as a message, bearing in itself a certain context, meaning and complexity and not the level of uncertainty as defined by Claude Shannon (1948). While using the term, I consider information of different types, depending on the context – for example, for a biologist, information could be a pattern stored in some gene, for a physicist, information could be a quantum, and, for a computer scientist, information could be a set of symbols. Cells in the cellular automata patterns are also considered to bear information of a certain type.

Communication. In an interactive environment, the proposed information has overcome some information carrier in order to reach stimuli-response behavior, which, in turn, is considered communication. That could either be a signal sent from a nonbiological molecule to a biological cell, a digital message sent from one computer node to another, or a vocal interaction between two humans. The communication between the information source and the destination overcomes some noise source, as outlined in Shannon's general communication system (Shannon, 1948). As a consequence, information reaches the destination with some loss of information, which is important for the processes evolving.

Evolution. In this work, evolution is considered as a content-oriented or qualitative change over time through self-reproduction, self-organization, and communication processes.

Node. In this work, the term node means computer or any kind of machine that is able to compute and exchange information with some other machine of a similar nature or environment, challenging stimuli-response behavior. In this work, I do not make any distinction between a node of organic or nonorganic nature.

Network. Network is considered a set of nodes of a similar nature connected to each other, like computers or people. The proposed network is capable of communication between nodes.

List of Abbreviations

A-life, Artificial life

AI, Artificial Intelligence

CCC, Computer Chaos Club

CHK, Content-Hash Keys

CPU, Central processing unit

DHT, Distributed Hashed Tables

DNA, Deoxyribonucleic acid

DNS, Domain Name System

DREAM, Distributed Resource Evolutionary Algorithm Machine

DRM, Distributed Resource Machine

FCP, Freenet Client Protocol

FCPv2, Freenet Client Protocol, second version

FNP, Freenet Node Protocol

FProxy, Freenet proxy

GNU, General Public License

GPS, Global Positioning System

HTML, HyperText Markup Language

I2P, Invisible Internet Project

IANA, Internet Assigned Numbers Authority

ICANN, the Internet Corporation for Assigned Names and Numbers

IP, Internet Protocol

IPv4, Internet Protocol version 4

IPv6, Internet Protocol version 6

IRC, Internet Relay Chat

JANet, Joint Academic network

NAT, Network address translation

P2P, Peer-to-Peer

RAM, Random-access memory

RNA, Ribonucleic acid

RWI, Reverse Word Index

SHA-1, Secure Hash Algorithm, version 1

SMS, Short Message Service

SSK, Signed-Subspace Keys

TCP, Transmission Control Protocol

TCP/IP, Internet Protocol Suite

Tor, The Onion Routing project

TTL, time to live

UDP, User Datagram Protocol

URL, uniform resource locator

USK, Updateable Subspace Keys

UTF-8, 8-bit Universal Character Set Transformation Format

VPN, Virtual Private Network

WAN, Wide Area Network

WWW, World Wide Web

Figures

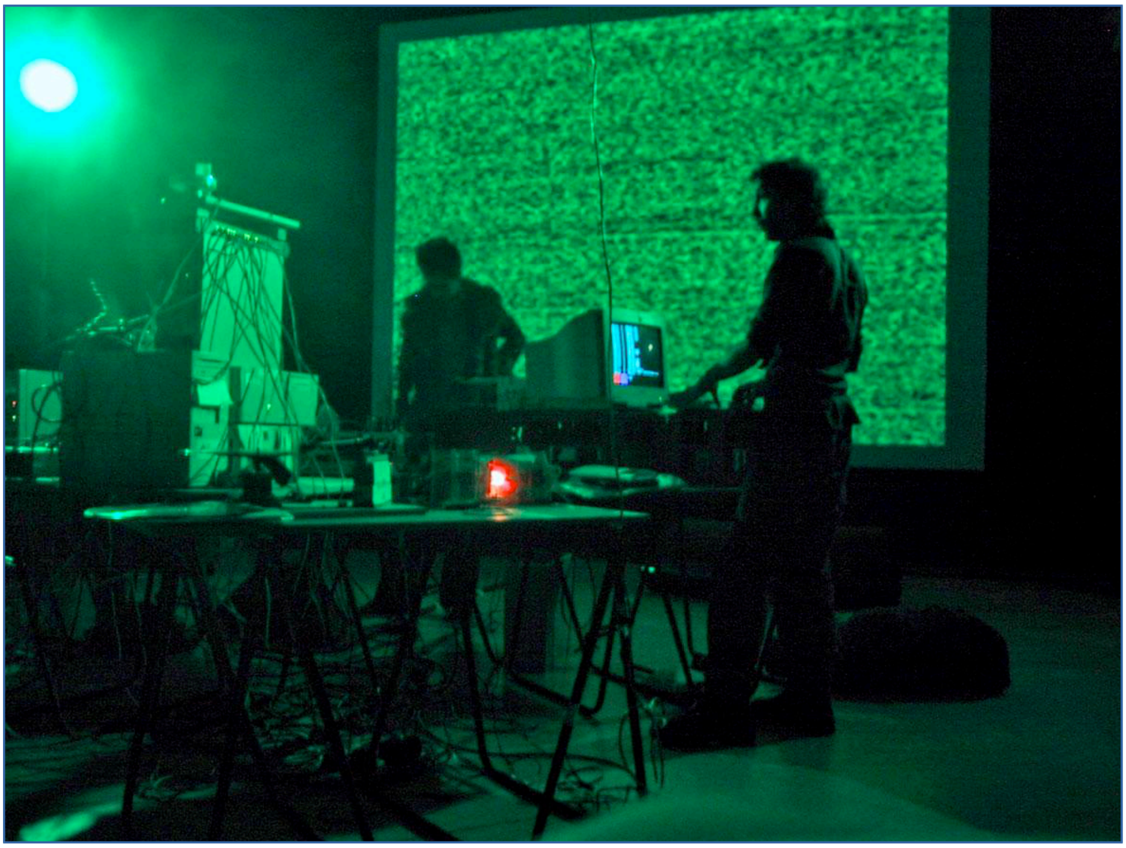


Fig. 1. *Artificial Paradises* of Martin Howse and Jonathan Kemp during Electrohype festival in Copenhagen in 2002.[72]

72 Available at: http://www.electrohype.org/2010/pressbilder/artificial_2002.jpg (Accessed: 31 May 2015).

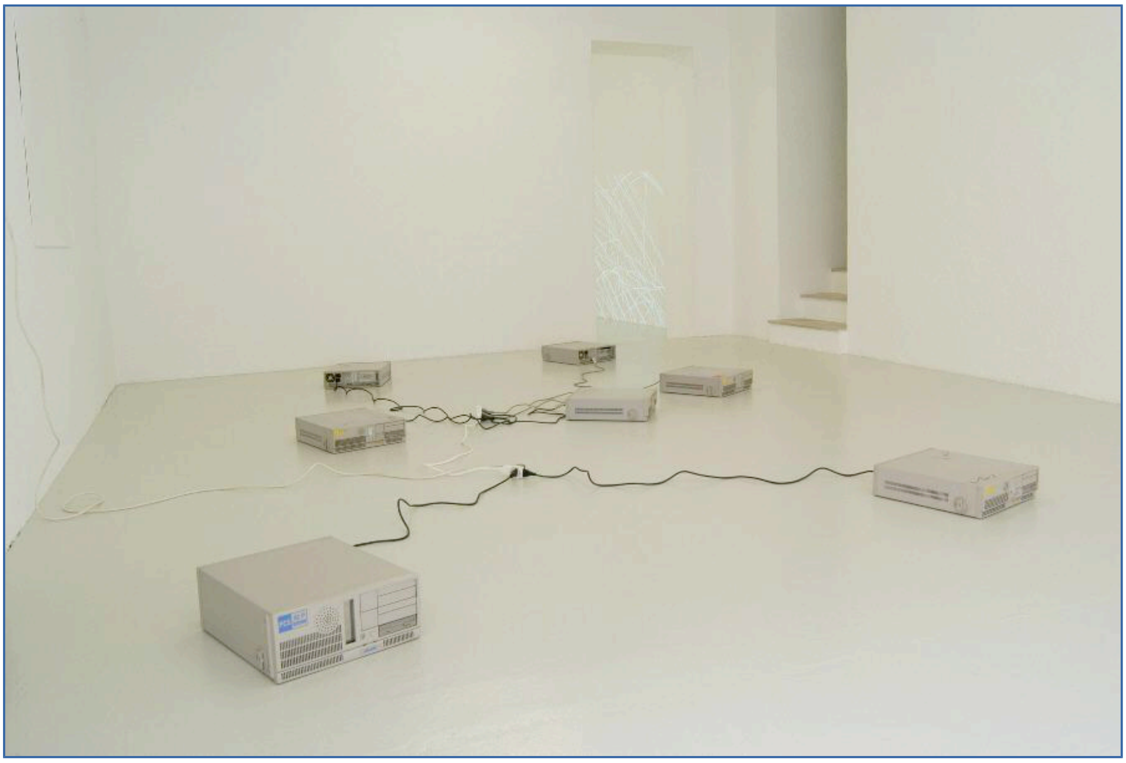


Fig. 2. Bolognini. *Programmed Machines*; Sealed Computers series. CACTicino Center of Contemporary Art, Switzerland, 2003.[73]

73 Available at: http://www.bolognini.org/foto/printversions.htm (Accessed: 31 May 2015).

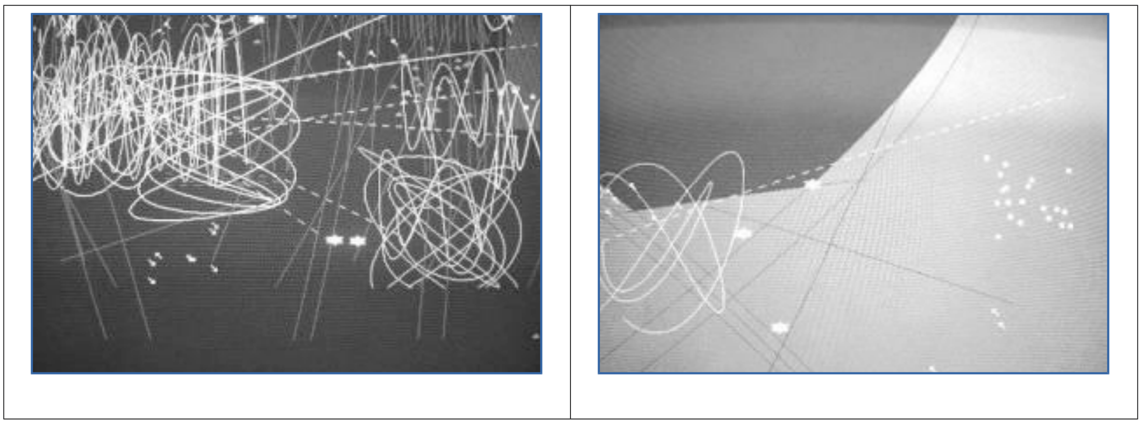


Fig. 3. Bolognini. *Programmed Machines. Atlas 2*, 2001-2004. The images produced through codes modified in Bangalore.[74]

74 Available at: http://www.generativeart.com/on/cic/papersGA2004/b9.htm (Accessed: 31 May 2015).

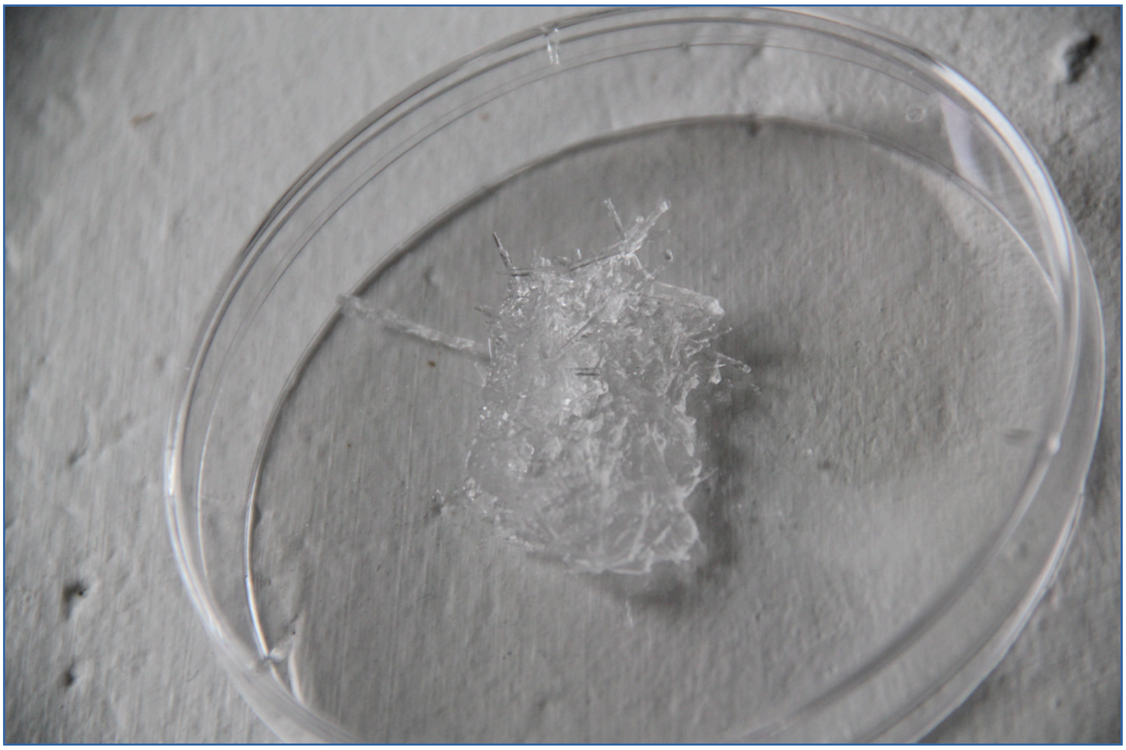


Fig. 4. Mindaugas Gapsevicius. *A Piece of "Livable,"* 2014. Chemicals, water, objects. In science, a crystal is considered to be a non-living system. Despite its inorganic nature, it can demonstrate life-like processes, including growth. During the experiment of growing crystals, I researched the phenomenon of salts (sodium chloride and magnesium sulfate) that altered their structure over time and interacted with their environment. With the result, I question the uniqueness of organic life on Earth and propose that the concept of life be reconsidered.

Fig. 5. Conway's *Game of Life*. Screen shot taken from the pattern generated with *Golly* for mac OS X v2.5.

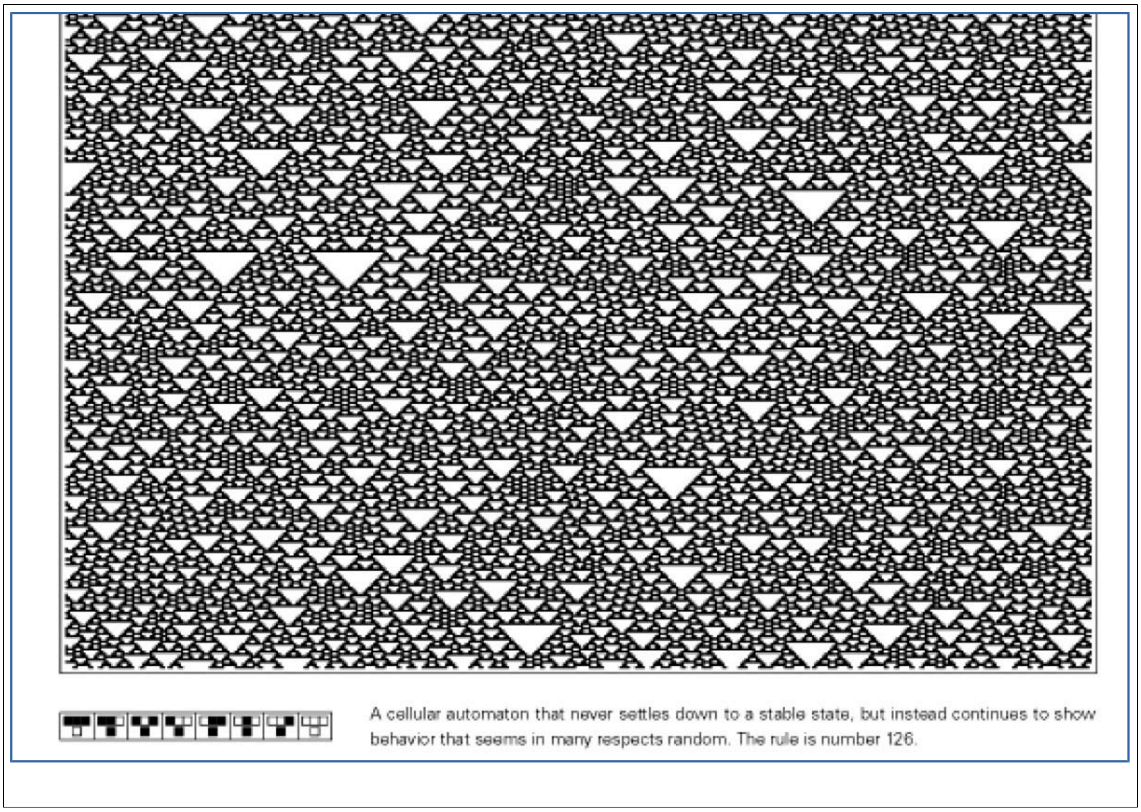


Fig. 6. Wolfram's cellular automata rule 126 (Wolfram 2002).

Fig. 7. Cone shell.[75]

75 Available at: http://en.wikipedia.org/wiki/Conus (Accessed: 31 May 2015).

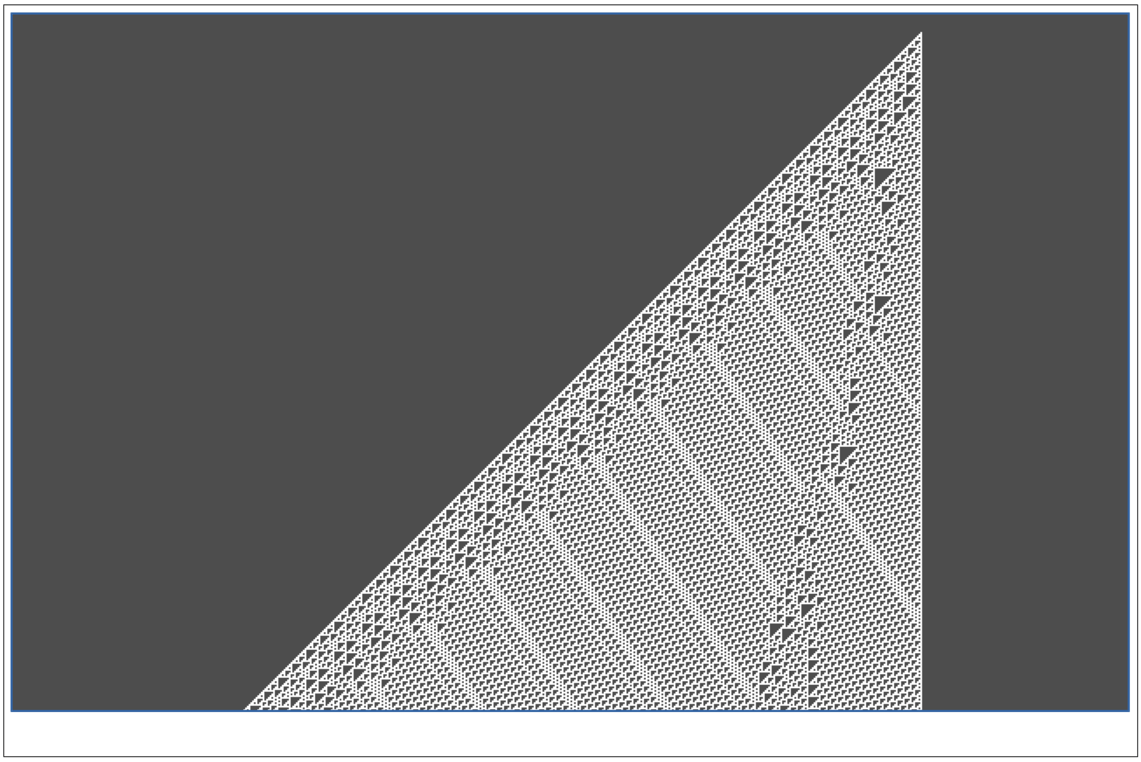


Fig. 8. Pattern of elementary cellular automata rule 110, generated with Golly for mac os x v2.5.

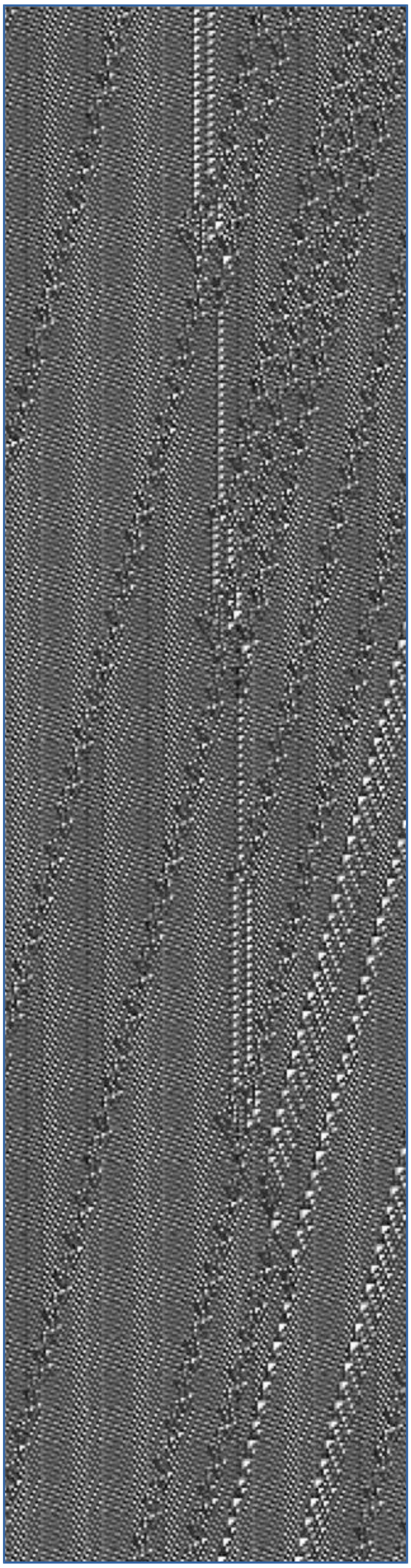


Fig. 9. Emulated example of a cyclic tag system in rule 110 in 3,200 evolution steps (Wolfram 2002:685).

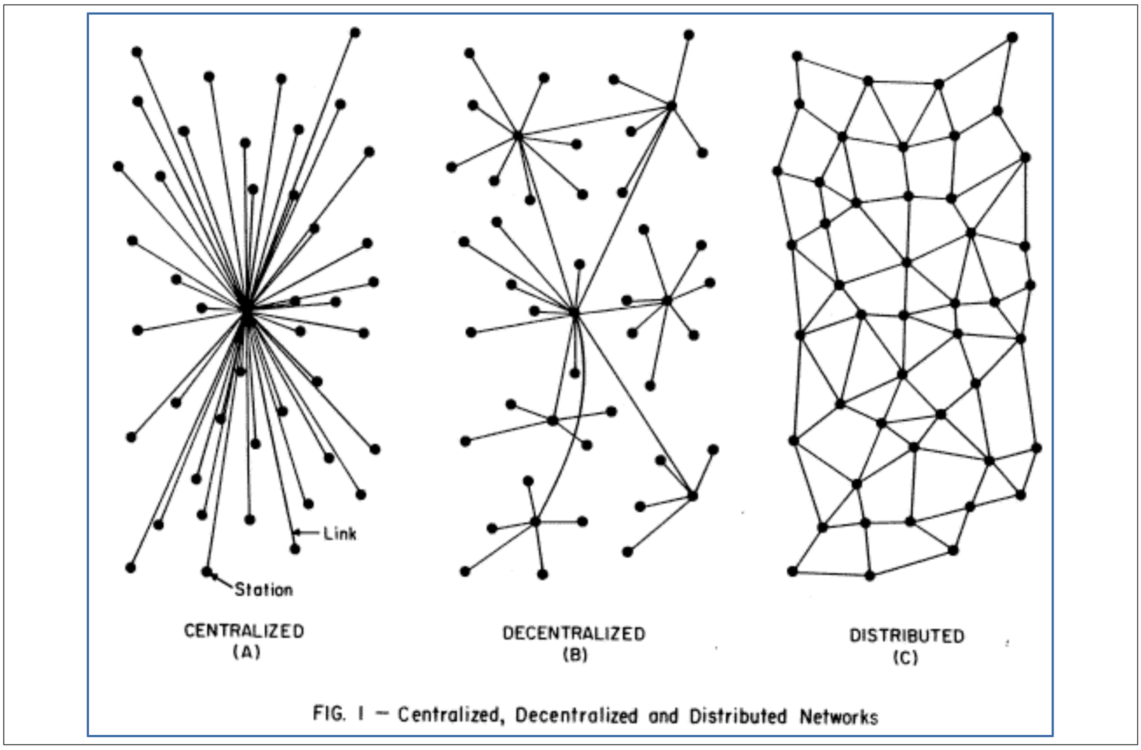


Fig. 10. Centralized, decentralized, and distributed networks.[76]

76 Available at: http://en.wikinoticia.com/Technology/general-technology/73667-why-is-it-possible-to-disable-the-internet (Accessed: 31 May 2015).

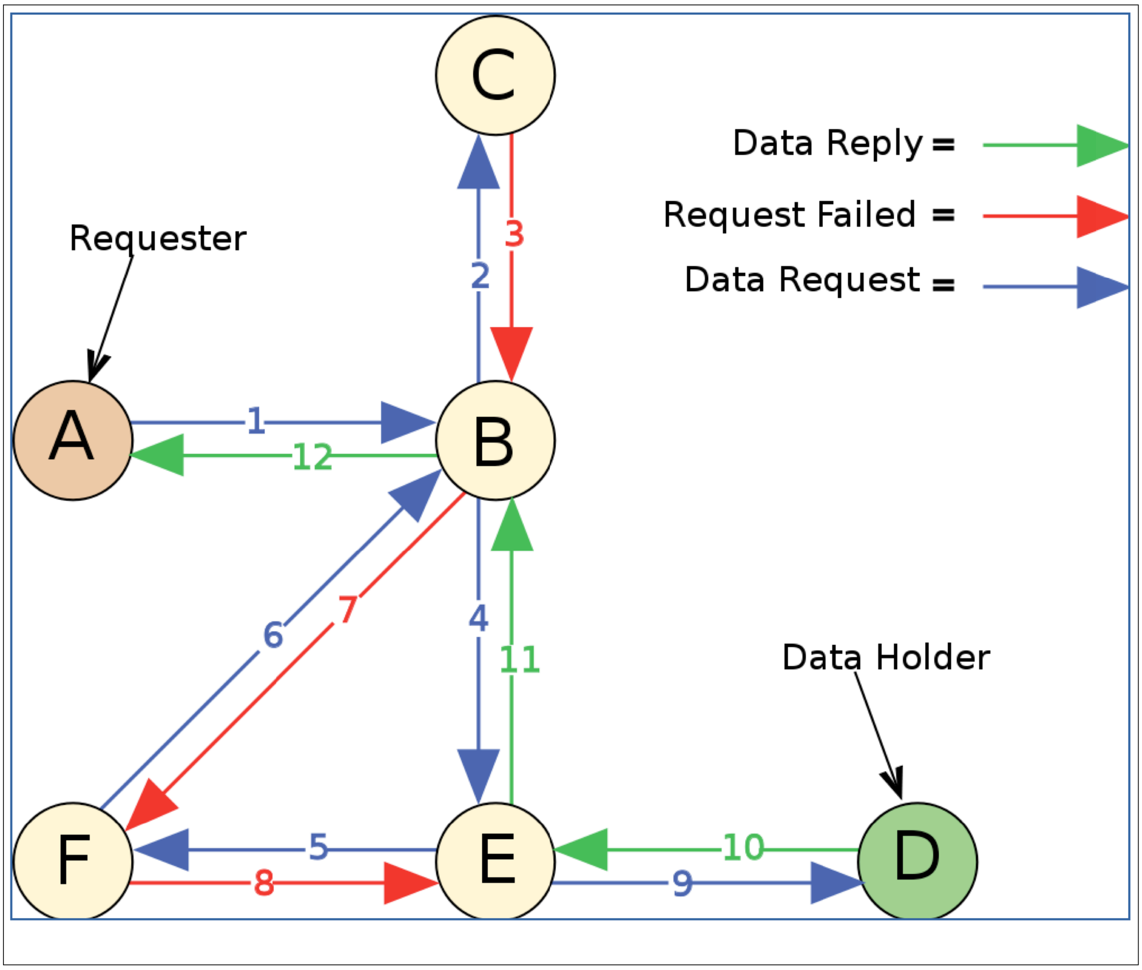


Fig. 11. The request moves through the network from node to node, backing out of a dead-end (Step 3) and a loop (Step 7) before locating the desired file.[77]

77 Available at: http://en.wikipedia.org/wiki/Freenet (Accessed: 31 May 2015).

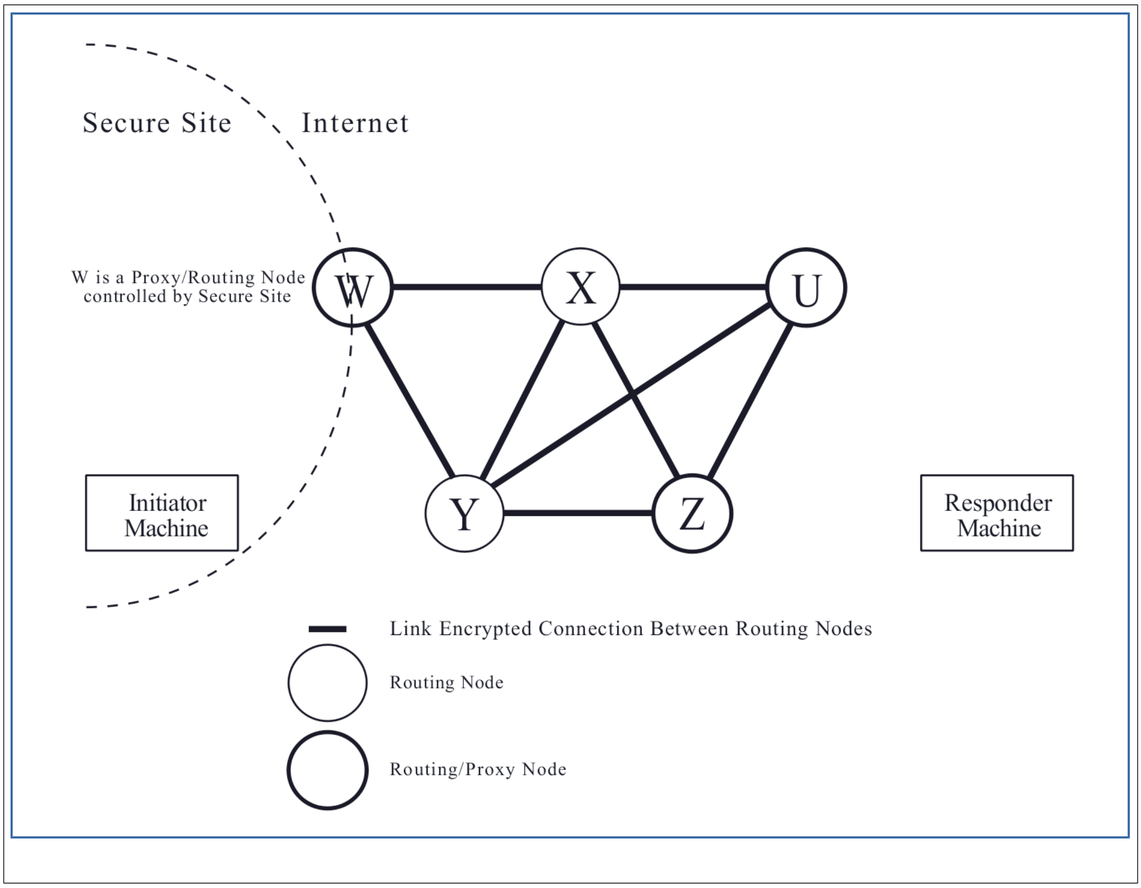


Fig. 12. Onion Routing. “Hiding Routing Information” (Goldschlag et al. 1996).

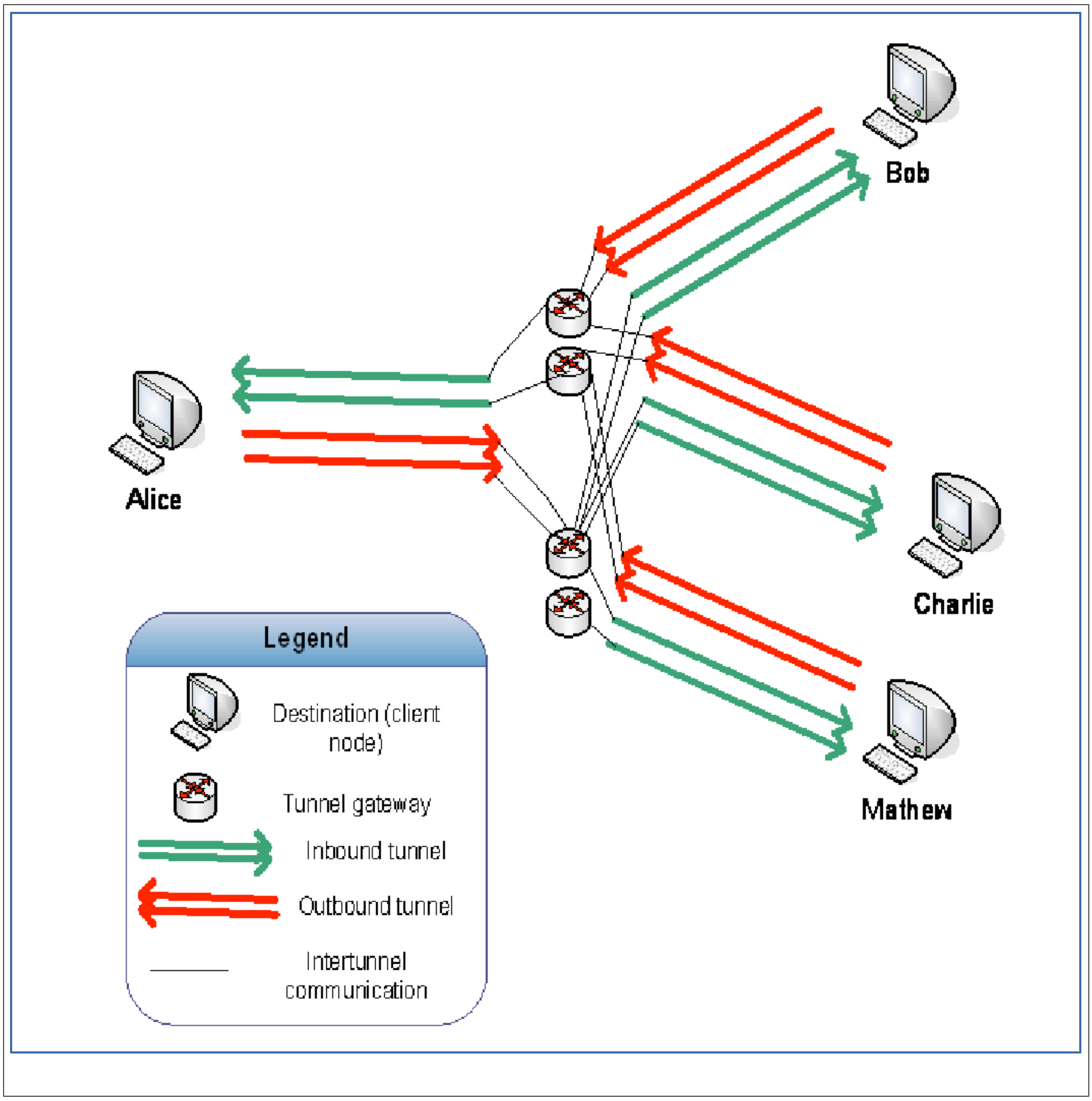


Fig. 12. Onion Routing. “Hiding Routing Information” (Goldschlag et al. 1996).

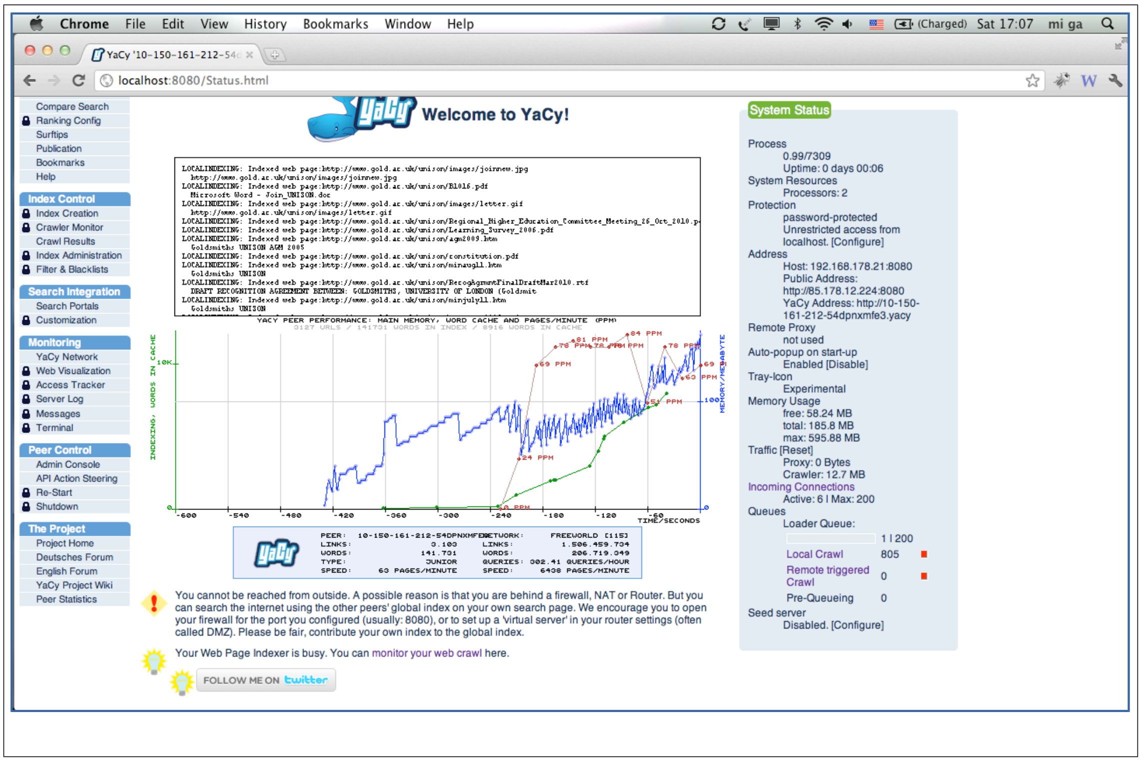
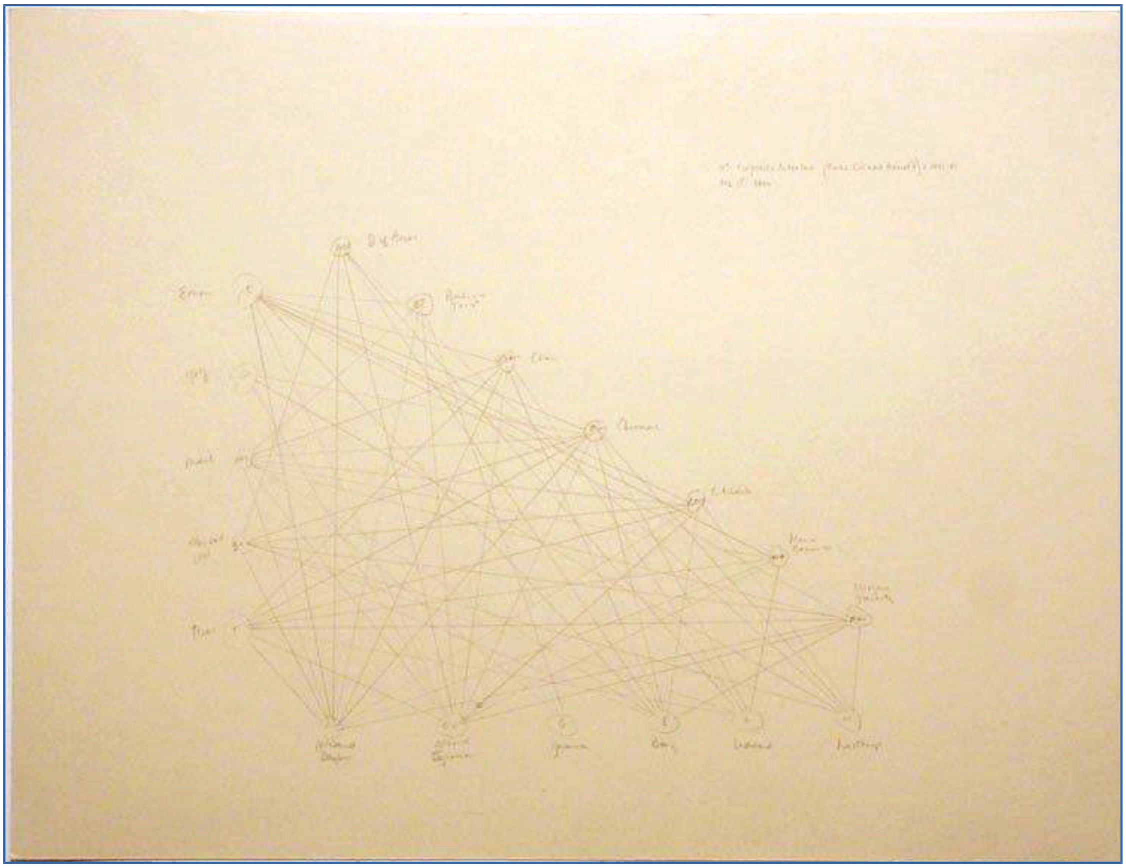


Fig. 14. “You cannot be reached from outside,” states YaCy on its status site. *Fritz!* router used. Test executed on October 29th, 2011.

Fig. 15. Installation in "In the Graveyards of Interdisciplinarity," JMVAC and Vilnius Gates in Vilnius, 2013.



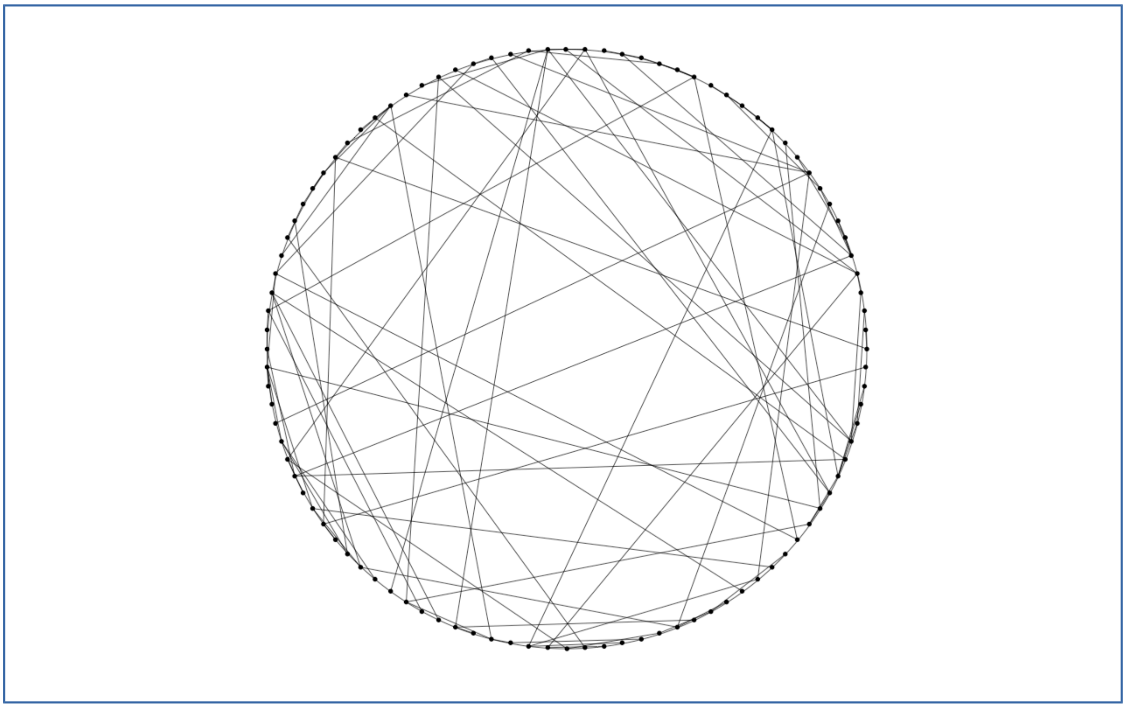
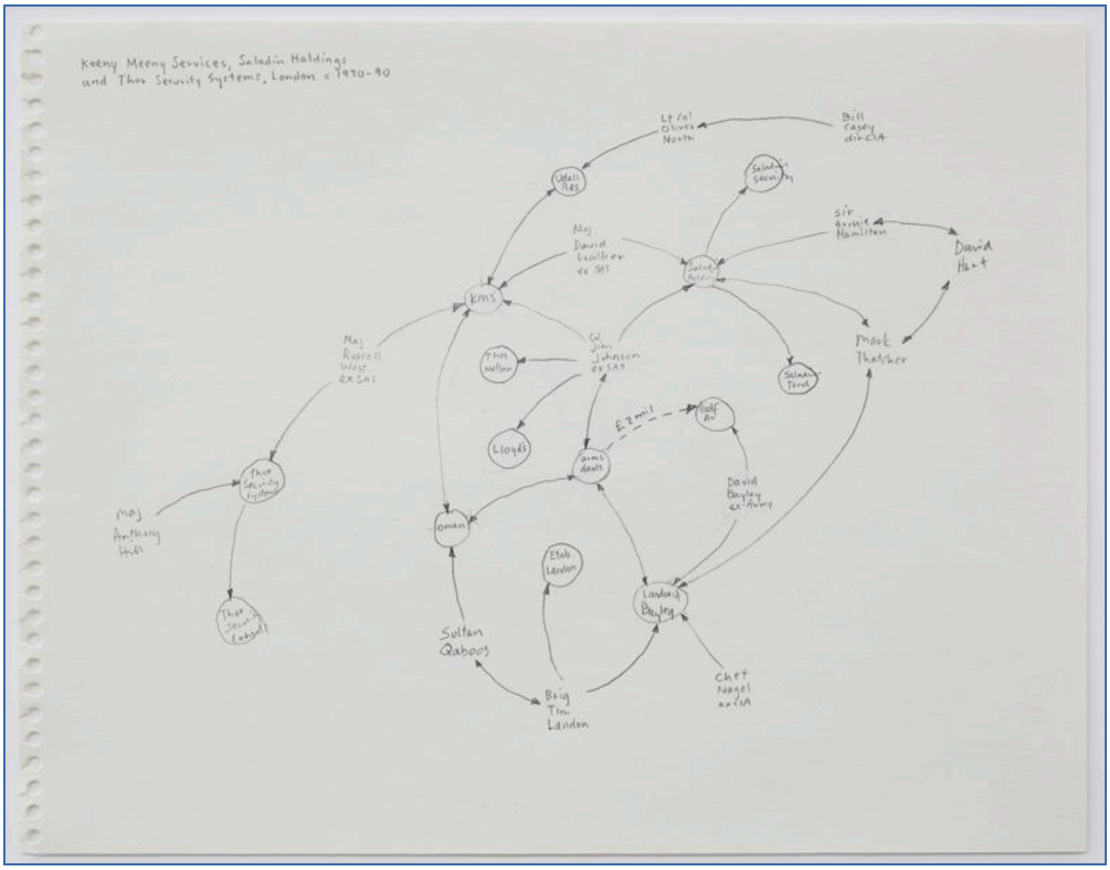


Fig. 16. Top: Mark Lombardi. US Corporate Interlock, c. 1971-81.[78] Bottom: Freenet shortcut graph (Sandberg 2005).

78 Available at: http://www.pierogi2000.com/artists/mark-lombardi (Accessed 31 May 2015).



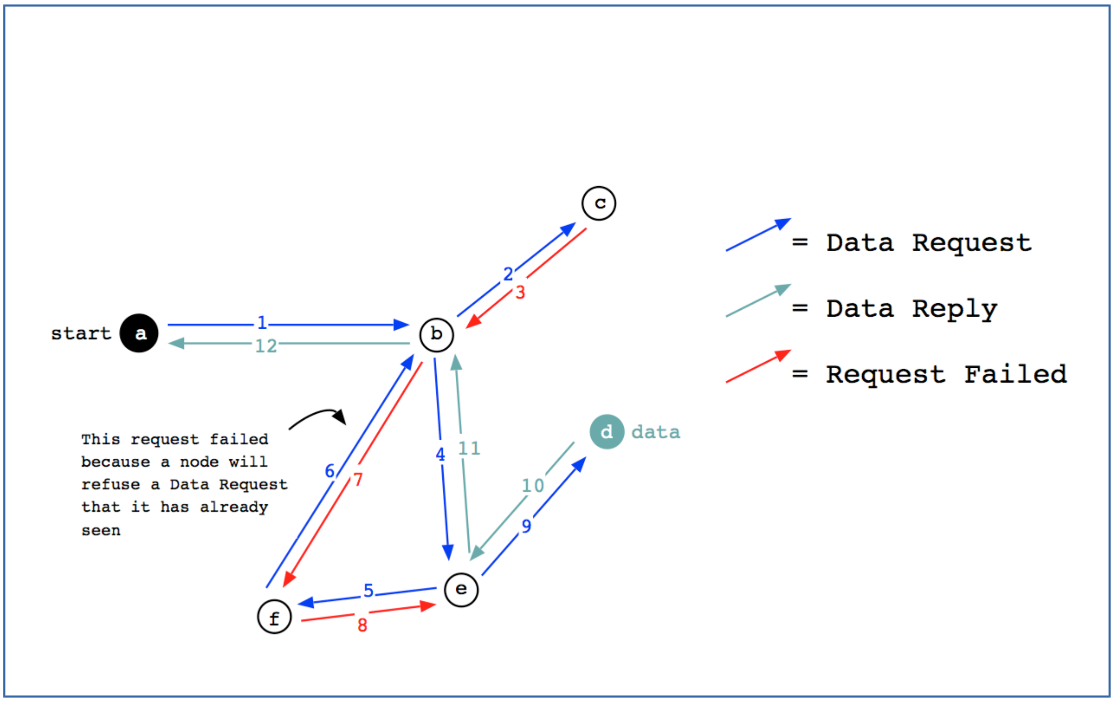


Fig. 17. Top: Mark Lombardi. Ben Barnes, c. 1968-72.[79] Bottom: Freenet routing (Clarke 1999).

79 Available at: http://www.pierogi2000.com/artists/mark-lombardi (Accessed 31 May 2015).

Fig. 18. Mindaugas Gapsevicius, *0.30402944246776265*. Installation at OKK/Raum 29 in Berlin, 2014.

Fig. 19. Mindaugas Gapsevicius, *0.30402944246776265*. Installation at Malonioji 6 in Vilnius in 2014.

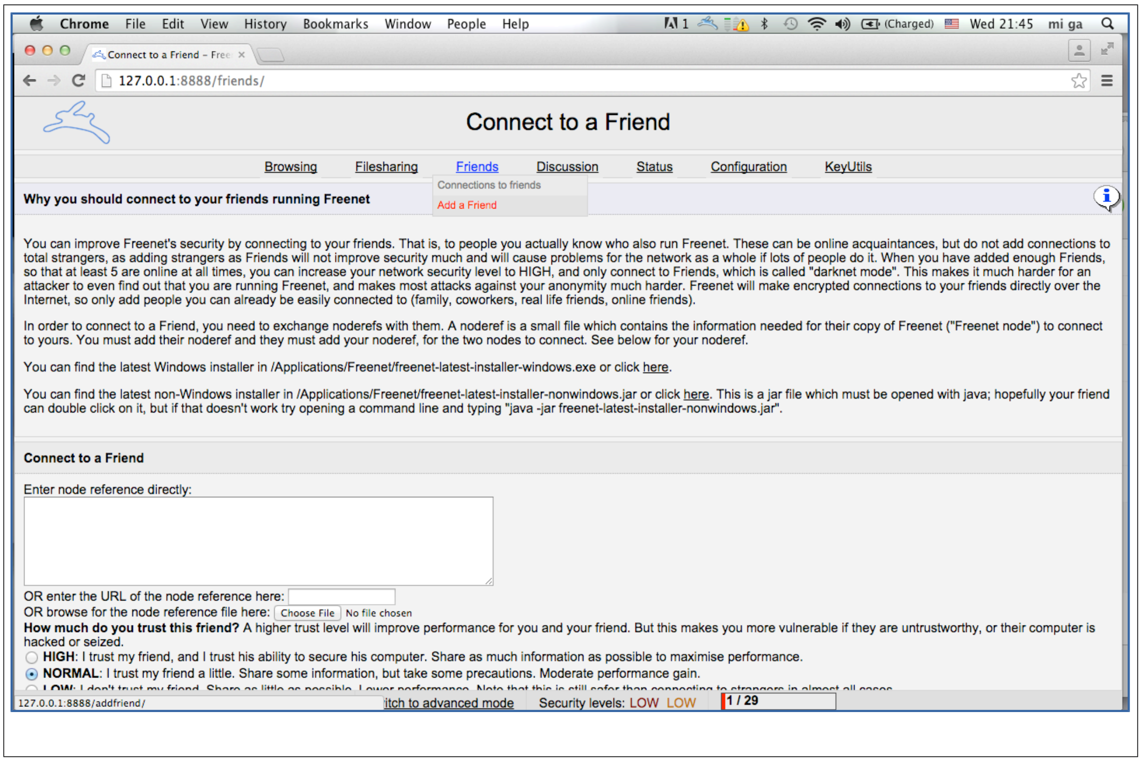


Fig. 20. Freenet interface to add friends. Screen shot.

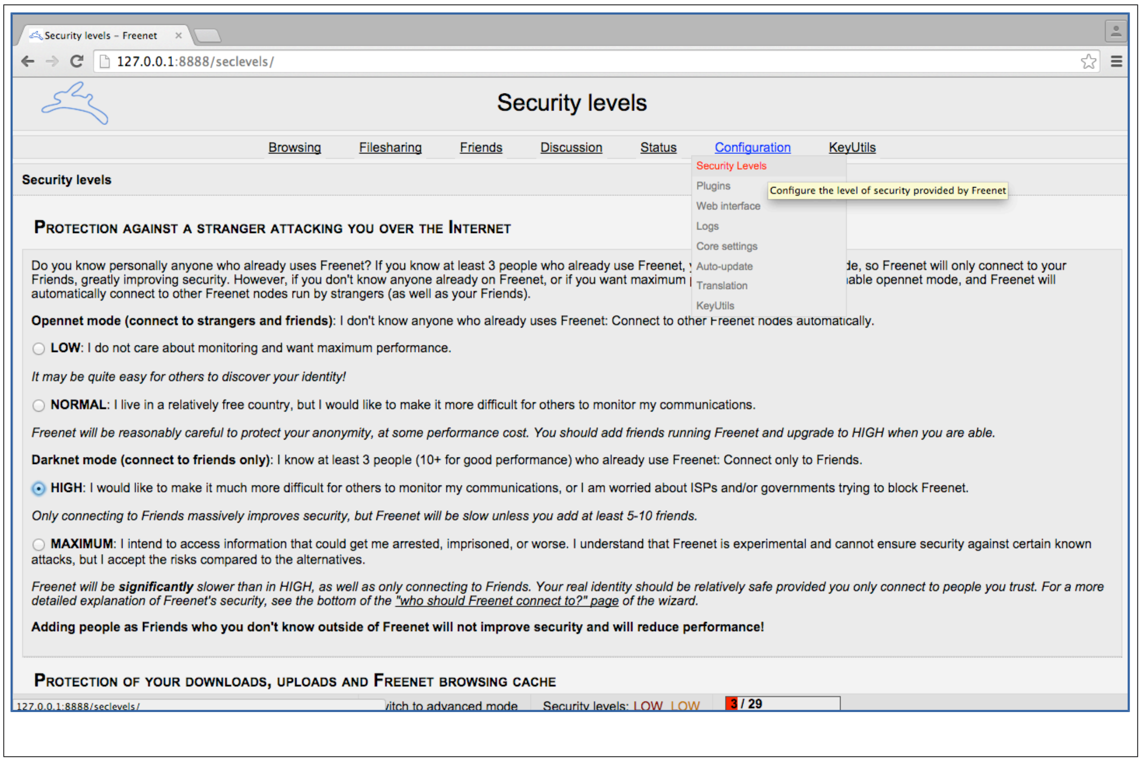


Fig. 21. Freenet “Darknet” mode configuration. Screen shot.

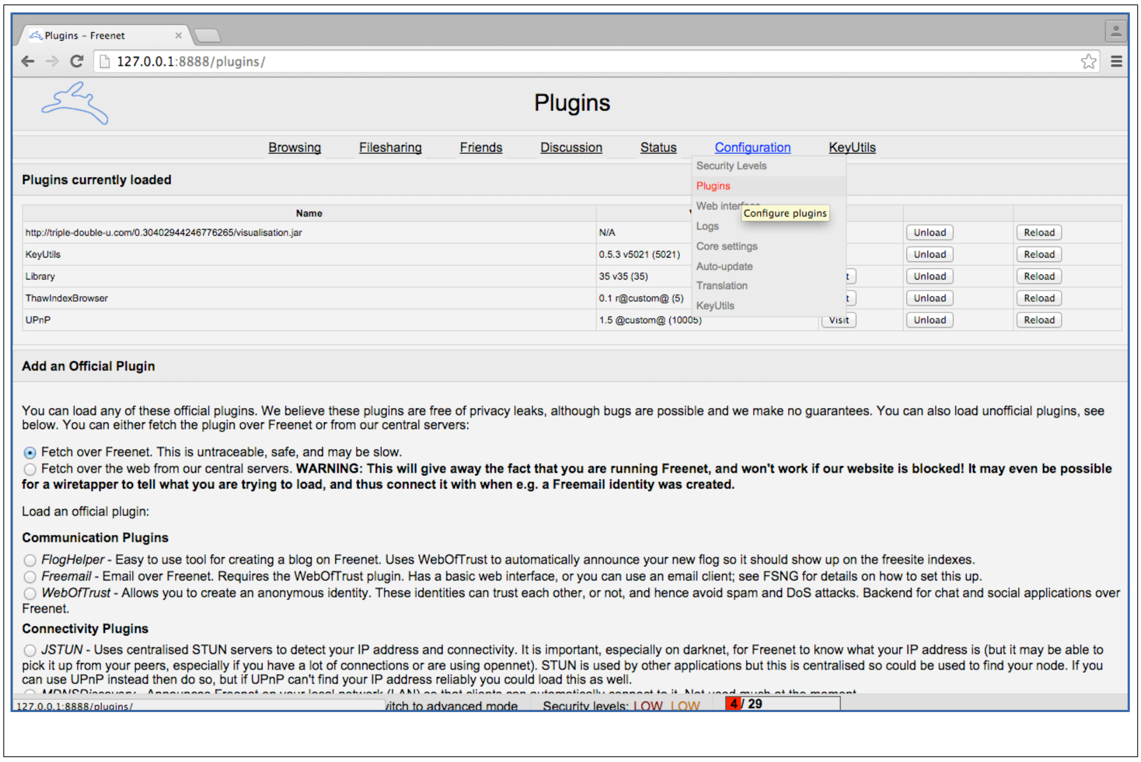


Fig. 22. Freenet interface to add plugins. Screen shot.

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