The Dialectic of Open Technology

by

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Abstract

This paper explores the concept of openness in the technology domain. In contrast to the common notion of openness as transparent access, I define the concept as the degree of liberation or suppression of potentiality. To develop a theory of openness as potentiality, I draw on the works of Gilbert Simondon and Umberto Eco. Simondon's theory of individuation explains the potentiality of incompatible relations between disparate domains. Resolving the incompatibilities actualizes the underlying potentiality, which is the energy source of constant, ambivalent changes in the lifeworld. Eco suggests that the semantic codes in contemporary art are unstable. They constantly oscillate between the rejection and the preservation of conventional systems. By appropriating Simondon's and Eco's theory to the realm of technology, I formulate a theory of openness in technology. I conclude with an inquiry on the significance of openness in practice and propose a design approach for developing open technologies.

Keywords: Open Technology; Individuation; Concretization; Dialectic; Simondon; Eco

To my wife Teresa for her love and prayers,

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Chapter 1.

Introduction

In the movie *Steve Jobs* (Boyle, 2015), Apple Inc.'s co-founders Steve Jobs and Steve Wozniak were engaging in a heated discussion at a garage, their start-up laboratory for prototyping the Apple II personal computer. To Wozniak, the Apple II ought to be an open and expandable system so that computer hobbyists could swap in and out their desirable components. Meanwhile, Jobs was adamant that a computer ought to be a totally closed system, sealed up and impossible to modify, perfect like a work of art. This fictional dialogue brings out a pervasive issue in the history of computer engineering: the principle of openness and transparency in software and hardware design. The Wozniak's camp is epitomized by the free source initiative, a social movement by software engineers who hold sacred the principle of transparent openness. At the other end of the spectrum, during his tenure as Chief Executive Officer at Apple Inc., Steve Jobs instilled his closed system conviction into the company's product design principles. In the past decade, Apple Inc.'s design principles typically favor user-friendly simplicity for computer illiterates and denounce a flexible, open architecture that may be prone to intrusions by software viruses. Even though many computer hobbyists criticize Apple Inc. for its stance on producing closed systems with proprietary components and accessories, we may consider its products as open from other perspectives. The introduction of the App Store supports an open market where freelance programmers can publish and sell their products. Hence the features on an iPhone or iPad evolve openly with users' demand and the creativity of hobbyist programmers. The introduction of novel product features, such as the dual-touch screen, can open up new possibilities for technical inventions. The concept of openness seems to connote a mixture of interpretations depending on the context of its usage.

One of these contexts is the philosophical discourse about technological determinism in the twentieth century. Does technology evolve deterministically in an autonomous fashion, or do the social and cultural milieux shape its evolutionary trajectory? Technological determinism, taken up by the instrumentalist and the dystopian view on technology, is a perfect closure. Opposition to determinism, such as social constructivism, perceives technical evolutions as open ended. In this century, the Enlightenment's optimism on technical and social progress runs its course in the face of atrocious circumstances. It was the progress in science and technology that made possible the unprecedented scale of massacre in the two World Wars and the Nazi's Holocaust, the atomic bomb and the nuclear crisis, the surveillance by secret police in dictatorship nation states, as well as the ruthless abuse of nature that causes the prevailing ecological crisis. At the same time, researchers in science and technology invented penicillin, automobiles, computers, and many breakthroughs that alter the human condition and presumably improve people's standard of living. These breakthroughs rekindled optimism about the positive potential of technology. This mainstream view advocates technical progress and absolves technology of causing atrocities by stressing the neutrality of technology. Depending on who uses a technology, its application may improve life condition or it may bring disaster to a society. In this instrumentalist account, technology progresses autonomously toward higher ends in value-neutral technical criteria, such as efficiency. A number of dystopian critics contended this instrumentalist view, the most important being Martin Heidegger. His philosophical inquiry in The *Question Concerning Technology* (1993) led him to the following conclusion: The essence of modern technology is in the revealing of a cultural milieu in which the meanings of human and physical beings are reduced to standing reserves serving the autonomous development of technology. The reduction abstracts from the nature of human and physical beings only those qualities that technology can utilize. He uses the term "enframing" to denote this specific revealing. In the cultural milieu of enframed modern societies, the reduction logic of all things into standing reserves will eventually lead to justifications over dehumanizing acts and ruthless extractions of natural resources in ever expanding domains. In Heidegger's determinism, modern technological societies move autonomously and perpetually toward the endless reduction of meanings. In both the instrumentalist and the dystopian perspectives, the evolutions of modern technology or technological societies are deterministic closures that leave no possibility for human or social efforts to deter their courses.

Nevertheless, a new current of thoughts began to counter technological determinism in the second half of the twentieth century. This current began with Thomas Kuhn's *The Structure of Scientific Revolutions* (1996). Kuhn differentiates normal science from revolutionary science. Normal science progresses by solving puzzles from new observations within the established paradigm. Revolutionary science explores alternatives to the seemingly obvious assumptions of the established paradigm. If the majority of the scientists prefer the new paradigm, then a paradigm shift occurs. Kuhn's argument opens up the possibility that science may be socially constructed and is an important influence on the strong programme of science studies. Substituting the science with technology, social constructivists of technology examined case studies of the lineage in technology and found the results irreconcilable with technological determinism. In *The Social Construction of Technological Systems* (1987), Wiebe Bijker, Thomas Hughes, and Trevor Pinch describe the development process of a technological artifact as "an alternation of variation and selection … in a 'multidirectional' model," and the historical stages in the development could have gone in other directions (p. 28). Each stage occurs as a concretization of technical possibilities and controversies in the social meanings of an artifact, where social meanings are unique under specific contexts. This interpretive flexibility explains why a technological artifact, such as a bicycle, evolves openly in adaptation to social needs. The invention of the bicycle was not an isolated event, but went through a nineteen-year stabilization process of negotiations between a wide range of social demands such as speed for sport, safety measure for ordinary users, and dressing problem for women cyclists (p. 39). These demands were translated into design conflicts in aspects such as wheel sizes, and the resolutions of such conflicts involved both technical and political choices.

Because social constructivists opt to draw conclusions from case studies about particular technological artifacts, their methodology repudiates macro critiques on social issues. They have no interest in the differentiation between the modern technological civilization and the pre-modern ones. Is it possible to develop a non-deterministic account of technology that can explain the power domination through technology in modern societies? One possible direction comes from Herbert Marcuse's analysis of modern technological societies. He develops a concept of technological rationality that is similar to the enframing by Heidegger. But because the a priori of his critique is social rather than ontological, his seemingly dystopian analysis actually accepts the historical possibility to ameliorate social and natural conditions (Marcuse, 1991, pp. xlii-xliii). This a priori leaves open the possibility of a social transformation of technology, and he maintains this opening by employing Hegelian dialectic. Dialectic allows his reasoning to circumvent technological determinism and to rationalize the possibility of recovering the suppressed nature of physical and human beings. While a technocratic society may seem like a totality at a certain historical moment, this totality will eventually run its course and a new social and cultural milieu will dialectically negate the incumbent one. The cycle of negations moves toward the liberation of the freedom and potentiality in humanity. In *One Dimensional Man* (1991) and *An Essay on Liberation* (1969), Marcuse delineates how the formal rules of the system reduce human and physical beings into abstract functional elements. But the closure of this technological rationality is imperfect because it only inhibits human nature but cannot annihilate it. The suppressed nature can turn into the source of reimagining an alternative trajectory for technology. Therefore, while modern technology confines human and ecological potentials, its emancipation does not necessarily entail a reversal of technology back to pre-modern craft technology. Rather, the technocratic society will evolve toward a culmination at which point social consciousness will become aware of the irrationality of suppressing the human and environmental potentiality (1991, p. 231). With this new mode of social consciousness, technology inventors are no longer bounded by the hegemony of technological rationality. They become free to direct their inventions toward humanistic goals such that technical progress will contribute toward improvements in human and social conditions (1991, pp. 231-232).

This holistic vision of humans in relation to technology raises some difficult questions if we consider Marcuse's argument reflexively. Formal specifications of a technology necessarily come with universal assumptions about the actual human nature. These assumptions are imperfect approximation of particular social contexts, which will continue to evolve. As a new invention is concretized into a stable structure, the imperfect assumptions are encoded into the invention along with humanistic goals. Due to the discrepancies with the actual world, these encodings will eventually turn into a reified reality. If the invention has a rigid structure beyond modification, and if the social and cultural milieu continues to evolve, then the gap between human reality and the invention will continue to widen, leading to the intensification of alienation in human-technology relations. The temporary reform eventually falls back to an alienated and reified totality.[1] To circumvent this apparent closure of cyclical reversals back to alienation, technology ought to be open to changes and adaptable to its evolving milieu.[2]

This problematic of reflexivity in Marcuse's holistic vision is the point of departure for my thesis. Through an investigation into the openness of technology, I intend to further complete Marcuse's humanistic project for emancipation from hegemony in critical theory. In the rest of this introductory chapter, I begin this investigation by giving several illustrations that represent different types of technological openness. Drawing from these illustrations, I present two types of openness in the context of technology, which I call bounded and unbounded openness. I conclude this chapter by introducing Simondon's philosophy and its relevance to the study of technological openness.

1.1. Examples of Technological Openness

Technological openness denotes a special type of relation of technology with individuals or with its associated milieu. Individuals may be human or nonhuman, organic or inert. A relation is formed when an individual repeatedly interacts with a technical object. For example, a human individual interacts with a laptop screen by moving an index finger on the mousepad. Over many repetitions, the human individual cultivates a habit that confines its behavior. In *Technology and the Lifeworld* (1990), Don Ihde concurs: "To enter any human-technology relation is already both to 'control' and to 'be controlled'" (p. 140). A technology may also cause changes to its associated milieu,

[1] For instance, the recently developed user-centered design echoes Bakardjieva's suggestion for direct participation of everyday users (2005, p. 195). But any sampling of users as research participants is bound leave out some practical scenarios. Thus the new, improved technical code is nevertheless bound to consist of political biases.

[2] To be open and adaptable, technology may exist in an amorphous form as a technical object, or it may evolve within the production process where new versions substitute older ones.

and we may consider such results to be confining to the milieu. For example, an air conditioner narrows the possible range of room temperature.[3] Hence an open relation cannot be a relation freed from all restraints. Instead, I consider openness as a relation that vitalizes rather than suppresses the potentiality in an individual or in a milieu. For example, the potentiality of a human being includes the faculty to freely think and act. I shall clarify this conception of openness with the following examples: a factory assembly line, a computer software development process, and a centralized air conditioning system.

A factory assembly line epitomizes a closure in a human-technology relation. Workers on an assembly line perform the same actions repeatedly and rhythmically in conformance to the temporality and spatiality of automated machinery. The structure of the relation squeezes out the workers' creative freedom in actions and thoughts. The machinery rhythm restricts the spatiality of their possible bodily motions as well as the temporarily for deeper thoughts and reflections. The factory setting embraces the culture of efficiency, accuracy, and stability while repudiating contingency and creativity. Charlie Chaplin's movie *Modern Times* (1936) is a parody of how this harsh environment reduces humans being into cogs of machines.

In comparison with assembly line workers, software programmers in the computer industry have a more open relation to their tools and to the product development process. These tools and processes grant programmers a greater degree of freedom in designing and writing their code. The market demand for skills gives programmers leverage in negotiating for high salaries. To optimize their profit margin, corporations have attempted to reduce the high cost of programmers by deskilling and outsourcing. One of the deskilling schemes imitates Taylorism, the scientific management of an assembly line. The adaptation takes the form of standardization of

[3] Other examples, such as a lamp bringing light to a room, may not seem to be confining. But from the perspective of the milieu itself, the relation is defined by the reflection of light by the objects in the room. Even though the reflection does not seem to affect the objects' properties, it does put the milieu in a new state. In other words, the technology forces the milieu to enter a certain state. In that sense we can consider the relation as confining. It appears to be non-confining from a human perspective because it opens a horizon of new relations between our eyesight and the objects.

the software development process. Capability Maturity Model Integration (CMMI) and International Organization for Standardization (ISO) are two well-known industry standards. Independent consulting agencies assess software vendors and certify their level of conformance to CMMI or ISO. Presumably, software vendors at the highest level are the least dependent on the contingency of individuals and thus more guaranteed to produce high quality software.[4] One key assessment criteria is concerned with the division of labor. If a few skillful programmers are crucial to the success of a software team, the assessment will give a very low score to the team. Accordingly, in designing a system, senior engineers and managers are responsible for breaking down the system design into modules that are as small as possible. They go through months of meetings to specify the detailed requirement of each module, including descriptive rule-like clauses about each specific feature of the user interface and of the system runtime behavior. The document may contain hundreds of pages. While each clause is open to interpretation, the gist of the specification is to narrow down (close down) rather than leave open contingent interpretation. The more clauses the document contains, the less open are the specifications. They then assign each module to a single or a team of programmers.

The division of labor supposedly reduces the coding responsibility so that even an inexperienced programmer can handle the task. Nevertheless, many hands-on programmers repudiate this scheme and prefer a more flexible approach, such as the agile software development method ("Manifesto for Agile Software Development," 2001). In addition to their antagonistic reaction to deskilling, one reason for their preference comes from the resemblance of software programming to writing. Imagine the following scenario. An author decides to model her writing process after Taylorism. She begins her endeavor by dividing a storybook into ten chapters, each with five subsections. She then outsources each subsection to an independent writer. After receiving the subsections, she integrates them into a single book. To attain a consistent style and a coherent theme, she needs to understand every detail in others' writing prior to the effort of editing and rewriting. Compared with writing the whole book by herself, this process

[4] From what I have heard from others in the software industry, they are more interested in paying for the certification than truly believing in the process.

costs more money and takes up much more time. Moreover, the process of writing allows authors to immerse in the written content so that their minds are saturated with all the minute details and relations among them. Authors cannot acquire this mental state if they outsource major book sections to third-party writers.

Software programmers also immerse into the virtual world of coding. This mental state allows their imagination to imitate the actual run-time behavior of a software process. This ability is similar to musicians' ability of hearing music in their minds when they read music scores. In their imagination, programmers interpolate the gaps between this actual process and their knowledge about the coding logics. For programmers with limited coding responsibility, their codes still need to interact with the rest of the program, which they can only understand through the discrete, pseudo-formal clauses in the specifications. They need to interpolate the gaps between the software process and the specifications instead of their knowledge of the code. These gaps are larger than those for programmers who know the code inside out. Because the specifications are open to interpretation, the person reading the clauses may interpret them differently from the ones who translate them into software code.[5] The more restricted is the coding responsibility, the more groundless are the assumptions in interpolations. In general, every time when programmers integrate their code, well tested independently, the program almost always crashes on the initial trial. If the team of programmers is small enough, they can have better communication about their interpolations, and the interpolations are more consistent and easier to manage. But if the technical lead splits up the same programming task into small units and assigned them to a large team of programmers, the programmers' interpolations may bury many wrong assumptions into the program, causing mysterious crashes and irrational run-time behavior.[6]

The open-source initiative offers an alternative model to CMMI or ISO. Most open-source projects begin with a few core contributors with no detailed design specification before they invite the eye-balls of the software community to discover and fix bugs (Raymond, 2001). For example, Linus Torvalds wrote the entire Linux kernel

[5] The idea presumably is to counter this openness by specifying more clauses to narrow down these hermeneutic gaps.

[6] My argument is similar to that in *The Mythical Man Month* (Brooks, 1995).

mostly by himself, and Linux operating system is arguably more stable than most commercial operating systems. The technical achievements of many open-source projects raises doubts about the effectiveness of inflexible standards like CMMI or ISO. The current form of computer software seems inherently resistant to the closure of scientific management.

On the other hand, the user interfaces of open source applications are typically not user-friendly. One reason for this difficulty is the lack of a standard. In contrast, Apple publishes a user interface standard for their iOS developers (“iOS Human Interface Guidelines,” 2001) without restricting their creativity. Hence not all standards lead to closure. I shall discuss further on the differentiation between open standards or structure from closed ones in the other chapters.

The concept of openness covers not only technology interacting with human beings, but also with its surrounding milieu. One example is the centralized air conditioning system. A simplistic, workable algorithm can be implemented as follows: (a) If the room temperature is greater than the configured temperature, turn on the cooling subsystem; (b) if the two temperatures are equal, turn off the cooling and the heating subsystem; (c) otherwise, turn on the heating subsystem. This system changes its surrounding environment, keeps track of the actual changes, and feeds them back as inputs to its internal state machine. The environment and the system mutually adapt to each other in a feedback loop. This feedback design is also applicable in designing a pollution-conscientious vehicle engine. While all new vehicles need to undergo governmental regulatory tests to certify the content in their gas emission, older vehicles with deteriorated engines may be susceptible to the violation of the emission standards required by environmental protection agencies. Hypothetically, a feedback design can resolve this issue. By installing a device for measuring the chemical content in its gas emission, a motor vehicle can feed the measurement back to the vehicle engine. When the measurement violates the emission standards, the engine reconfigures itself to a less efficient mode in order to emit a lower concentration of chemicals. This hypothetical feedback design can prevent older engines from becoming a major source of air pollution.

In the examples of the factory assembly line, the software development process, and the two feedback systems, the distinction between openness and closure is not only related to freedom per se, but to freedom that allows human beings and the physical environment to maintain their potentialities. In the next section, I shall develop this idea further into a more precise meaning of the concept of openness in the context of technology.

1.2. Defining Technological Openness

In the preceding section, I argue that, in a relation with technology, the technological schema necessarily confines the behavioral pattern of an individual or the activities within a milieu. Accordingly, the quest for openness cannot be tantamount to the single-minded pursuit of freedom from all restraints, of a minimalist technical structure that consists of no restraining characteristic. Therefore, we must come up with a more appropriate interpretation of openness. Through the examples of a factory assembly line, the software development process, and an environmental-sensitive machine, I illustrate how technological openness, being a relation of technology with an individual or with its surrounding milieu as an independent agent, vitalizes rather than suppresses the agent's potential activities and its possible evolving trajectories. I now want to develop further this notion of potentiality by drawing parallels with the philosophical concepts of positive and negative liberty.

According to the *Stanford Encyclopedia of Philosophy*, positive liberty is "the possibility of acting ... in such a way as to take control of one's life and realize one's fundamental purposes" (Carter, 2012). Technology may grant positive liberty to its users by providing formal structures that bring them new "possibility of acting" in accordance to their "fundamental purposes." As Don Ihde suggests, "human activity from immemorial time and across the diversity of cultures has always been technologically embedded" (1990, p. 20). As such, "the technological form of life is part and parcel of culture, just as culture in the human sense inevitably implies technologies." In this view, human and cultural activities always take place in a technologically textured world. The logical or material structures in technology are foundational to the creative development of human and cultural activities. In a world without technology, the range of human activities becomes very limited. The implication of this foundational role of technical structures can be illustrated by the significance of piano key frequencies to musicians. Whereas a string instrument produces sound with pitches belonging to a continuous spectrum of wave frequencies, a piano produces sound with pitches that conform to discrete multiples of frequencies in twelve tones, the standard notation of Western music. The musical performer's responsibility of playing in tune is delegated to the mechanics of the piano and some piano tuning service. On the one hand, this instrumental conformation to the twelve-tone musical standard restricts a pianist from improvising musical nuances, such as a vibrato or a gypsy-style sliding pitch that would be possible on a violin. On the other hand, by relieving a pianist of the responsibility of playing in tune, it becomes easier to play with ten fingers simultaneously. This empowerment has inspired new musical genres and allows a composer to simulate the harmonic sequences in an orchestral piece. Inferring from this illustration, while formal structures impose conformity on an individual or a milieu, they may simultaneously expand the possibility of actions by opening up a new order of activities.

Nevertheless, as many critics pointed out, over the past century the domination of modern technology has brought violations upon the human and the environmental nature. The struggle for independence from such technological domination is parallel to the pursuit of negative liberty, which denotes "the absence of obstacles, barriers or constraints" (Carter, 2012). Trimming down and eradicating incumbent structures that are dehumanizing or toxic to the environment can attain technological openness in the sense of negative liberty.[7] Yet, from the preceding delineation on openness as positive liberty, certain technological structures are basic building blocks for the breeding and the preservation of cultural forms. In fact, the obstacles and barriers in one culture may empower the imagination of another culture. For instance, an effective management style in a Canadian corporation may spell disaster if a Chinese corporation copies the same management style. Therefore, it takes more than a simple listing of attributes to

[7] In technology studies, the concept of "technology-as-text" by Steve Woolgar (1991, 1996) and "scripts" by Madeline Akrich (2010) to represent designers' strategies for inscribing "preferred readings" into technological. A technology as a "black box" is a "prescription" of users' behaviors; users behave as if they are acting out a "script." In many scenarios, users re-interpret these "preferred readings." Akrich calls the process of re-interpretations "de-scriptions."

discern between empowering technical aspects and those detrimental to the social and natural environment.[8]

I shall use the term “unbounded openness” to describe a technological relation that is analogous to positive liberty. This type of relations engenders creative activities that promote the realization of one’s fundamental purposes. A relation of unbounded openness may also be confining through some foundational structure such as a computer network based on protocols, or it may be teleologically directed toward an end, but the structure nevertheless fosters creative activities.[9] In contrast, participants of certain technologies may need to conform unwillingly to the technical structures. They would instinctively yearn for emancipation from such restraints. In parallel to negative liberty, removing obstacles, barriers or constraints in technological relations may expand the scope of possible actions. I shall use the term “bounded openness” to denote openness in this negative sense. In sum, both bounded and unbounded openness are concerned with engendering possibilities of actions and evolutions. The former engenders by structurations in a relatively amorphous medium, whereas the latter by deconstructions of structural barriers.

1.3. Bounded Openness

As mentioned above, technology may yield a greater degree of bounded openness through deconstructions. If we push this approach to the extreme, deconstructions eradicate all structures, resulting in an amorphous, empty, and

[8] In Marxism, the discernment can be traced back to the means and relations of production. I do not intend my inquiry to follow this Marxist view. Rather, this thesis is a study of specific technologies and of design characteristics that foster open human-technology or environment-technology relations.

[9] For instance, as Marcuse explains, Platonic dialectic is teleological but it also has an open horizon: “Prior to this formalization [of Aristotelian Organon], the terms “Being,” “Non-being,” “Movement,” “the One and the Many,” “Identity,” and “Contradiction” are methodically kept open, ambiguous, not fully defined. They have an open horizon, an entire universe of meaning which is gradually structured in the process of communication itself, but which is never closed” (1991, p. 131).

meaningless medium.[10] This medium may hold limitless possibilities but offers no material base for meaningful actions. In addition, if Ihde is correct that human activities from immemorial time are technologically embedded, then no practical historical project can uproot every technology from the technologically textured world without wiping out civilization. Therefore, the most obvious strategy of enhancing bounded openness is to find and reach an ideal balance between removing and retaining incumbent structures. This is the approach taken by So-Young Park in *Understanding 'Open Work' in Interactive Art* (2006). She proposes a methodology for finding a proper balance of openness in interactive art. The methodology is based on a particular sensibility, an aesthetic judgement, for determining the ideal balance or "means" on different values (pp. 34-46). For instance, "changeability" of an interactive art can be associated with an astronomical number of possible variations, but the art loses its communicative value with too many variations. Artists make decisions on the balance based on their aesthetic judgement. While Park derives her work on *The Open Work* (1989) by Umberto Eco, I identify another model from Eco analysis of the openness in contemporary work of art.

In *The Open Work* (1989), Eco differentiates contemporary art from classical art in the way they violate the conventional order (p. 60). (I shall use "art" and "work of art" throughout as including the visual arts as well as literature and music.) Classical art respects conventional forms of organization and deviates from these forms within well-defined limits. Contemporary art challenges the conventional forms by imposing an "extremely 'improbable' form of organization." But then Eco realizes, if "contemporary art imposed a totally new linguistic system, then its discourse would cease to be communicable." Instead, contemporary art "constantly oscillates between the rejection of the traditional linguistic system and its preservation." The "the dialectic between form and the possibility of multiple meanings, which constitutes the very essence of the 'open work,' takes place in this oscillation." Summarizing Eco's conjecture, the dialectical oscillation of rejection and preservation of a system constitutes the essence of an open work. The essence of openness is not static, but is constituted of perpetual movements in oscillations.

[10] Ihde pushes this imagination of a technology-free world to the extreme and shows its absurdity (1990). The world will be left with naked human beings among one another in uncontaminated nature. But without tools they will probably all starve to dead and become extinct.

While the interactions of a human being or a milieu with a technology have a different nature from its interactions with a work of art, both a technology and a work of art consist of structural forms that shape these interactions. Each form has a unique set of affordances for adaptation or interpretation. A diversity of forms affords varying degrees of openness. In the case of human-technology relations, an open technology allows the possibility of multiple interpretations of its usage or its structural enhancements. Rather than conforming to the usage defined narrowly by technology providers, users can appropriate the technology based on their unique contextual interpretation. Engineers have the freedom to interpret the trajectory of technical enhancement. In other words, openness is the a priori condition for interpretative flexibility or hermeneutic multistability in a human-technology relation.[11] A technical design can minimize the degree of openness and force users to conform to an oppressive structure. In resistance, users, hackers or inventors may thrive to circumvent or to abolish the oppressive structure to recover suppressed multistability.

But depending on the concreteness of the technology, reifying features may be entangled with fundamental and crucial features. The abolition of reification may simultaneously signify the loss of certain necessary features. To recover these features, the resistant project needs to disentangle them from the oppressive code before reconstruction. But this project also takes place within a cultural context with implicit assumptions. Subconsciously encoding these assumptions would lead to a new reified form of human-technology relations, which in turn awaits the next project of emancipation. Ideally, this dialectic of reconstruction and negation moves toward a greater degree of openness. Appropriating Eco's conjecture to the technical realm, when technical designs are directed toward openness, decisions oscillate dialectically between deconstruction and reconstruction.

Tracing the history of the plugin framework for Web browsers presents one practical illustration of openness as a dialectic oscillation. When Tim Berners-Lee invented the original Web browser in CERN (Conseil Européen pour la Recherche

[11] I am specifically referring to the hermeneutic multistability in Ihde's work (1990) and interpretative flexibility of social construction of technology (SCOT).

Nucléaire) laboratory, it was a simple text-graphic browsing client-server tool with no schema for browser plugins ("cern.info.ch - TIm Berners-Lee's original WorldWideWeb browser," 2008). In the process of its commercialization, browser vendors recognized the benefits of opening up an application programming interface (API) to third-party software developers for customizing and enhancing the browser functionality. They began to distribute web browsers that support a plugin API. Third party vendors and independent developers can implement plugins to contribute their technical expertise to the browser's functionality. We may consider the introduction of the plugin framework as dereifying in the sense that the web browser's evolving trajectory adapts more closely to users' actual needs.

But plugins also expose security holes. Malicious "Trojan horse" plugins intercept and collect users' private data surreptitiously behind the appearance of advertised features. The open plasticity of the plugin framework gradually developed into impositions of many problems for the users of the technology. We can attribute some of these problems to the capitalist rationality of profit optimization. For instance, the so-called "Big Data" trend has amplified the market value of users' private data, and browser plugins can collect data surreptitiously behind the scene. Many problematic plugins are packaged with a freeware downloadable on the Internet. Computer illiterates are usually not aware of the packaged installation of these intrusive plugins.[12] Because these plugins intercept each request and transmit statistics back to some data-collecting server, they also slow down the web browser's performance considerably. These plugins become the means of translating human activities into collectible statistics, of reifying them into marketable commodities.

Perhaps due to the problems with plugins or to the competitions between vendors, the latest HTML standards incorporate some core functionality that plugins have been providing.[13] For instance, if users want to watch video streaming on a web

[12] I make this claim based on my experience in helping out my father in cleaning his computer from malicious plugins every few months.

[13] This technical trend may have a lot to do with competitions between corporations, such as Apple and Adobe. But typically the standardization process is a discourse based on technical rationale. The problems that plugins have raised become the ammunition for abolishing them in negotiations.

browser, they had to install the Flash plugin in the past. But now, browsers supporting the HTML5 specification can support this feature without the plugin. In this high-level depiction of the history of browser plugin, the technical system went from a closed form (Tim Berners-Lee's original web browser) to a relatively open form (browser affording adaptations through plugins), and then went back to a less open form (an HTML standard with more comprehensive features).

I contend that the bounded openness in a technology has the following shortcoming. While the rejection of the conventional order in art shakes up the entire order, a technical system systematizes bounded openness under the control of the overall schematics. The programmers developing a plugin must adhere to the API as well as the mechanism of the web browser. The bounded openness of a browser plugin submits to a circumscribing realm of technical control. This limitation resembles Marcuse's critique of repressive tolerance (2007). He argues that the socialist-capitalist system resolves internal tensions by co-opting resistant movement. Thus protests and freedom of speech are only tolerated if they do not pose threats to the stability of the overarching system. Tolerations are repressive because they tend to stabilize the incumbent system of oppression. While some may doubt the fairness of his critique in light of the actual social reforms since his writing, we can still apply this rationale to a critique of bounded openness of technology. This critical rationale is no longer applicable as we venture into the inquiry of unbounded openness.

1.4. Unbounded Openness

While bounded openness is about the recovery of suppressed potentiality through deconstruction, unbounded openness is about the discovery of latent potentiality by generating new possibilities through structuration. New logical or material structures can be basic building blocks for activities that are dependent on but not determined by the structures. I classify unbounded openness into two categories: an open environment and an open evolving trajectory. Both categories involve activities that cannot be anticipated at the design moment. An open technological environment is designed to facilitate activities belonging to another realm with unique rules and customs. Examples include buildings, playgrounds, musical instruments, computer operating systems or programming API's. An open trajectory entails perpetual transformations of the technology and of its associated milieu beyond any linear projection of the original design. For instance, the World Wide Web was originally conceived as an all-encompassing information retrieval system. After a short while, business tried to adapt the framework into a platform for electronic commerce (e-commerce). Because the original designers did not consider this potential adaptation, the e-commerce solutions of trust and security have been far from foolproof. In the past decade, the web has become a platform for social networking.

Differentiating a technological environment from a goal-oriented technical application is not a straightforward exercise. Consider a massively multiplayer online game (MMOG). It is a computer program with specific goals and missions similar to single player computer games. It is also an environment for mediating interactions between players around the globe. To clarify the criteria that make a technology operate as an environment, I depict the case of document editing software. As I am typing my thesis with a document editing application, it supports my activity with convenient features such as cut-and-paste, font editing, or footnote management. The design specifications of these features are as detailed as possible to narrow down possible interpretations. Yet this closure in feature specification does not prevent the overall software from openly accepting variations in content, genres, and languages. These variations belong to other conventions or realms of techniques outside the domain of the software application. The university stipulates the basic requirement for this thesis. Grammatical rules govern sentence composition. In an open technological environment, the form of human (or nonhuman) actions is not determined by the technical structure, but by another realm with a unique order based on its own conventions, knowledge, or material structure.

This characterization of an open technological environment is consistent with the way the term "environment" is used in a study of online learning systems by Andrew Feenberg and Edward Hamilton (2012). The study compares a computer-aided distance learning system with an online conferencing learning platform. The former "is designed to stand in for the teacher" in a program of automation, whereas the latter "stands in for the classroom as an environment for interaction, dialogue, and the formation of community" (p. 60). A distance learning system aims at encapsulating the form of teaching into the formal structure of its design. An online conferencing learning platform maintains an open space for professional teachers to guide students in their learning process. The platform's "functional delegations are not simply built into the technology, but are actively configured out of a combination of social and technical options that ... include a role for the professional teacher" (p. 60). Experienced and knowledgeable teachers who understand students' needs are more valuable than unskillful teachers in this open space because the activities of learning and teaching belong to pedagogy. Similar to a document editing application, users' primary activities in an online conferencing environment are circumscribed by domains extrinsic and irreducible to the formal specifications of the technical platform.

An open evolving trajectory of a technology consists of technical or social transformations that go beyond the linear projection at the time of the original invention. Just like an open technological environment, it corresponds to activities that are not well-defined at the time of invention. But unlike an open environment, the unanticipated activities are human projects that enhance the technology or use it for new technical or social inventions. We can identify this type of evolving trajectory in Neil Postman's assessment on the impact of the printing press (1993), Andrew Feenberg's account of the Minitel (1995), and Maria Bakardjieva's ethnographic studies on the appropriation of the Internet by computer illiterates (2005).

According to Postman, the invention of printing fostered literacy and made the Scripture accessible to a wider population. One unexpected result was the growing distrust of the authority of the Catholic Church. The distrust subsequently contributed to the rise of the Protestant Church. Whereas the printing press led to unforeseen social transformations, technologies may also transform unpredictably as users adopt them in their specific social contexts. In Feenberg's account of the Minitel, the system was originally designed to "bring France into the 'information age' by providing a wide variety of information services" (1995, p. 150). But users were not enticed by this mainstream feature. Instead, the heaviest usage came from an underground service for person-to-person messaging. Hackers converted a messaging functionality for technical support into a service available for online users. Eventually, the popularity of this underground messaging service prompted the operator to implement and support an identical service, shifting its strategy from the vision of an information hub to the actual service as a medium for communication. Nevertheless, not all users have the technical expertise to appropriate technical systems by hacking, but they may still have other means to co-opt technologies. Maria Bakardjieva's ethnographic study on computer illiterates describes their hermeneutic co-optation of the Internet to address their unique needs in daily life (2005, p. 191). Some of her interview respondents are socially isolated because they are "house-bound" due to physical, social, or financial reasons. The Internet helps them deal with their loneliness by connecting them with others and by allowing them to form new relationships from within their situation of being isolated (p. 121). Thus they discern the affordance of the Internet not according to its functional utility, but to its unique therapeutic impact on their psychological distress. They invent new meanings for the Internet without changing its physical properties.

What causes these unforeseen evolving trajectories? Is it the social or the technical? I believe both are accountable. In a work that I allude to earlier, Bijker, Hughes, and Pinch argue rather convincingly that technology development may follow any one of multiple trajectories. The final choice is the result of a long process of social interactions (Bijker et al., 1987). But this argument does not undermine the ramification of the technical form. If the Minitel did not implement a basic messaging service for technical supports, hackers could not have turned it into a messaging service for the general public. Hackers can be more creative playing with a system with transparent functionality than a closed system that encapsulates features from implementation.

Can we describe the criteria that make some technical forms more open than others? This question, central to this thesis, is concerned with a technical rather than a social or spiritual explanation. Marcuse was also looking for a non-economic explanation of technical progress in his exploitation into the reconstruction of science and technology, and he found it in the philosophy of Gilbert Simondon. His philosophy "entails a substitution of ontogenesis for traditional ontology, grasping the genesis of individuals within the operation of individuation as it is unfolding" (Combes, 2013, p. 3). His philosophy is antagonistic to hylomorphism. An a priori form does not prescribe the becoming of an individual, or the process of individuation. A living individual is never a final and static term, but instead, it undergoes perpetual operations of transmutation in a process of individuation. From the perspective of openness, an individuation in hylomorphism presumes an evolutionary trajectory pointing toward its pre-deterministic end, whereas Simondon's philosophy outlines an individuation with an indeterminate end. Based on the philosophy of individuation, he formulates a theory of technical progress. In this thesis I choose to formulate my theory based on Simondon's ontogenetic philosophy because it gives a materialist perspective about the way technical and social realities evolve.

1.5. Simondon's Philosophy

I shall expound on Simondon's philosophy in Chapter 2. Because his philosophy is so fundamentally different from others, I present a brief overview here to show the relevance of his philosophy to technological openness. Individuation, concretization, and transduction are the fundamental concepts in his philosophy. Concretization is an open process that leads to ambivalent closures. Individuation and transduction are operations with open evolving trajectories. In this section, I introduce these concepts by depicting three paradigmatic examples. The analogy of brick making explains the process of individuation. The Guimbal turbine epitomizes the concept of concretization. Crystallization reveals an operational model for transduction.

Simondon revises Aristotle's brick-making example from a hylomorphic horizon to the perspective of physical relations in which energy and force are exchanged (Chabot, 2003, pp. 76-77). In a typical scenario, a brick maker fills a wooden mould with clay. To Aristotle, the clay is a malleable, formless substance, which requires the wooden mould to give it the form of a brick. Simondon argues that the wooden mould is not a pure form but rather a matter that needs to be treated to become hardened. Neither is the clay purely indeterminate matter. Rather it is a processed material, "extracted from marshy soil, ... dried out, ground into powder, immersed in water, kneaded for a long time," and "its molecular properties determine its quality, porosity and density" (p. 76). When heated, the compressed clay expands and presses up against the wooden mould, which acts as an opposing force to the expansion. This exchange of force and energy produces the hardened form of the clay. In sum, the concepts of matter and forms are, in actuality, reduced abstractions of formed matter and material forms. It is not the metaphysical essence, but the interactions of physical relations between the formed matter of clay and the material form of wooden mould that give rise to the individuation of a brick.

Concretization denotes an operation that eliminates the gaps between a formal abstract technical design and its concrete actualization. An engineer may design a technical object as an ensemble of elements whose behaviors are predicted by the formal laws of physical science. But these predictions are imperfect in the actual scenarios. The engineer needs to review the issues and to resolve them in an iterative process. A series of resolutions may result in an overly complex object with many functional modules. Due to its unmanageable complexity, the object eventually breaks down and is unable to further evolve. Concretization simplifies a complex technical structure by replacing multiple modules with a single module serving multiple functionalities. Simondon elicits the Guimbal turbine for hydroelectric plants, an invention by Jean-Claude Guimbal in 1953, as a paradigmatic example (Iliadis, 2015, pp. 90-91; Simondon, 2012). The invention combines a turbine and a generator into a single unit for installation under water. With the generator under water, the water becomes multifunctional. It not only supplies the energy to activate the turbine and the generator, but also evacuates the heat that is produced by the generator. Another difficult challenge is to ensure a functional generator when placed under water. To attain this goal, the invention requires the generator to be contained inside a crankcase filled with pressurized oil. The oil also serves multiple functions. It lubricates the generator and insulates the coil. It conducts heat from the coil to the crankcase, allowing the heat to be dissipated through the water. It also prevents the seepage of water into the crankcase since the pressure of the oil is greater than that of the water. Under the condition specified by the design, both the water and the oil are multifunctional and they substitute the functionality of a separate cooling module. With no cooling module, the generator becomes small enough to be placed under water.

This example reveals another property of concretization: it is “an invention which assumes that the problem is solved” (Simondon, 2012, p. 55). Thus an engineer cannot come up with an invention based on linear logic. Instead, she invents with an imaginative leap over existing constraints. The imagination simultaneously creates the invented technology and its associated milieu that support the technology with favorable conditions. Simondon calls this property "recurrent causality," and considers it essential to concretization.

The process of crystallization serves as a paradigmatic model of genesis in living and nonliving matter for Simondon. He uses the term transduction to denote this genesis. He defines transduction as "a physical, biological, mental, or social operation, through which an activity propagates from point to point within a domain, while grounding this propagation in the structuration of the domain, which is operated from place to place: each region of the constituted structure serves as a principle of constitution for the next region" (Simondon, 1995, p. 30, 2005, p. 32). This series of propagation and structuration are analogous to the actual events in crystallization. Prior to the encounter with an external catalyst, a crystalline solution remains in its liquid state. When an experimenter inserts an external catalyst, such as a stick, into the solution, crystalline structures begin to form around the stick. This structuration continues as long as the newly formed crystalline structure remains inside the solution. As long as the region of the newly constituted structure is in contact with the solution, the activity will continue to propagate. If the experimenter removes the stick and the crystals wrapping around it, the structuration will stop.

According to Simondon, the crystal and the solution correspond to two disparate regimes with distinct orders of magnitude. The activity of transduction requires a preindividual resonance between the disparate regimes. A resolution of the regimes actualizes the activity. Simondon uses the analogy of vision to illustrate this type of resolution: Two incommensurable two-dimensional planes are conjugated into the projection of a single three-dimensional space (Crary & Kwinter, 1992, p. 315). Discrepancies between two-dimensional spaces hold positive potentials for the visualization of a three dimensional space. Therefore, apparently negative aspects have the potentiality to become positives, and a paradigm shift can actualize such potentiality.

1.6. Outline

This thesis is a theoretical exploration about the concept of openness in technology. In the coming chapters, I shall further explore the concepts presented in Chapter 1. Such concepts include openness as the condition for actualizing potentiality, bounded and unbounded openness, unbounded openness as an open environment and as an open evolving trajectory, openness as interpretative flexibility, and the dialectic oscillation of rejection and preservation. I shall develop these concepts based on the philosophy of Gilbert Simondon and the theory of open work by Umberto Eco. Chapter 2 is a detailed discussion on Simondon's philosophy. I shall analyze how Simondon's concepts, such as concretization, individuation, and pre-individuality, are related to the openness of technology. I shall compare his concepts with Marcuse's dialectical theory and alienation, and discuss the point of convergence between their theories. Chapter 3 presents Eco's analysis of aesthetic openness in *The Open Work* (1989). I shall compare Eco's theory to Simondon's philosophy, and derive three types of aesthetic openness from his analysis: interpretative flexibility, systemic conversion, and continuous structuration. I appropriate these three types to the technological realm. In the final chapter, I explore the practical implication of openness. I propose a design approach to develop an open technology, deliberate on the value of openness under different circumstances, and discuss its political implication.

Chapter 2.

Openness in the Philosophy of Simondon

In Chapter 1, I briefly introduce Simondon's concepts of individuation, concretization, and transduction. In this chapter, I want to conduct a more comprehensive survey of his philosophical concepts and relate them to openness. Most of Simondon's works have not been translated to English. Thus my analysis is primarily based on the commentaries and critiques available in English. They include the English translation of Muriel Combes's *Gilbert Simondon and the Philosophy of the Transindividual* (2013), David Scott's *Gilbert Simondon's Psychic and collective individuation* (2014), Chabot's *The Philosophy of Simondon* (2003), Alberto Toscano's *The Theatre of Production* (2006), Adrian Mackenzie's *Transduction* (2002), and a collection of essays in *Gilbert Simondon: Being and Technology* (De Boever, Murray, Roffe, & Woodward, 2013).

There are two approaches to comprehending Simondon's philosophical concepts. We may view them as a metaphysical speculation similar to mythology. Or we may view them as hypothetical models based on analogies with the current knowledge in science. These models express the concealed relations between separate domains. In this thesis I favor the second approach. For instance, instead of comprehending a pre-individual being as a metaphysical energy field, the abstraction of energy field serves to explain how the disjoint domains with incompatible orders are nevertheless related. The concealed relations are the potential sources of further genesis. The dormant potentiality awaits some catalytic event to engender a phase shift of the domains, such as a paradigm shift in a scientific discovery.

In the following, I discuss how Simondon's philosophy is useful for studying what constitutes an open relation. Section 2.1 explains Simondon's critique of hylomorphism and structuralism with his theory of individuation. Section 2.2 describes the relation between individuation and openness. Section 2.3 investigates the relation between individuation and concretization. Section 2.4 deliberates on the openness of Marcuse's dialectical theory. Section 2.5 examines Simondon's approach to reduce alienation. Section 2.6 discusses Simondon's critique of cybernetics and information theory.

2.1. The Theory of Individuation

David Scott presents Simondon's critique of structuralism in *Gilbert Simondon's Psychic and collective individuation* (2014). Structuralism explains human experiences and behaviors based on an overarching system or structure. But because structuralism is unable to account for how one structure transforms into another one, or how new structures come to be formed, the theory implicitly advocates a static view of reality (p. 10). If our epistemology of living beings is based on static forms or structures, we cannot perceive their genesis and subsequently coerce them to conform to the static forms. For instance, a technical apparatus can objectify an ideal form into a static physical structure that prescribes human behavior.[14] The conformance of dynamic living beings onto prescriptive static forms impedes their development.

Post-structuralists, such as Jacques Derrida or Michel Foucault, also hold similar critiques of structuralism. But whereas post-structuralists respond to structuralism with theories on deconstruction and on destabilization of meanings, Simondon wants to theorize the genesis, or the becoming, of forms. He does not advocate a theory of formlessness. Instead, he offers a theory of individuation, which reconceives the "Good Form" energetically such that "the Good Form represents the highest attainment of stability achievable" at the lowest energetic state (Scott, 2014, p. 51). This theory relies on the concept of pre-individuality. In *L'Individuation psychique et collective* (2007), Simondon provides the following explanation about what he means by the pre-individual reality:

[14] This critique of structuralism is similar to Marcuse's concern about the alienation of humanity by the universals advocate by technological rationality.

> The individual would then grasp as a relative reality, a certain phase of being which supposes like it a pre-individual reality and which, even after individuation, does not exist all alone, for individuation does not exhaust at once the potential of the pre-individual reality and, on the other hand, what individuation makes appear is not the individual alone but the individual-milieu couple. (Simondon, 2007, p. 12; translation from Scott, 2014, p. 38)

Scott explains this passage by highlighting the incomplete being of an individual versus the complete, self-sufficient being of the pre-individual reality: "Individual must be taken as relative in two senses: first, it is not all being (*tout l'être*) and, second, it is the result of a pre-individual reality of being" (Scott, 2014, p. 38, emphasis in original). The individual is not a reality but "a relative reality," not a "being" but only a "phase of being." The reality of the individual is relative to the pre-individual reality. It is the actualization of one phase out of many potential phases held by the pre-individual being. Until the pre-individual potentiality is exhausted, the individual will have the potential to transition to another phase, to dephase. It is "only ever in metastable state, always on the cusp of individuating itself" (Simondon, 2007, p. 28; translation from Scott, 2014, p. 40). The individuation makes appear the individual together with an associated milieu, which also shares the same pre-individual reality. Therefore, the individual and the associated milieu are not isolated from one another because they are phases of the same pre-individual being. They are coupled to each other through their shared pre-individual reality.

Individuation is the continual dephasing of an individual to resolve the tension in the preceding phase. In contrast to a "Theory of Form," which "defines form's birth as the resolving of tensions" (Simondon, 2007, p. 28; translation from Scott, 2014, p. 40), the internal tensions of an individual remain unresolved until the exhaustion of the pre-individual potentiality. These tensions emanate from the tensed relations between two incompatible disparate domains. Simondon calls these tensed relations "disparations." He also explains the operation of individuation and the series of tension resolution with an "energetic theory of form-taking:"

> [T]he being of pre-individuality is itself purely energetic. The relation of a structural germ to the potential energy of a metastable state is precisely what causes the polarization; the spark of individuation is this event of disparity. (Scott, 2014, p. 41)

This description generalizes the example of crystallization presented in Chapter 1. The stick is a structural germ whereas the solution is a structurable, metastable field. The germ and the field share the same pre-individual being. The two belong to disparate domains and their mutual tensions hold the pre-individual potentiality, which makes the structurable field metastable. A catalytic event, such as placing the structural germ into the structurable field, destabilizes the pre-individual being and causes it to dephase. This event, reunifying separate shares of the pre-individual being, modulates the potential energy previously suspended by its separation of the disparate domains. As Scott points out, "[o]ne might say that the limit between the structural germ and the structurable metastable field modulates the latter's energy, causing the structure, the form, to advance" (Scott, 2014, p. 43). The energy modulation causes the pre-individual being to resume its individuation, transitioning into another phase of being. Regarding crystallization, the individuation of the new phase of being is the structuration of crystals.

Borrowing the concept of entropy from the Second Law of thermodynamics, Simondon "reconceives the Good Form *energetically*; that is to say, rather than it designating the simplest and most coherent geometric form possible, it symbolizes the state of a system's lowest, non-entropic level of energy. At this lowest energetic state the Good Form represents the highest attainment of stability achievable" (Scott, 2014, p. 51, emphasis in original). When a technical object approaches concreteness such that no further progress seems possible, it means that its genesis has "[diminished] the tensions of the system from which it appears" to the point where pre-individual potential energy is exhausted, achieving the "Good Form" (Scott, 2014, pp. 49-50).[15]

This theory of individuation provides Simondon with the tools to address the philosophical debate between nominalism and idealism. Nominalism, or metaphysical realism, argues for "the existence of individuated objects inhabiting an actual spatiotemporal reality, independent of human experience or knowledge"[16] whereas

[15] A living individual, however, is always in the process of becoming. Thus its reserve of pre-individual potential energy is not exhausted until death.

[16] For David Humes, the "perceived object exists as nothing more than the accidental accumulation of elements, whose coherence is likewise accidental, given existence by the activity of the subject's imagination" (Scott, 2014, p. 51).

idealism “makes the claim that whatever reality objects possess is given to them by the mind perceiving them; the ‘external world,’ rather than being independent of the perceiving mind, is its presentation” (Scott, 2014, p. 45). In David Hume’s version of idealism, the “perceived object exists as nothing more than the accidental accumulation of elements, whose coherence is likewise accidental, given existence by the activity of the subject’s imagination” (Scott, 2014, p. 51). In Kant’s version of idealism, the mind “is equipped with its own pure concepts by means of which it organizes the flux of sensory impressions into substances, qualities, and quantities, and into causes and effects” (Lavine, 1984, p. 183). In Kant’s famous words, “mind is the law-giver to nature” (Lavine, 1984, p. 197).

Simondon circumvents nominalism and idealism with the theory of individuation. To Simondon, “an operation of individuation (of which perception is one mode) is not a process limited to one unique domain of reality, psychological or physical, but traverses and transductively connects multiple realities, from the psychological, to the physical, the metaphysical, and the social” (Scott, 2014, p. 45). In the individuation of the subject and its perceptual knowledge with its milieu, the subject and the object belong to two disparate realities that undergo a single operation of individuation. The operation traverses and connects the reality of the subject and that of the object. As the subject “reflects her grappling with the problem of how to live in the world,” it invents new form to resolve inconsistencies between the perceived object and its structure of knowledge. This is how “the genesis of the subject and object operate on the same plane of individuation” (Scott, 2014, p. 51). The subject does not impose forms upon the physical reality, and there is no assumption about the accidental coherence between perceptual knowledge and the coherence in objectivity. Instead, the subject’s perceptual knowledge and the milieu co-evolve, and the co-evolution is possible because the subject and the objective reality are in relation to the same pre-individual being.

For example, suppose a baby is born in a family. The parents’ perception of the baby individuates along with the baby’s development, from an individual who only knows how to cry, eat, and poop, to one who can sit and crawl. During the process of the baby’s growth, the mental representation of the baby evolves while maintaining a single identity of the baby. It does not perceive multiple babies despite the change in sense impressions. If the mental representation in the parents is not flexible and does not evolve, they may go mad and perceive multiple babies. Or more likely, they may be unable to adapt to the changing demands of the baby, such as the number of feedings at a certain stage. In layman's terms, the parents ought to feel open toward the changing baby in order to adapt to its development. As this example of transductive traversals between multiple realities is also one about openness and closure, we can understand more about openness by relating it to individuation.

2.2. Individuation and Openness

In this section, I want to assess the degree of openness or closure in a relation between two realities based on how they individuate. I argue that, for two realities that share the same pre-individual being, if they individuate independently in isolation, without a process of structuration traversing between them, the relation is a closure. If the structuration of one reality influences the structuration of another reality but not the other way around, the relation is also a closure. If the operation of individuation traverses between the two realities in the structuration, but the structuration does not encounter and resolve incompatibilities, conflicts, or contradictions between the two realities, then the relation is still a closure. The relation is open and actualizes the pre-individual potentiality only when the traversal between the two realities is transductive. I shall illustrate my argument with the following examples.

To see how isolated individuations lead to closure, we can go back to the example of parents taking care of a baby. If the parents insist in giving their baby twenty ounces of milk per day because they have previously been feeding this volume, they will be unable to adapt to a baby who does not feel hungry on particular days, or has grown to another stage that requires different volume of milk. In other words, there is a disconnect between the baby's development of eating and the parents' perception of the "correct" framework of feeding. The parents' perceptual knowledge about the baby's demands is not open to the baby's genuine demands.

The relation between factory workers and machine is an example of one-way influences in structuration. We can analyze the situation as if the factory machines are physical individuals in their completed forms, or we can consider machines as conceptual individuals whose functionality still evolves through their version upgrades. As a static physical presence in an already completed form, the machine does not individuate further other than material depreciation. A factory worker individuates mentally and physically to adapt habits that conform to these machines, but not the other way around. There is no traversal of individuation between the factory worker and the machine. The one-way relation is a closure. Now, consider a factory machine as a technological concept that evolves through version upgrades. Unlike the first case, the machine does individuate. Nevertheless, the only goal of an upgrade is to maintain competitiveness in the market. The factory needs to continually optimize their operational efficiency through better management and faster machines. Factory machines individuate by becoming more efficient in speed and in productivity. Some factory owners may be more humanistic, and once in awhile, a human disaster may initiate the legal stipulation of safety requirements. But in the bigger picture, other than meeting the minimum safety constraints, the conceptual functionality of the machine evolves independently from the factory workers' growing awareness of their mental, psychological, and physical needs in their labor.

Yet, even if an operation of individuation traverses back and forth between two realities, the relation may still be one of closure. Consider the individuation of a human subject whose reasoning is framed by technological rationality as defined by Herbert Marcuse in *One Dimensional Man* (1991). Technological rationality is a self-contained formal system that is capable of coherently rationalizing matters and events in the world. The subject's structure of knowledge still individuates with the genesis of the objective reality, and its structure still evolves to resolve conflicts with the objective reality. Yet, the resolutions are structurations as extensions of technological rationality. Technological rationality is capable of expanding its form in order to adapt to the objective reality. When the subject encounters conflicts between its knowledge structure and the objective reality, it can modify its structure to resolve the conflictual tension in most cases. For other cases, it can disregard the outliers as invalid exceptions. This is analogous to Kuhn's theory of scientific progress within a paradigm. Certainly some observations are outliers to the paradigm, but they are only rare occurrences. Nevertheless, these outliers may be important indication of an alternative reality that is only explainable by another paradigm. Marcuse's social critique is similar. A formal rationality, such as technological rationality, is for Marcuse what a paradigm is for Kuhn. Marcuse argues that no formal system can capture all of the objective reality, including the most basic human values. Resolutions within the framework of technological rationality can continue to evolve with social changes. But technological rationality will systematically miss out critical aspects of the social reality that other rationalities can reveal. Unlike a transduction, these resolutions stay within the single domain of technological rationality and do not transcend across multiple domains.

There are always contradictions between different rationalities, as well as between a single rationality and the actual reality. If a subject cannot accept contradictions in its perceptual and rational horizon, it will accept only a single rationality and repudiate all others as false. In other words, it holds a closed approach to interact with the actual reality. On the other hand, if it holds an open approach to face the actual reality, it ought to accept multiple rationalities that may mutually contradict each other. Under the right circumstance, the subject can resolve the contradictions by a paradigm shift, or a dephasing of being. These resolutions go beyond the boundary of any single rationality. They are transductions that actualize the pre-individual potentiality.

Note that the pre-individual potentiality has a unique definition distinct from the ordinary meaning of potentiality. The concept assumes that the potentiality in any individual is the consequence of a pre-individual being split into heterogeneous dimensions (Combes, 2013, p. 4). The being is in a metastable state, ready to dephase when a catalytic event resolves the incompatibility between the heterogeneous dimensions. In the crystallization example, placing the stick in contact with the solution is a catalytic event that causes their pre-individual being to dephase from a metastable state to the phase of crystallization. Another example is the H_2O chemical compound, which is in a metastable state with potential to dephase into a liquid phase, a gas phase, or a solid phase. The change of temperature to zero or a hundred degree Celsius is the catalytic event that causes H_2O to dephase. Simondon describes the metastable potentiality of multiple phases as a "doubling of being" (Simondon, 2012, p. 159; translation from Combes, 2013, p. 4), as we can think of each phase as a unique subsystem governed by independent physical laws.

2.3. Individuation and Concretization

Simondon's philosophy stands on the two pillars of technical concretization and individuation (Chabot, 2003, p. 107). Concretization is the logic of technical progress (De Boever et al., 2013, p. 208). While living beings are concrete from the very beginning, technical objects are never absolutely concrete; they concretize asymptotically (De Boever et al., 2013, p. 208). In the concretization of a technical object, it becomes more coherent internally and externally. Recurrent causality with its associated milieu reduces the number of its elements. Fewer elements, each serving more functions, contribute to the object's internal resonance.

According to Pascal Chabot, Simondon has not made explicit how technical concretization and individuation are related to one other.

> Technical concretization and individuation appear to be self-contained concepts. And yet objects are created by individuals whose lives are, in turn, structured around technology. Let us leave aside the question of whether Simondon might have wished to make explicit the nature of this connection had he produced a third volume of writings. Perhaps, for Simondon, the relations between individuals and technologies were already clear. This is not the case for all of us, however. Simondon's work demonstrated that technologies follow a particular logic. It also indicated that individuation culminates in the individual's relationship with the other, with the sacred, and with the imagination. The silence that follows these two lessons is dense with questions. (2003, p. 107)

Due to this silence, there is no definite interpretation about the relation between individuation and concretization. Bernard Aspe gives one possible interpretation in *Simondon: politique du transindividuel* (2013, p. 142). Aspe distinguishes between technical objects from technical individuals. A technical object is a functional schema. It is a type obtained through the process of concretization, whereas the operation of individuation creates a plurality of technical individuals based on the functional schema of a technical object.[17] This understanding about technical object and technical individual

[17] In Chapter 3 and 4, I introduce the differentiation of "technology as a physical object" and "technology as an evolving concept." Technology as a physical object is identical to technical individual. Technology as an evolving concept is similar but not identical to the concept to technical object as a functional schema. See also footnote 29.

is analogous to object class and object instance of the object-oriented programming language in computer software. A programmer designs her software by dividing the codes into types or classes of objects. For instance, to develop a soccer computer game, a software programmer may write a class called “Player,” which holds functions such as “shoot” and “pass,” and attributes such as “name,” “height,” “weight,” “offensive capabilities,” and “defensive capabilities.” When a game player starts the computer game on the Windows operating system, the runtime process of the program instantiates the class “Player” multiple times into different soccer players. Lionel Messi and Cristiano Ronaldo may be two object instances of the “Player” class.

This software analogy may help our understanding of Aspe’s interpretation. Concretization involves an act of technical design, such as the design of the Guimbal engine. Individuation of a Guimbal engine translates this static design into a technical individual that operates in its associated milieu. This translation involves the actual construction of a Guimbal engine and the act of placing it underwater to make it operate. We can compare this description of the Guimbal engine to the example of crystallization, which I present in Chapter 1. The design schema of the Guimbal engine corresponds to the physical laws of crystallization. The act of placing the engine underwater corresponds to placing a stick in a crystalline solution. The act creates an individual of a running turbine engine and its associated milieu, which is the multi-functional water that supplies the energy to activate the turbine and the generator and evacuates the heat that is produced by the generator. While there is no transduction in the individuation of a Guimbal engine with its stable internal structure, we can identify other technical objects that transduce information to change their internal structure. For example, in the runtime memory of a social networking software program, the memory structure of the social networks dynamically changes whenever a user adds a friend. In that sense, the social networking software individuates by mirroring the individuation of the social network in real life. I shall discuss more about the transduction of technical objects in the critique of cybernetics in Section 2.6.

What does the theory of concretization reveal about the openness of technical evolution? As a technical object becomes increasingly concrete, the technical individual becomes more stable due to a simpler, more coherent design. This gives the illusion of a trend toward closure, with fewer possibilities for future changes. But a more stable technical individual does not imply that its design is rigid and unable to evolve. As Marie-Pier Boucher explains in her essay "Infra-Psychic Individualization: Transductive Connections and the Genesis of Living Techniques" (De Boever et al., 2013),

> Technological lineages develop as stability plateaus emerge within the technical environment. Once they have reached a particular saturation point in their evolution – that is, after having accumulated various micro-changes saturating their technical environment – reconfigurations occur in order to allow new exploitations and new expansions into the environment itself. Concretization as a process operates within incompatibilities that force technical objects to perform compromises between requirements in conflict. In technical evolution, incompatibilities are means for realization rather than obstacles. (p. 97)

The potentiality for future concretizations lies in the incompatibilities of the technical object and its environment. A concretization involves a reconfiguration that exploits and expands into the environment to resolve the incompatibilities. In Barthélémy's words, "the technical object calls forth an associated milieu that it integrates into its functioning" (De Boever et al., 2013, p. 217). This relation with an associated milieu is one of "recurrent causality," which is analogous to the permanent exchange between the living being and the associated milieu (De Boever et al., 2013, pp. 207-208).[18] This analogy with the living being is possible because the "functioning of the [technical] object is analogous to mental schemas that act upon one another in the subject at the moment when she or he invents the object" (De Boever et al., 2013, p. 206; Simondon, 2012, p. 138). If this analysis is correct, then the process of concretization and the operation of individuation have the same form. As a consequence, concretization is as open as individuation.

In his new book *Technosystem: The Social Life of Reason* (in press), Andrew Feenberg provides more reasons to consider concretization as an open process. In his

[18] Jean-Hugues Barthélémy explains, "With the living being, the associated milieu becomes the pole of a permanent exchange, whereas for the psycho-social personality … In so far as the 'technical individual' goes, it can be thought by analogy with the living to the extent that its individualization is 'recurrent causality' with an associated milieu" (De Boever et al., 2013, pp. 207-208).

interpretation, or "creative use," of concretization, he expands the definition of milieu from strictly physico-chemical structure to broader conditions:

> Although [Simondon] usually defines the milieu in strictly technical terms, it is unclear why it would not also include the human, social and ecological conditions of acceptability. In that case why not consider social stimuli among them? They surely qualify as "information" in Simondon's sense. For example, an already existing culture of miniaturization in Japan (think of bonsai) "transduces" the technologies of the fax machine and the calculator, initiating a new path of development. (Chapter 2)

Feenberg's innovation resolves the apparent incompatibilities between Simondon's techno-centric concretization and the school of social construction of technology (SCOT). This is why the title of the chapter is "Concretizing Simondon and Constructivism: A Recursive Contribution to the Theory of Concretization." From the perspective of Simondon's philosophy, Feenberg's innovation "concretizes," and perhaps "transduces," Simondon's concepts into a socially significant theory compatible with SCOT. Technical progress as concretization improves the technical objects' extrinsic coherence with their associated milieu. If the associated milieux include the human, social, and ecological conditions, then technical progress may lead to greater harmony between technology and these extrinsic conditions. Under the culture of miniaturization in Japan, smaller devices are more coherent to Japanese's lifestyles than bigger devices. Concretizing the culture of miniaturization into the design of technical devices opens up a new path of development for inventions. These inventions in turn reinforce the culture of miniaturization in "recurrent causality," an essential characteristics of concretization. A different culture points to an alternative path of concretization, similar to how a different set of conditions in a physico-chemical milieu point to an alternative path of concretization.

2.4. Openness of Dialectic Negation

In Simondon's theory of individuation, the actualization of potentiality is revealed in dephasing instead of in dialectic negation, which denotes "a temporal movement destined to be replaced by another" (Combes, 2013, p. 4). He appropriates thermodynamic to his theory of individuation, "[entailing] a shift from dialectic to energetics" (Combes, 2013, p. 83). He is critical of dialectic because, by making "the negative the logical motor of being[, dialectic] is incapable of perceiving the richness of the pre-individual tension between physical potentials that are incompatible without being opposed" (Combes, 2013, p. 11) Is Simondon justified in his criticism, that dialectic negation overemphasizes opposition and cannot account for richness of incompatibilities? In this section I address this question by engaging Simondon in a dialogue with Marcuse.

Perhaps due to his different grasp of dialectical theory, Marcuse's writing does not seem vulnerable to Simondon's criticism. In *One Dimensional Man* (1991) and in *An Essay on Liberation* (1969), Marcuse is critical of technological rationality, which penetrates into all areas of human life, from government bureaucracy to education to health care. This total closure "not only reduces the environment of freedom, the 'open space' of the human existence, but also the 'longing,' the need for such an environment" (1969, p. 18). Even human imaginations are reified (1991, p. 249). To liberate from this totality requires both the liberation of the reified imagination and the reconstruction of the political and technological structures that reproduce the reified imagination. As Marcuse explains, even though dialectical theory "cannot be positive" (1991, p. 252), it points to a path of liberating the reified imagination (1991, p. 249), opening the space for "the liberation of inherent possibilities" (1991, p. 254). Hence, Marcuse's dialectical theory is not only about a negation of totality, but also about deriving "an 'open space' of the human existence" from this negation. This requires a reconstruction of science and technology so that their direction and goals are aligned with "the demands of the life instincts" (1969, p. 19). An open environment allows "the free development of individual faculties," resulting in a "new type of man … an all-round individual, free to engage in the most varying activities" (1969, pp. 19-20).

Marcuse elaborates further on the reconstruction of science and technology by suggesting the inclusion of the aesthetic as a factor in the technique of production (1969, p. 26). Because reason in the form of technological rationality has been opposed to art, art was "granted the privilege of being rather irrational – not subject to scientific, technological, and operational Reason" (1991, p. 228). Hence, art can liberate the reified imagination of members in a capitalist society and bring about a new sensibility and a new consciousness, which define and communicate new values to guide scientific and technological reconstruction (1969, pp. 32-33). The key is to define such values in "technical terms, as elements in the technological process" so that they can be translated "into technical tasks–the materialization of values" (1991, p. 231). Here we arrive at the point of convergence with Simondon's theory. Simondon identifies true progress as transcending resolutions of disparate domains, and Marcuse is trying to transcend the aesthetic and the technological domains. Marcuse writes about "the aesthetic as the possible Form of a free society" (1969, p. 25). We can translate this statement into Simondon's transduction. The technocratic society transduces the form (or information according to Simondon's definition) of aesthetic, and dephases into a free society. This convergence between Simondon and Marcuse is consistent with Feenberg's argument that the social condition can be the associated milieu of a technology (see Section 2.3).

2.5. Simondon's Approach to Reduce Alienation

According to Jean-Hugues Barthélémy, Simondon sees a more fundamental "physical and mental" alienation behind Marxist social-economical alienation (De Boever et al., 2013, p. 203).[19] Muriel Combes provides the following explanation of how Simondon understands alienation:

> labor is alienating in essence... "we may define a precapitalist alienation that is essential to work as such" (Simondon, 2012, p. 248). The alienation of which Simondon speaks is thus in his view more fundamental than what he designates as "the economic aspect of alienation" (Simondon, 2012, p. 249), which he attributes to analysis in the manner of "Marxism." (Combes, 2013, p. 72)

Accordingly, the source of alienation is hylomorphism, and labor is the origin of hylomorphic schema because the schema "represents the transposition into philosophical thought of the technical operation drawn from labor and taken as the

[19] Combes suggest that Simondon perhaps intentionally ignores the dehumanization aspect of Marx's concept of alienation in order to highlight the contrast between his view and the socio-economic view (Combes, 2013, p. 73).

universal paradigm for the genesis of beings" (Simondon, 2012, p. 241). That technical operation "is a matter of the individual impressing a 'form-intention' that is of human, not natural, provenance, upon 'matter to be worked'" (p. 242). Therefore, both nature and humans are alienated when an abstract "form-intention" is impressed upon them in such a way that restricts the actualization of their pre-individual potentiality.[20]

According to Simondon, by becoming more automated and independent, modern technology gradually replaces the historical human role as "tool bearer." Simondon calls such technology a "technical individual." In its autonomy, a technical individual is not necessarily an extension or a prosthetic of the human body. This role substitution has brought psychological discomfort to humans whose "tool bearer" skillsets are threatened by modern technology. Though Simondon does not employ the Marxist social-economical definition of alienation, he recognizes the sociopolitical reality of domination.[21] By coercing workers to follow their machinery regulations, factory machines suppress the workers' humanity and therefore fail to mediate human to nature. But to Simondon, the hylomorphic schema likewise alienates pre-capitalist labor. Pre-capitalist technical inventions already coerced matter to adopt their conceptual forms. In other words, technologies are the objectification of conceptual forms that are determined by social demands or religious teleology. Even though, as Heidegger has reminded us in *The Question Concerning Technology* (Heidegger, 1993), pre-modern technical crafts

[20] In Andrew Feenberg's instrumentalization theory (2002), primary instrumentalization is the technical activity that abstract technical elements from matter in nature. Secondary instrumentalization is the integration of technical elements into a concretized individual or ensemble, and recontextualizes them into a relation with the associated milieu of the technical apparatus. The site of reducing alienation is in the secondary instrumentalization, in which technical activities can recognize the various affordances of the technical elements and the demands of the associated milieu. In Simondon's terminology, the primary instrumentalization is the site of hylomorphism because abstracting technical elements, such as extracting planks from tree trunks (Combes, 2013, p. 72), is an "[imposition of] form on passive and indeterminate matter" (Simondon, 1995, p. 49). Yet, according to Feenberg, this is nevertheless a necessary stage of all technical activities. In order for a technology not to bring alienation upon human beings, its individuation needs to respect the individuation of its associated milieu and of its elements, neither of which are necessarily already completed individuals. For instance, the milieu can be the ecological environment and the elements can be human beings such as factory workers. Therefore, the technical activity that harmonizes the technical product with its new contextual environment and with the affordances of its elements is an operation of individuation that "traverses and transductively connects" between the realities of the environment, the technical elements, and the technology under construction.

[21] See also p. 49 of *L'individu et sa genèse physico-biologique* (according to Combes p. 74)

used to appreciate the affordances and potentiality in matter and in technical elements, their hylomorphic schema on matter still suppresses the pre-individual potentiality shared across the realities in nature, in technology, and in humans.

Therefore, nostalgia and going back to the past does not truly bring liberation. Instead, Simondon recognizes "liberatory potential" in the "displacement of the tool-bearing function from human to machine" such as the "mechanization of labor processes" (Combes, 2013, p. 59). He sees the essence of technical activity in the mediation of the humans-nature relation. Technical activity "reconnects humans to nature with far richer and better defined linkage than that of the specific reaction of collective labor. A convertibility of human into natural and of natural into human is established through technical schematism" (Simondon, 2012, p. 245; translation from Combes, p. 76). A new technical object represents the "site of a new relationship to nature ... a relationship of immediate coupling of human thought to nature" (Combes, p. 76). When modern technology has evolved into technical individuals, replacing humans' historical role as tool bearers, it has brought about a new relation between human and nature. "[T]he human can be coupled with the machine as equal to equal, as a being that participates in its regulation" (Simondon, 2012, pp. 119-120; translation from Combes, p. 70). In this new relation, humans can "[exist] at the same level as machines" (Simondon, 2012, p. 125; translation from Combes, p. 60).[22] One consequence of this new relation is that "work should become technical activity" (Simondon, 2012, p. 125; translation from Combes, p. 251-252). Human workers as "tool bearers" or as a support component of an assembly line are alienated because "the alienation of the worker results in a rupture between technical knowledge and its conditions of use" and workers are "forbidden to regulate their own machines" (Simondon, 2012, p. 125; translation from Combes, p. 250). Barthélémy gives a similar explanation of Simondon's approach to reduce alienation: A reform of work allows human workers to "[take] on the task of repairing and overseeing the machines" (De Boever et al., 2013, pp. 203).

[22] Since human beings belong to nature, if technology and nature is in a non-alienated relation, so are human beings to technology, human beings to nature, and human beings to human beings. Hence Combes argue, "Simondon discerns the 'true way to reduce alienation' (Simondon, 2012, p. 249) in 'transindividual collective' as an amplifying mode of relation between humans, which is the flipside of nonservile relation to nature" (p. 77).

On this point, I disagree with Simondon that “a rupture between technical knowledge and its conditions of use” necessarily results in alienation. A pianist is not alienated in playing the piano even though she may delegate the tuning and maintenance of the instrument to a piano technician. Nevertheless, the openness of the piano seems to correspond with Simondon’s vision of technical objects as the sites of “a new relationship to nature … a relationship of immediate coupling of human thought to nature” (Combes, 2013, p. 76). A musical instrument is not only a mediator of sound, but opens up a new world of relating human thought to variations of sound. The new world is an actualization of a pre-individual being, shared by human, the musical instrument, and the physical nature of sound. Combes’ following passage suggests how humans and technical object such as the piano may share the same pre-individual being:

> [R]educing alienation means showing that technical objects are not the Other of the human, but themselves contain something of the human: the “object that comes of technical invention carries with it something of the being that produced it” (Simondon, 2012, p. 249). But it is crucial to understand that what technical invention carries is not what is specifically human in the human; it is “this charge of nature that is conserved with individual being, and which contains potentials and virtuality.” (Combes, 2013, p. 77)

In the claim that technical objects “contain something of the human,” that something is the human share of pre-individuality to which the technical objects also belongs.[23] It is “this charge of nature that is conserved with individual being, and which contains potentials and virtuality.” In this human-technology relation, neither humans nor technology dominates the other. Instead, the relation actualizes the potentiality of the pre-individual being and creates something new. In the example of musical instruments, the actualized potentiality brings about the expansion of the musical world, of how humans may relate to the nature of sound.

[23] Marcuse quotes a related passage from Simondon: “During the past centuries, one important reason for alienation is that the human being lent his biological individuality to the technical apparatus: he was the bearer of tools; technical units could not be established without incorporating man as bearer of tools into them, The nature of this occupation was such that it was both psychologically and physiologically deforming in its effect” (Simondon, 2012, p. 103, note).

2.6. Transmission vs. Transduction

Treating humans and machines as equal is an approach shared by cybernetics. Norbert Wiener defined cybernetics as “the scientific study of control and communication in the animal and the machine” (Wiener, 2007). This transdisciplinary field investigates the regulatory structure of multiple systems in distinct scientific realms by studying how the transmissions of signals between systems, such as feedback loops, regulate their stability. These systems may be mechanical, physical, biological, cognitive, or social systems. Simondon paid homage to it as the first attempt at a “study of the intermediary domain between the specialized sciences” (Simondon, 2012, p. 49; translation from Combes, 2013, p. 10). Both Simondon’s theory of individuation and cybernetics are studies about signaling that communicates multiple realms of distinct order, each operating under a unique set of physical laws. Their major distinction comes in the type of signaling. In cybernetics, a signal is a transmission of a “readymade information” (Toscano, 2006, p. 143). In Simondon’s philosophy, a signal is “information in the making” that is transduced by a system.

To Simondon, cybernetics falls under the hylomorphic schema because cybernetics separates information from matter. In cybernetics, information is ‘substrate independent’ (Toscano, 2006, p. 142). In information theory, a mathematical subbranch of cybernetics, abstract codes are extracted from disparate physical realms of specialized sciences into “information,” whose ontology is a “readymade” form that can be encoded, transmitted, and decoded by devices. For instance, both genetic data and personal web browsing data can be encoded into zeros and ones, a digital form that can be transmitted over the network, stored in the database, and decoded back to a genetic representation or data for analyzing web browsing tendencies. The digital form can represent a diversity of systems, from the human nervous system to any living or social system. As in other branches of cybernetics, these system representations are formal abstractions that disregard the systems’ concrete individuations. Therefore, cybernetics can only represent living and social systems as automatons “capable of adaptive behavior,” but not of development beyond some self-regulatory system design. This is why Simondon criticizes cybernetics in its “danger of reductionism” (Combes, 2013, p. 10).

Simondon wants to employ the definition of information as "a margin of unpredictability in a sequence of signals" in information theory[24] without falling into the trap of reductionism (Mackenzie, 2002, p. 26). He does so by developing a richer notion of information. Under this richer notion, Simondon does not regard machines in the same way cybernetic mainstreams do. Machines are not producers or consumers of information, but are transducers of information (Mackenzie, 2002, pp. 25-26). Machines, by retaining a margin of indeterminacy, can transition between numerous critical phases in their functioning. A machine is "able at certain 'sensible' instants to receive information as a temporary and variable determination" (Mackenzie, 2002, p. 26). When a machine transduces information, it converts the information into an internal signal that imparts a temporary form to the machine within its margin of indeterminacy. In other words, a metastable machine can transduce information to transition between its potential phases.[25]

We can take this concept of a machine as a transducer of information to narrate the case of the Minitel, which I previously describe in Chapter 1. As a complex system of many functionality, the original Minitel already possesses the potential to be an information hub or a messaging system. After the hack to create a publicly accessible messaging utility, and after the shifting of usage from information access to instant messaging, the internal state of the Minitel system had changed. The system transduced these hacking and users' activities, and transitioned from its original phase as an information hub into the phase of a messaging hub.

This approach also holds for any technology that is open enough to be appropriated from its originally conceived form into a contextualized form. A Neanderthal man may use a stone from nature as a weapon or as a hammer. The act of using the stone imparts the form of a weapon or of a hammer to it. Another example is the process

[24] A signal that is completely consistent with a system does inform or add anything to the system. Hence it is not an information.

[25] "[Information] supposes the existence of any system as only ever in a state of metastability and, so, always on the cusp of individuating itself ... Information displaces form. Information reveals itself through the "emergence of signification" out of a relation Simondon calls the "disparation" (Simondon, 2007, p. 28). A Theory of Form ... defines form's birth as the resolving of tensions. By necessity such a theory must ignore the very idea of metastability" (p. 40).

of bicycle invention. If we consider technology as a conceptual individual instead of as a physical individual, the evolution of a bicycle prior to concretization also underwent phase transitions between different designs. We can consider these phase transitions as the result of the technology transducing the inputs of bikers and bicycle designers. The social and technical negotiations determine the form of a bicycle out of the rich possibilities of the technical concept.

I first brought up these examples in Chapter 1 to illustrate the social constructivist concepts of interpretative flexibility and of multistability. Nevertheless, if a technology is designed to be an encoder or a decoder, but not a transducer, of information, it may provide only a single interpretation about its functionality. Consider a device that converts temperature from Fahrenheit to Celsius degree. Other than interpreting the conversion as a random number generator, there does not seem to be any other way of contextualizing this functionality in different cultural contexts. Social constructivists seem to neglect the scenarios where technology supports very limited range of interpretations or is not multistable. Simondon's philosophy accounts for such scenarios by arguing that the condition of open interpretation and multistability presume a transducing technology.

What happens internally to machines that transduce information? Machines transducing information is a special case of transduction (Mackenzie, 2002, p. 16). Simondon formulate his concept of transduction as follows:

> This term [transduction] denotes a process – be it physical, biological, mental or social – in which an activity gradually sets itself in motion, propagating within a given domain, by basing this propagation on a structuration carried out in different zones of the domain: each region of the constituted structure serves as a constituting principle for the following one, so much so that a modification progressively extends itself at the same time as this structuring operation … The transductive operation is an individuation in progress; it can physically occur most simply in the form of progressive iteration. However, in more complex domains, such as the domains of vital metastability or psychic problematics, it can move forward with a constantly variable step, and expand in a heterogeneous field. (Simondon, 1995, pp. 30-31, translation from Mackenzie, 2002, p. 16)

We can apply this definition to the examples of the interpretative flexibility of a stone, the historical process of bicycle invention, and the Minitel system. In the Neanderthal interpretation of a stone's utility, the "constituted structures" are mental concepts about the form of a stone weapon and of a stone hammer. The "propagation" is the consolidation of a cultural consensus about specific stone weapons and their usage. Regarding the bicycle invention, the "constituted structures" include both the mental concept of a bicycle as well as the physical parts making up a bicycle along with the ensemble of these parts that constitute a bicycle. In the case study of the Minitel system, the structuration may include both changes in technical structure to accommodate the heavy volume of messaging or new utilities that enhance user. The activity of propagation ranges from changes in usage behavior to changes in the technical infrastructure. As these examples show, a transductive technology individuates through its multifaceted engagement with the activities in its associated milieu. It is different from a cybernetic automaton and it evolves toward an open-ended future.

2.7. Summary

In this chapter, I begin with Simondon's critique of structuralism and hylomorphism, and explain how his theory of individuation addresses the critique. In his theory, Simondon identifies potentiality in the relation between realities that seem disjoint in appearance, but are actually connected. He conceptualizes their connection through a common being that exists prior to the beginning of their individuation, and calls it the pre-individual being. I then argue that individuation is closely tied to the concept of openness, as defined in Chapter 1. I borrow the idea of transductive traversal across multiple realities to conceptualize an open relation between two realities as a continuous and reciprocal process of communication between them, without any one side or structure dominating other structurations. The transduction actualizes the potentiality of pre-individual being and causes the being, and both realities, to dephase. I then discuss Marcuse's project of reconstructing science and technology and the attempt to incorporate the aesthetic into the project. The combination of two distinct domains converges with Simondon's theory of concretization and transduction. Simondon is similar to Marcuse in their refusal to technological nostalgia, but he proposes a unique approach to reduce alienation. This approach involves the affirmation of the continuous shift of the "tool bearer" role from humans to automated machines. This trend allows humans and machines to engage in a relationship as equal to equal, allowing the liberation and actualization of the pre-individual potentiality in humans and machines. I conclude this chapter with his critique of cybernetics, and his conceptualization of machines as transducer instead of producer/consumer of information to circumvent the danger of reductionism in cybernetics.

When Marcuse examines the liberatory potential of art in *An Essay on Liberation* (1969), he draws on concepts from contemporary art (p. 38), such as “methodical reversal of meaning” (p. 35) or “systematic linguistic rebellion” (p. 35). I shall follow this direction in the next chapter when I examine Umberto Eco’s analysis of open works of art. I shall compare Eco’s dialectic approach to Simondon’s philosophy, and discuss its relevance to the inquiry of the openness of technology.

Chapter 3.

Openness in Aesthetic Form

This chapter is a discussion on Umberto Eco's analysis of aesthetic openness in *The Open Work* (1989). In Section 3.1, I present Eco's claim that all genuine works of art are open works, along with how he distinguishes the types of openness in classical and contemporary art. (Throughout this thesis, I shall use "art" and "work of art" as including the visual arts as well as literature and music, and "art addressees" as including readers and music audiences.) I then compare his analysis to Simondon's theory in Section 3.2. In Sections 3.3 to 3.5, I combine Eco's theory of open work and Simondon's theory to analyze the openness of technology. This chapter does not cover the significance of openness in practice, which I examine in Chapter 4.

3.1. Ambivalence of Aesthetic Message

According to Eco, the aesthetic of art has an ambivalent quality absent from other messages. Other messages, such as a road sign, embody the social intention to prescribe a specific course of action. The designer is responsible to create a lucid form that sets off an intuitive reaction without second-guessing its meaning. An ambiguous design probably contributes to Steve Harvey's blunder of naming the wrong Miss Universe winner (see "Steve Harvey Didn't Ruin Miss Universe, Bad Design Did," 2015). Depending on the context, the ambiguity of an open design can confuse the addressees and lead to disastrous outcomes.

In contrast, an aesthetic message is intentionally ambiguous such that the addressees would find themselves in a situation of interpretative tension (Eco, 1989, p. 196). This ambiguity is a fundamental feature of aesthetic forms in general and "forces the addressee to approach the message in a different fashion." The ambiguity becomes “a constant source of continually shifting meanings—a source whose typical structure, begging relentlessly to be decoded, is organized so as to coordinate all the addressee’s possible decoding and force him to repeatedly question the validity of their interpretations by referring them back to the structure of the message.” Thus a work of art can be enjoyed over and over again, each time with a fresh experience and re-interpretation on top of the previous experiences. Accordingly, “a work can be considered ‘good’ only if, on direct contact, it offers us something richer, more varied, more elusive and allusive. Every time we reread Ulysses we understand things that the mere enunciation of its poetics could not have told us, and this, in turn, helps us amplify and verify the enunciation of its poetics” (Eco, 1989, p. 178). A genuine work of art is “never really ‘closed’ because even the most definitive exterior always encloses an infinity of possible ‘readings’” (p. 24).

Eco describes this “infinity of possible ‘readings’” in musical systems. For instance,

> a classical sonata represents a system of probability that makes the succession and superposition of themes easily predictable. The tonal system institutes other rules of probability, whereby the pleasure and the attention of the listener are stimulated by his expectation of the inevitable resolutions of certain tonal progressions. In both cases, the composer can repeatedly break away from the established scheme of probability and introduce a potentially infinite number of variations into even the most elementary scale. (Eco, 1989, p. 62)

When a pianist plays a classical sonata, she and the listeners are engaged in an emotional experience by interpreting the sound movement according to the conventional meanings of the tonal music system and the sonata form. They react emotionally to dissonances and resolutions, to the recurrences of themes, to modulations, and to the resolved finale. Nevertheless, the adherence to conventional systems is not absolute. Composers and pianists can “break away from the established scheme” in creative endeavors. “[C]lassical art violated the conventional order of language within well-defined limits” (p. 60). That is why listening to David Oistrakh playing the violin is a different experience from listening to Jascha Heifetz, and why Beethoven or Brahms can invent new musical forms with signature styles. Eco calls such composers “progressive musicians:”

> Suffice it to say that, despite Tchaikovsky's popular concerns, highly melodic compositions have never been able to change the viewpoint of the bourgeoisie who favoured them, whereas Brahms's "return" to the seventeenth century may have been crucial in giving music the direction it took at the end of the century. But Brahms notwithstanding, a musician can be considered "progressive" to the extent he manages to translate a new vision of the world into new musical forms. Schoenberg, in his Warsaw Survivor, is able to express an entire culture's outrage at Nazi brutality: having worked on forms for a very long time, he was able to find a new way to look at the world musically. Had Schonberg used the tonal system he would have composed not the Warsaw Survivor but the Warsaw Concerto, which develops the same subject according to the most rigorous laws of tonality. (p. 143)

According to this passage, Brahms and Schoenberg differ from composers like Tchaikovsky whose creativity remains bounded in the old musical forms. They translate their new visions of the world into new musical forms, which can express emotions that the old language is incapable of expressing. Once the addressees have understood the structural mechanism of the work, they "keep encountering new incarnations of its structure which make us realize that this is really the first time we have truly savored it" (p. 176).

Nevertheless, new musical forms will eventually run their course. Once the ambiguity is understood and "introduced into a circuit of constantly enriched perception, the work starts to lose its interest for the addressees, who have gradually grown used to it. The way of forming that was once a violation of the code has become one of its new possibilities" (Eco, 1989, p. 196). For instance, the tonal and stylistic convention of the baroque period was an invention that violated the existing musical code at the time. But once the addressees become familiar with the baroque style, they reuse the same formulae to decode meanings, and the "poetic message ceases to surprise" them. This is true even for the music of "progressive" musicians who give music new directions. An atonal system such as Arnold Schoenberg's twelve-tone system is, according to Eco, "just another system of probability" (p. 62). This static system is not structurally open like the more contemporary serial compositions, which present "a constellation of sounds that can lend themselves a variety of possible connections" (p. 62). Judging by the traditional order of conventions, this constellation of sounds in serial composition may appear to be in a disorder. But if the addressees delve into a serial composition and participate in the continuous creation of new codes of meaning, the former semantic structures decenter and partially dissolve. The dissolution facilitates “operational mobility” and create “infinite possibilities for new structures,” which turns out to be the defining characteristics of Simondon’s transduction (Mackenzie, 2002; Simondon, 1995).

3.2. Eco’s Open Work and Simondon’s Transduction

An art addressee experiences aesthetic pleasure when she discovers new codes of meanings. The condition of her surprise discovery is an open work of art with an ambivalent semantic structure.[26] Drawing from Eco’s differentiation between art genres, I categorize the openness of art into three types. The first is based on the different contexts and experiences of an addressee. The second takes place within the process of discovering a new set of aesthetic convention by an addressee. The third is the ambivalent structuration of aesthetic codes when an addressee experiences a contemporary work of art.[27]

In the first type of openness, the source of aesthetic inspiration is the renewed interpretations of a work of art under a different context. For example, a person who has undergone the atrocities of World War II can appreciate Schoenberg’s music more than post-World War II baby boomers. A person in her forties, having experienced life and death, as well as daily struggles with absurdities of all sorts, is more likely to feel the stressful tension in Brahms’s music than a teenager does. A work of art may be a static

[26] So-Young Park in *Understanding Open Works in Interactive Arts* (2006) provides an explanation on how the artist’s semantic structure meets with the addressee’ semantic structure: “The degree of openness stands at the balance between the audience’s world and the artist’s world. Each world has a social sector, which corresponds to the real world of daily life, and a personal sector, which relies on one’s imagination. The world of the audience and artist cannot see each other if they meet in their personal sectors. The two worlds overlap in the social sector. The audience suspends their disbelief and explores the artist’s imaginary world. Along the way, they try to find clues to understand the world of art. The artist should provide them with these clues.”

[27] In *Understanding Open Works in Interactive Arts*, Park distinguishes between contemplative and structured openness (p. 4). I see both as openness of some structure. Her contemplative openness is related to the openness of semantic structure. Her structured openness corresponds to the openness of a physical structure.

form itself, but when a person with growing life experiences is engaged in an emotional interaction with it, the engagement becomes a creative process of new movements in feelings. The richness of this type of aesthetic openness cannot be isolated to the work itself. Instead, it emanates from the work's coalescence with the addressee's personal history and cultural background. This coalescence of disparate domains evokes Simondon's concept of pre-individuality, which holds the potentiality of resonance between human individuals and the art form.

The second type of aesthetic openness entails the shifting of one set of conventions to another, a parallel to Thomas Kuhn's "paradigm shift" in scientific discovery (Kuhn, 1996). Throughout the process of transition from one art system to another, the human being enjoys the pleasure of discovering new codes of meanings that the old system cannot represent. Each human being goes through a non-linear path toward the discovery, and arrives at a unique set of meanings on top of a stable system of conventions. This category includes the works of "progressive" musicians who translate "a new vision of the world into new musical forms" (Eco, 1989, p. 143). According to Eco, musicologists today reject the classical theory about the tonal system. The classical theory holds that the tonal system is derived from the natural law of sounds. Instead, the current theory perceives it as culturally dependent, coherent with the feudal social order and its associated religious beliefs, political hierarchy, and scientific theories (Eco, 1989, p. 14). Poetic affect needs to resonate with the historical and cultural perspectives of the addressees. They can then internalize the work within their shared contexts with the composer. There comes a time when the prevailing musical languages, just like verbal languages, require inventions of new vocabularies and grammars to catch up with the world. Hence no music conforming to the tonal system can "express an entire culture's outrage at Nazi brutality" like *Warsaw Survivor* does (Eco, 1989, p. 143). In Simondon's terminology, the resonance is derived from the pre-individual potentiality distributed across the work of art, the human individuals, and the social milieu. Systemic conversion brings about the resolutions of incompatibilities between the previous art system and society.

Once the art community becomes familiar with the conventions of a new form, the familiarity gives rise to formulaic reactions that can be co-opted by commodification

(Eco, 1989, pp. 196-197). As the living condition changes, formulaic stylemes no longer resonate with the addressees the way they once did. They numb the addressees' aesthetic sensibility. The impact of a new system eventually runs its course. The dynamic form of contemporary art reveals a third type of aesthetic openness that breaks away from this eternal return to banal forms. Contemporary art has no well-defined form and no standard convention to decode all its meaning. There is no stable, univocal set of codes for decoding the meanings of every aesthetic message. Rather, "the main goal of [contemporary] serial thought is to allow codes to evolve historically and to discover new ones, rather than to trace them back to the original generative Code (the Structure). Thus, serial thought aims at the production of history and not at the rediscovery" (Eco, 1989, p. 221). The addressee is supposed to discover the code within the work itself. In her interaction with the contemporary art, the addressee actively participates in the production of new meanings that violate conventional rules. Some sceptics criticize that contemporary art brings about the "death of art" (Eco, 1989, pp. 170-174). Eco responds to the criticism by delineating the authentic aesthetic experience in contemporary art literatures: "Once we have understood the structural mechanism of the work and have summoned up enough courage to venture into the pages of the book, we keep encountering new incarnations of its structure which make us realize that this is really the first time we have truly savored it" (Eco, 1989, p. 176).

In Simondon's terminology, the system of meanings in contemporary art is structurally metastable. The contemporary artists cannot anticipate how her works may inspire addressees to conjure up new semantic structures. Addressees create new semantic structures that spawn further structuration. This structuration is a transductive operation, in which "each region of the constituted structure serves as a constituting principle for the following one" (Simondon, 1995, pp. 30-31, translation from Mackenzie, 2002, p. 16). A contemporary art and the semantic structure of a human subject are analogous to the stick and the crystalline solution in Simondon's prototypical example of transduction (see Section 1.5). The contemporary art, embedded with the artist's intention and an incomplete decoding scheme, serves as the catalyst of transduction. The semantic structure of a human subject is a structurable metastable field. When an addressee first encounters a work of contemporary art, she starts by exploring the clues of an incomplete decoding scheme. When the exploration begins to resonate with her aesthetic sensibility, the structuration of her semantic structure begins. This moment of aesthetic resonance is analogous to the insertion of a stick into a crystalline solution. Both are the beginnings of a process of structuration that does not stop unless the catalyst is removed from the structurable field. Like a living being, both are related to a pre-individual reality with inexhaustible potentiality. In contrast, the pre-individual potentiality for a classical art form becomes exhausted at the point when addressees can only accept pre-established formulaic decoding schemes.

The creative experience of an art addressee is comparable to that of an artist. When an artist initially conceives a work of art, she also experiences a transduction of semantic structures. Eco describes this process of initial conception by referring to the proposal of "forming form" by Luigi Pareyson:

> [A] work exists from the very start as a "cue," a germ that already possesses within itself the possibility of expanding into a complete form ... But this "germ" acquires a value—that is, assumes all its qualities and becomes fertile—only if it is grasped, understood, and appropriated by a person. A brush stroke, a musical phrase, a line of verse ... are all germs of forms which, by the mere fact that they are and exist as the premises of future configurations, presuppose the coherence of organic growth. (Eco, 1989, p. 162)

This depiction matches Simondon's theory of individuation. The "germ that already possesses within itself the possibility of expanding into a complete form" is analogous to the catalyst of a transductive operation because it is a "premise of future configurations" and "presuppose[s] the coherence of organic growth." It holds a share of the pre-individual being, which awaits a human subject to grasp, understand, and appropriate it. When an artist is inspired with "a brush stroke, a musical phrase, a line of verse," under a specific personal and social context, the germ resonates with and transduces the artist's inner world of imagination. Contemporary art is simply an attempt to democratize this aesthetic experience for the addressees.

3.3. Openness in Technology

After the preceding discussion on open works of art, I now want to appropriate the findings to the technological realm. From the perspective of political democracy, the openness of technology, as a product form or as an evolving concept, is concerned with who holds the power to make technical decisions. If the associated milieu of a technology is the human or social conditions (see Feenberg's interpretation of Simondon in Section 2.3), then its lineage of technical inventions may be concretizations of conflicts between inventors and relevant social groups. In such cases, the more distributed is the power, the higher the degree of openness. In other words, for technologies immediately associated with a social milieu, democratic participation leads to a more open technical product or process.[28] Conversely, if the power is concentrated solely in the product suppliers or in the state bureaucracy, the human-technology relation is a closure. In the contemporary context of the capitalist economy, we can rephrase the question of openness as follows: How far may the power of decision-making shift toward the consumers? For example, regarding technology as products, there is the power shift in the increased flexibility of computer software to configure and to personalize, or a hockey skate that forms around a unique foot shape after a break-in period. Regarding technology as an evolving concept, openness is concerned with lowering the typical barriers-to-entry in manufacturing and in the control of technological standards. In both perspectives on technology, users play an increasingly active role, instead of a passive one, in modifying the product.

I want to combine this democratic perspective of openness with Eco's analysis of aesthetic openness. Can we appropriate Eco's analysis of art to technology? According to Eco, all genuine works of art communicate messages that are essentially ambiguous, and such ambiguities are the source of openness. But certain technologies, such as a traffic light, ought to be univocal with minimal ambiguities. Is technology necessarily prescriptive with univocal messages? If not, in what ways can technology be

[28] This is very similar to the Eric von Hippel's ideas in *Democratizing Innovation* (2005).

ambivalent? I address these questions by first regarding technology as a physical object, and then technology as an evolving concept.[29]

In *Where are the Missing Masses? The Sociology of Mundane Artifacts* (2010), Latour explains that “nonhuman delegates prescriptions” where “[p]rescriptions is the moral and ethical dimension of mechanisms ... no human is as relentlessly moral as a machine” (p. 157). Latour gives examples such as a hydraulic door or a speed bump to explain how human morality is often subconsciously governed by the acceptance of certain technologies and technical standards. This analysis describes a prescriptive technology that ought to be simple and univocal, affording minimal ambiguities in the available course of users’ actions. Nevertheless, not all technologies are prescriptive. As discussed in Chapter 1, computer software such as word processors or operating system does not prescribe users’ activities even though they prescribe basic actions, such as a menu item to save a file, to support the open activities. In fact, in most aesthetic activities, such as playing a musical instrument or painting with a brush, artists are also users of technical artifacts. Therefore, the openness of a work of art is applicable to the design of such non-prescriptive technology.

In the consideration of technology as an evolving concept, the social-constructivists have argued convincingly against technological determinism with their empirical case studies (see reference to Bijker et al. in Chapter 1). The interpretation of technology is flexible, and the concept of a technology evolves through a series of negotiations over controversies between inventors and potential users. Every negotiated decision is a resolution of conflicting social concerns, a concretization of incompatible disparate domains. The decision is encoded in the conceptual form of the technology.

[29] In Section 2.3, I refer to Aspe’s work, which differentiates between a technical object from a technical individual. Technology as a physical object is identical to technical individual. Technology as an evolving concept is similar but not identical to the concept to technical object as a functional schema, because the former includes both the functional design and the interpretation of the social meaning of the technology. In addition to this minor difference, I decide not to use the terms “technical individual” and “technical object” as defined by Aspe in Chapter 3 and Chapter 4 for my analysis for the following reasons: (1) Aspe’s definition is far from self-evident from the etymology of these terms, (2) the correctness of Aspe’s definition, the correctness of which is not a certainty, and (3) other scholars may interpret the terms differently.

Since these decisions are not pre-determined, the evolutionary trajectory of the technology is ambivalent. Therefore, it is possible to study a technical evolution by referring to Eco's aesthetic openness or Simondon's transduction. In the following, I shall compare a technical evolution to the three aforementioned types of openness in work of art: interpretative flexibility, systemic conversion, and continuous structuration. I shall also adopt Simondon's theory to further analyze each comparison.

3.3.1. Interpretative Flexibility

Among the three types of aesthetic openness, interpretative flexibility is shared most clearly by both art and technology. In either realm, interpretative flexibility results from the unbounded possibilities of social contexts. Neither art nor technology can communicate meanings if they do not stand above a cultural horizon, which varies across space and time. A twenty-first century American hears a different Beethoven in comparison with a Viennese in the early nineteenth century. A stone may signify a paperweight to a writer or an Acheulean hand axe to an anthropologist (Ihde, 1990, pp. 68-69).

Are there situations where a technology or a work of art is devoid of interpretative flexibility? In order to bring a meaningful technical concept into being, interpretations of technology need to identify technical affordances that resonate with the social context. For instance, the technical affordances of an obsolete typewriter cannot be reinterpreted to serve other purposes in today's context. With no alternate meanings that resonate with its affordances, a technical object affords no interpretative flexibility.[30] This resonance is the same as the one during the early adoption of a new technology, where a user community co-evolves with a technology in growing resonance. When end-users adopt a new technology, they appropriate the design intention of the technology provider by imagining their own contextual interpretations. Some of these interpretations are fed back to the next round of technical design. This cycle of negotiations between end-users and technology providers repeats in a co-evolutionary process. In Simondon's

[30] In Section 4.1.3, I argue that a more concretized technology, such as a typewriter, becomes less flexible to interpretation if we assume that no change is made to the technology.

terminology, interpretative flexibility presumes a pre-individual potentiality in the disparate domains of technical development and social needs. An interpretation is one possible resolution of incompatible disparate domains. It is a new mental structure that resonates between technical affordances and social needs.

For a work of art to convey meanings, it also needs to resonate with the addressee's personal experience and cultural context. Due to the essential ambiguities in art, recontextualizing the artist's original intention, in comparison with technical intention, seems much less constrained. For instance, two different lyrics can impart opposite meanings to the same melody. Nevertheless, the quality of an aesthetic experience is higher if the lyrics match the semantic structure of the melody. Likewise, the resonance between a work of art and addressee's interpretation deepens her aesthetic satisfaction. In Simondon's theory, the disparate domains are the addressee's system of meanings and the ambivalent codes of a work of art. The resonance corresponds to the series of transductive resolutions of the incompatibilities of the disparate domains. These resolutions lead to the development of the addressee's semantic structure.

Once the ambiguities of a work of art have been absorbed into a standard system of meanings, such as in formulaic stylemes, addressees are left with a univocal interpretation. In this closure, addressees can no longer experience aesthetic pleasure when they reuse formulaic coding to decode the meanings in works of art. In Simondon's terminology, the semantic structure has become a homogeneous system without incompatible disparate domains. Such a homogeneous system is devoid of potentiality. Addressees use the same formula to interpret even when the contextual circumstance of the addressees has changed. They no longer experience the aesthetic pleasure of inventing interpretations, since such pleasure comes from the transduction of the semantic system.

3.3.2. Systemic Conversion

The second type of aesthetic openness arises during the transition from one system of meanings to another. The technological counterpart is the dialectic negation of one technological system by another. The openness does not emanate from the new system, but from the process of transition. It does not rely on the degree of openness in the new technological system. Instead, it corresponds to a state of temporary freedom when the old system is overthrown. In art, the state of temporary freedom allows the reconstruction of new semantic structures. In technology, it makes feasible the birth and the genesis of new technical concepts that replace the old ones. Prior to the transition, the old system may be a closure such that art addressees and technology users cannot recontextualize or modify it. The introduction of a new art genre or a new technological system challenges the old system. The challenge results in tensions between the new system and the semantic structures accustomed to the old system. These tensions are, in Simondon's terminology, between incompatible disparate domains that await resolutions. Aesthetic resolution resonates with the addressees' context, giving them aesthetic pleasure when they acquire a new system of meanings to embrace the new art genre. Technological resolution resonates with the users' context and transduces the semantic structure of their technical culture, resulting in a more harmonized human-technology relation.

The limitation of systemic conversion on openness in art is also applicable to the openness of technology. As I allude to Eco's argument in a preceding section, once the addressees become familiar with the new system of meanings, the familiarity gives rise to formulaic reactions. Therefore if the new system is essentially a closure like the old one, revitalizing aesthetic openness requires another systemic conversion. This cycle can go on forever in an eternal return to a temporary closure. The same argument holds for the technological realm. Over time, users adapt their behavior to the novelties of a new technology. In Akrich's wording (see footnote 7), their habits gradually conform to the "scripts" inscribed in the technology. Similar to formulaic stylemes in art, technology has become a "black box" and users stop interpreting, or "de-scripting," its meanings.

Since the openness of contemporary art addresses this limitation of systemic conversion, I want to investigate the possibility of a similar openness in technology. As I argue earlier, Eco's interpretation of the openness of contemporary art reveals a continuous process of structuration that is similar to Simondon's transduction. Therefore, in my inquiry, I specifically discuss the continuous structuration in technology and relate this operation to the Eco's and Simondon's theories.

3.3.3. Continuous Structuration

The semantic structure of contemporary art is stable enough to communicate effectively and yet metastable to entice further structuration. Systemic conversion removes the entire structure of the old system and constructs a new one. The structuration in contemporary art goes through a similar process of removal and construction, except they occur at a smaller scale and more often. For a technology to undergo a similar structuration, it must support the affordance for end-users to modify its structure at a miniature scale.[31] The affordance shifts a fraction of the decision making power on determining the path of technical evolution from suppliers to end-users.

The nature of the affordance is different between technology as a physical object and as an evolving concept. As a physical object, the affordance is concerned with how malleable is the object. Examples include the availability of tools to give forms to matter, the possibility for end-users to rearrange mechanical parts or hardware components, the availability of lower level application program interface (API), as well as unintended security holes for hackers to penetrate. As an evolving concept, the affordance is concerned with how democratic is the process of making technical decision and of contributions to technical standards. ISO Manufacturing, CMMI, IOS App Store, and the open-source software collaboration model afford different levels of end-user contributions.

From the perspective of Simondon's philosophy, the disparate domains are the specific living context for users and a technology encoded with intentions that are incompatible with the context. These domains are similar to those that lead to systemic conversion, even though what motivates systemic conversion may be a total closure. If the technology, as a concept or as an object, is malleable for adaptation and

[31] This idea is similar to Graeme Kirkpatrick's critique of computer on the importance of transparency to lower-layer programming interfaces (Kirkpatrick, 2004).

recontextualization, a reform of the substructure, instead of a revolt of the whole system, is probably enough to resolve the incompatibilities. One example is the concretization of Guimbal turbine that I describe in Chapter 1. If the technical structure supports no affordance for users to hack and modify, then only a dialectic negation of a revolt, a systemic conversion, can bring resolution. I further elaborate technical affordances to structuration, as a physical object and as an evolving concept, in the Section 3.4 and 3.5.

3.4. Continuous structuration in Physical Forms

In Simondon's theory of individuation, one of the conditions for transductive structuration is the presence of a metastable, structurable field. Therefore, we ought to ask the question, what makes a technology metastable and structurable? At the same time, if the structuration exhibits the same characteristics as the evolving system of coded meanings in contemporary art, what are some technical examples of new structures challenging and replacing the old? In the following, I first examine the malleability of industrial manufactured products and computer software on the question of structurable technology. I then look into the similarities between the spirit of hacking and the challenges to conventional meanings in contemporary art.

An industrial manufactured product has a hardware form that typically yields little flexibility for users to mould or reconstruct into other shapes. Nevertheless, there are exceptions. For instance, the inner holder in a hockey skate is composed of malleable material so that it can be moulded to a skater's foot. The material is malleable when heated. For skates to break in quickly, a sales representative can heat up newly purchased skates in an oven and then asks the customer to wear them for a few minutes. While a hockey skate construction needs to be sturdy and stable to withstand the impact of blocking shots, a malleable foot holder can custom-fit unique foot shapes. Another example is a plastic construction toy such as Lego. A child can assemble Lego pieces in many ways, constructing objects such as vehicles or buildings and taking them apart again to make other objects. Lego bricks, because of their feature to interlock with other pieces, allow a child to translate her mental construction into a physical form. Even though each plastic Lego brick is not made up of malleable materials, a collection of bricks is a structurable field. A third example, related to the second, is a hardware ensemble that can be broken apart into mechanical parts. Computer hobbyists can disassemble computer internal hardware and then reassemble them. These hardware hackers can experiment the effect of replacing integrated-circuit chips or other components on performance and stability.

Computer software is structurable in similar ways to industrial products. End-users do not have the means to modify a compiled software executable or a runtime application service. Yet many of these software and services are configurable so that users can customize them to match specific contexts. In some software, such as a speech recognition engine, the user can train the software to recognize her sound wave to improve the accuracy of speech recognition. This malleability and adaptability is similar to the malleable inner holder of a hockey skate. Analogous to Lego toys are software libraries or application services that support application-programming interfaces (API). Similar to computer hardware hobbyist, software programmer hobbyists can develop software applications using the APIs available on different operating systems or networking environment. If they can access the software code of a program, they can break it apart and reconstruct a version to their liking, comparable to a child who breaks apart a Lego ensemble and makes other objects.

After having discussed some examples of structurable fields in industrial and computer technology, I now turn to the operation of structuration. While a structurable field is an essential condition for structuration, it does not necessarily lead to the type of continuous structuration in contemporary art. The APIs or the Lego bricks support an unbounded open space for human imagination, but designers of library functions or Lego bricks' shapes may also inscribe their intentions to influence imagination within this space. In this regard, they exhibit traits of both bounded and unbounded openness, similar to musical and linguistic systems. Analogous to the closure of formulaic stylemes in art, when this open space is saturated with another layer of detailed conventions, formulaic reactions replace human imagination. The technical environment turns into a closed environment.

The openness of contemporary art comes from challenging these formulaic stylemes, rules and conventions. In the age of social media, derivative works such as Internet memes bring to mind this spirit of challenging conventions. They hijack the original intentions of images or videos to express satirical messages. Appropriating Eco's analysis of contemporary art, such violations of intentions are the sources of aesthetic pleasure because they invigorate open interactions that generate new meanings. The structurable field is the constellation that consists of digital representation of images and videos, software editing tools such as Photoshop, and the social media. Users can manipulate digital copies and easily spread them to others in this structurable field. As Internet memes spread around the Internet community, they gradually acquire recognizable tendencies such as the association of absurd utterances by politicians with a well-matched dialogue from an old movie. The banal forms may be no different from formulaic stylemes in art. Nevertheless, by associating them with the latest social absurdities, Internet memes continue to engender new meanings to media sources. The inexhaustible varieties of social events fuel the creativity of such derivative works.

Similar to Internet memes, a hacked software program or web site reflects hackers' playful attitude against establishment. This playfulness liberates hackers from the mentality of strictly following institutional standards, guidelines, or methodologies. The hacking activity may penetrate the security holes in a machine or a software application, resembling the way contemporary artists and their addressees experience the destabilization of aesthetic conventions. The possibility of hacking activities presumes a hackable system, which corresponds to the actual work of contemporary art. A hackable system is a structurable field in Simondon's terminology. It may be a complex ensemble of mechanical parts that technical experts have the know-hows to disassemble, or software with proprietary APIs or discoverable vulnerabilities in programming logic. In Andrew Feenberg's account of the Minitel (see Chapter 1), some hackers converted a technical support feature into a publicly accessible service. This hack detached the messaging component from the technical support module and redeployed it in a publicly accessible realm. The detachment is only possible if the component was originally designed to be a reusable independent component, decoupled from the technical support code and redeployable elsewhere based on a lower layer API. In that sense, a hackable system like the Minitel is a structurable field. The hacked messaging service resonates with users' demands, leading to its popular adoption. This result is a continuous structuration of the co-evolution of user behavior and technology.

Alexander Galloway underscores the importance of hacking activities to resist the total control of technological standard and protocol. In *The Exploit: A Theory of Network* (Galloway & Thacker, 2007), he argues that a decentralized network of power distribution is not necessarily less hegemonic than a centralized network:

> The rhetoric goes something like this: Technological systems can be either closed or open. Closed systems are generally created by either commercial or state interests—courts regulate technology, companies control their proprietary technologies in the marketplace, and so on. Open systems, on the other hand, are generally associated with the public and with freedom and political transparency ... in his elucidation of Castells, Lovink writes of the opposite, a "freedom hardwired, into code." This gets to the heart of the freedom rhetoric. If it's hardwired, is it still freedom (Galloway & Thacker, 2007, p. 125)?

A network participant is free as long as it conforms to the standard protocol. In that sense, a conformist freedom is hardwired into the standard protocol. Theoretically, whoever determines the protocols can alter the meaning of freedom. Though no node or hub dominates others in a decentralized network, hegemonic control takes the form of protocols. A networking protocol, acting as a background environment, can still prescribe behaviors. Even without any node acting as a power center, inscribing formal biases onto the protocol standards can exert controls.

Galloway further argues that, "it is not a contradiction to say that in societies of control there is both an increase in openness and an increase in control" (Galloway & Thacker, 2007, p. 73). The "increase in openness" gives people access to content, information, or software code that were previously proprietary.[32] But the open access gives only an illusion of freedom. Those who have access to manipulating the protocol can encode it with formal bias to introduce concealed advantages to certain network nodes. A node-to-node resistant tactic is no longer effective within an information network under protocological control. A more fitting tactic to bring participants liberation

[32] Note that I define of "openness" as conditions for liberating potentiality (see Chapter 1). This definition is different from Galloway's definition of openness as transparent access.

is to hack protocols with counter-protocols such as computer viruses, which take advantage of technical standardization to propagate through the network (p. 84). The tactic is possible because informatics spaces, with bugs and holes as by-products of their technical complexity, are vulnerable to penetration. Hacking does not “center around changing existent technologies but instead involve discovering holes in existent technologies and projecting potential change through those holes” (p. 81).

Is protocological control of a networking environment more life penetrating than control from above? Galloway gave examples such as Internet surveillance. But while many scholars agree about its significant impact on users (for instance, see *The Googlization of everything: (and why we should worry)* (Vaidhyanathan, 2011)), Internet surveillance is unrelated to the control of network protocol standards. Instead, it is based on the control of the network infrastructure and rides on the popularity of the network. Instead of the network protocol engineers, it is the Internet Service Providers, online advertising agents, search engine service providers, and social media web sites that are susceptible to conducting Internet surveillance. In that sense, all widely adopted technologies have similar potentials for technocratic control. Examples include vendors that monopolize the operating systems of personal computers or smartphones. Galloway considers the dominating market share of Microsoft Windows as an example of dominating a network. But this consideration conflates sales distributions with network technologies, and obscures the control of network protocol standards with the control of the network infrastructure. Based on my previous argument in this thesis, a network protocol is comparable to the design of Lego toys or a software library. They all facilitate creative freedom within certain boundaries. With regard to the Internet, the Open Systems Interconnection (OSI) model of its network protocols follows the design philosophy that the content of one layer is independent of the content of another layer. The design of the Transport Control Protocol (TCP) has no restriction over the design of application protocols such as Hypertext Transfer Protocol (HTTP) or File Transfer Protocol (FTP). Evidently, the concerns over Internet surveillance or net neutrality have more to do with the infrastructure set-up than the protocol design.

3.5. Continuous structuration in Evolving Concepts

Criticism of protocological control is perhaps more applicable to the standardization of technical development and production process. Unlike an OSI network protocol that leaves open the design of upper layer protocols and network applications, the Taylorism in Capability Maturity Model Integration (CMMI) or International Organization for Standardization (ISO) prescribes many rules that aim at minimizing contingencies, such as the judgement of a skilled worker. Here, while an OSI network is empowering for creative network, Taylorism stymie creativity. The "protocological control" of these operation standards is "encoded" with deskilling. By introducing this formal bias against craftsmanship, capitalists gain better control of the development and production process and more leverage in their salary negotiation with the laborers. Of more importance to the question of openness is the loss of craftsmanship that discourages creative contributions by the laborers. If well-defined standards dictate the processes from development and production to distribution and usage patterns, the social structure offers little room for new conceptualization of technical products. Entrepreneurs may generate new technical concepts but their products must conform to the standardized space of technology.

Nevertheless, in contrast to industrial products, new technical concepts of computer technology often emerged beyond futurists' anticipation in the past few decades. In addition to their more open design philosophies such as the aforementioned OSI model, I want to discuss two other drivers behind the continual technical evolution of computer technology: Moore's Law and the planned obsolescence of capitalism. The following is a discussion on how these drivers affect the openness of evolving concepts of technology.

Moore's law refers to Gordon E. Moore's forecast in 1965 that the number of transistors in an integrated circuit (IC) increases exponentially with time. Its implication is the exponential increase in speed and reduction in size of an IC and of devices composed of IC's. The prediction has proven to be accurate up until now. With Moore's law in effect, today's constraints will no longer be valid in the near future. In Simondon's concretization, a technology evolves by becoming more concrete, more coherent internally between its elements and externally with its associated milieu. But the coherence with the associated milieu breaks down if the milieu's properties have changed. This is the case with changes of the social milieu and also of the technical milieu. Moore's law drives the changes of the technical milieu associated with transistor-based products. When technical elements such as IC's can be replaced with more efficient elements, former constraints that led to previous concretizations may no longer hold. An ingenious concretizing design may become obsolete and redundant. Meanwhile, new technical possibilities emerge. Technologies lose their concreteness and resume another round of technical progress.

Some may argue that planned obsolescence of capitalism is the true driver behind changing technology. According to this view, technology providers intentionally develop schemes to entice consumers to upgrade their technical products prior to material depreciation. For instance, I bought an iPhone 3GS in 2010. To keep the phone functional with good performance, I stopped upgrading the operating system after a couple of years because the processor of an iPhone 3GS is too slow. This strategy worked until a couple of years ago, when the web browsing engine and the Youtube applications are no longer compatible with their new networking standards. Upgrading the operation system is the only way to upgrade of these two applications. So even though the hardware of my iPhone 3GS properly performs its functions, I can no longer use these two essential smartphone applications.

I concede that planned obsolescence plays a part in the unnecessary technological upgrades that consumers feel compelled to follow. Nevertheless, new technical inventions seem to emerge more frequently and abundantly in computer technology than in mechanical or electronic technology, even though both technical markets are under the same influence of planned obsolescence. The impact of new technical concepts is evident in the history of computer technology. There were market phases in which Microsoft Inc. monopolized the software market because they dominated the market share of operating systems on personal computers. But while everyone in the industry of information technology anticipates changes, few visionaries can truly anticipate the next big things. All the marketing hypes surrounding the next killer applications are as accurate as the daily horoscopes or Wall Street's forecast of the stock market trend. Because of this unpredictability, few killer applications are commercialization of well-funded research in institutions such as Microsoft Research. Often, the entrepreneurs innovate these technical concepts and bring them to the consumer market. This essential unpredictability of computer technology prevents one technical regime from sustaining their hegemonic domination, leaving the opportunities for entrepreneurs to succeed. For instance, Microsoft was not the first mover in entering the markets of web browsers, search engines, or social media sites. They failed to translate their domination of the Windows operating system into the markets of Internet technologies. In other words, due to the metastability of technical products under the effect of Moore's law, the domination of technical standards and their associated milieu is always temporary. Therefore, the field of computer technology is generally metastable and will periodically dephase into other modes of being.

3.6. Summary

In Chapter 1, I classify openness into bounded and unbounded openness. Using this classification, I now summarize Eco's differentiation between classical and contemporary work of art, as well as the analogy with technology. An established tonal or atonal musical system or verbal languages are open environments based on simple rules or conventions. These environments exhibit both bounded and unbounded openness. They are bounded by some simple rules, but they inspire creative human experience without bound. Nevertheless, when the environment's pre-individual potentiality is exhausted, the openness turns into a closure. This is the case when every artistic expression within an art system turns into formulaic stylemes. Appropriating these ideas to technology, technical environments provide an unbounded open space for human imagination, but designers can also inscribe their intention to shape human imagination within this space. When this open space is saturated with another layer of detailed conventions, imaginations give way to formulaic reactions. The technical environment becomes a closed environment.

When a catalytic event triggers a significant turn that gives new direction to music, the resulting process of generating new musical forms is an open genesis of the musical language. The transition in systemic conversion, in art or technology, is one type of unbounded openness. Contemporary art exemplifies another type of unbounded openness. It solicits the addressees to dialectically repudiate systemic and formulaic boundaries and to actively participate in generating infinite possibilities for new structures. Concerning technology as products, hacking activities and Internet memes exhibit the same spirit as contemporary art. At the same time, due to Moore's law, the genesis of computer technology is essentially metastable, in contrast to industrial products such as electronics and mechanical devices. The development of coded meanings in contemporary art, hacking activities, along with the evolutionary path of computer technology, resembles the metastable structuration of individuation in the actualization of the pre-individual potentiality in Simondon's philosophy.

Chapter 4.

Openness in Practice

In this final chapter, I switch my focus from philosophy to praxis. In Section 4.1, I begin by reviewing the characteristics of openness in a product development process and in a technical product. I then propose an approach to design an open technology by integrating the key concepts in previous chapters. In Section 4.2, I discuss the value of openness under different circumstances. Openness is not necessarily a desirable attribute for all technologies. For example, it would be disastrous if drivers and pedestrians have different interpretations of traffic light signals. I want to understand for what types of technology is openness a desirable attribute. In Section 4.3, I refer to the work of Eric von Hippel on democratizing innovation and compare my theory and design approach on openness to the trend of user-centered innovation. In Section 4.4, I venture into the political landscape and differentiate the continuous structuration of technological openness from the continuous revolution of the Cultural Revolution in China. In Section 4.5, I summarize the main ideas in this thesis and recommend possibilities for future research.

4.1. Designing an Open Technology

Drawing from the preceding chapters on Simondon and Eco, an open technology has the following characteristics. It co-evolves with the social or human reality. The co-evolution follows a non-linear path beyond one's anticipation. The realities do not move toward a formless disorder. Instead, borrowing from the terminology of Pareyson and Simondon, they evolve transductively as "forming forms" (Eco, 1989, p. 162), with "each region of the constituted structure serves as a constituting principle for the following one" (Simondon, 1995, pp. 30-31, translation from Mackenzie, 2002, p. 16). Generalizing Eco's theory on the open work of art, I classify three types of openness: systemic conversion, continuous structuration, and interpretative flexibility. All three types pertain to evolution in structuration, whether the structures are contemplative or physical, ephemeral or enduring. The openness of systemic conversion emanates from the transition process between the old and the new system. It is not contingent on the degree of openness in the old or the new system. In fact, a systemic conversion is more likely to occur if the incumbent system is a technological closure.[33] Hence, designing an open technology is irrelevant to the likelihood of systemic conversion, but crucial to the openness in continuous structuration and in interpretative flexibility. The condition for these two types of openness is the presence of a structurable field that is metastable, and of potential catalysts that resonate with the field. When a metastable field encounters a catalyst that belongs to a disparate domain, it is ready to dephase into another mode along with the catalyst. The dephasing is possible due to the a priori resonance between the field and the catalyst. Simondon uses the concept of pre-individual reality to represent this a priori relation between the two disparate domains. When the structurable field meets the catalytic germ, the field and the germ dephase into another mode under which structuration takes place.

Based on these characteristics, I now propose a design approach for developing an open technology. The goal of the approach is to guide technical designs into producing technologies that co-evolve with the social or human reality in non-linear paths. The key components of an open design are a metastable, structurable field and potential catalysts. Depending on the circumstance, a technology may either be a metastable field or a catalytic germ. On the one hand, we may consider an open operational environment or an open technical product as a metastable field. The corresponding catalytic germs are human ideas. On the other hand, if our goal is to design a technology with open interpretations of its potential usage, the semantic structure of a human subject or of a social milieu is the metastable field. A new technology or a modification of an existing technology is a possible catalyst that induces the human semantic structure to dephase and to further evolve. For each of these scenarios, I present an independent approach to foster openness in technical

[33] We may argue that, by bringing a system into a closed totality, the illusion of freedom through reforms vaporizes. So it speeds up the historical process of dialectic negation, as long as the closure does not blind the community from being aware of alternatives.

development. In Section 4.1.1, I describe the model of craftsmanship for an open product development process. In Section 4.1.2, I then propose a design methodology for developing a technical product with an open physical form. In Section 4.1.3, I explain the necessary conditions for flexibility in the social meanings of a technical product.

4.1.1. Metastability of a structurable technological process

What makes an operational environment a structurable field? A rigid, formalized procedure, such as the industrial production process of ISO or the software development model of CMMI, is not as structurable and metastable as a craftsman's workshop. In *The Craftsman* (2008), Richard Sennett argues that craftsmanship cannot be encapsulated into any formalistic axioms. In contrast, he defines a craftsman's workshop as

> a productive space in which people deal face-to-face with issues of authority. This austere definition focuses not only on who commands and who obeys in work but also on skills as a source of the legitimacy of command or the dignity of obedience. In a workshop, the skills of the master can earn him or her the right to command, and learning from and absorbing those skills can dignify the apprentice or journeyman's obedience.

Skills of the master, not an objective formalized procedure, hold the authority. To illustrate, he describes the workshop process of famous violin maker Antonio Stradivari (Sennett, 2008, pp. 75-80). Stradivari was all over the workshop, "popping up unexpectedly everywhere, gathering in and processing those thousands of bits of information that could not signify in the same way to assistants who were doing just one part" (Sennett, 2008, p. 78). No one, not even Stradivari's sons, could reproduce the sound quality of Stradivarius violins. Scientific analysis and replications have also failed. According to Sennett, a rediscovery of Stradivari's craftsmanship is only possible if some researcher travels back to Stradivari's time and records every moment of his work:

> Missing in these analyses is a reconstruction of the workshops of the master—more precisely, one element that has irretrievably gone missing. This is the absorption into tacit knowledge, unspoken and uncodified in words, that occurred there and became a matter of habit, the thousand little everyday moves that add up in sum to a practice. (Sennett, 2008, p. 77)

Therefore, no one can abstract Stradivari's tacit knowledge into a written guide. Abstract guidelines tend to oversimplify a craftsman's tacit knowledge. Such knowledge captures innumerable mistakes and successes throughout a lifetime of hands-on experiences. A formalized operational process suffocates a craftsman's freedom of applying his or her tacit knowledge. This distinction between abstract rules and craftsman's tacit knowledge is similar for other crafts, such as the programming skills to build and maintain a Linux operating system (Sennett, 2008, pp. 21-27).

Modelling after Sennett's depiction of a craftsman's workshop, an operational environment is structurable and metastable if its operations are loosely defined and subservient to the authority of the skilled workers (Sennett, 2008, p. 246). Whereas an operation conforming to a detailed standard often hinders their works, a loosely defined operation grants them the freedom to customize the details of the operation. A loosely defined operational environment ought not be disorderly. Otherwise, the workers cannot collaborate. Rather, it may be a malleable order, a "forming form," that workers can adapt to particular contexts. Instead of operating according to formal specifications, the environment fluidly shifts into different modes. For example, a craftsman in the violinmaker's workshop may discover a new type of wood that has good vibration potential for a violin. In reaction to the discovery, the craftsmen instinctively decide how they will collaborate, building on their tacit knowledge and the type of events. In Simondon's terminology, the catalysts of an operational environment are the craftsmen's ad-hoc decisions based on their tacit knowledge and the series of events. These catalysts transduce the environment into unique modes of operation.

4.1.2. Metastability of a structurable technological product

For a technological product to be both structurable and metastable, the condition of changeability is necessary but not sufficient. For instance, a system may allow users to configure their user identity and password, and an image viewer software application let users rotate digital images. The configuration and the image rotation modify some peripheral parameters but not the core content of the application data. These features can only produce limited variations. In contrast, an image editing application can modify the content of an image. Users are able to create new meanings by manipulating image content with editing tools. Similarly, hacking activities can create new meanings of a technology by converting its functionality. In each case, the condition of the technology permits modifications beyond its designer's original intention.

Drawing from these examples, I propose a two-layer design methodology for developing structurable technologies that are metastable. The top layer is the original product. The bottom layer is a toolbox for modifying the original product. In contrast to tools that afford a handful of configurable options, the toolbox gives users numerous functions to make fundamental modifications. It equips users with the capability to translate ideas into technical forms. Whereas specification details of a standardized operation restrict flexibilities, a detailed toolbox inspires creativity with functions that point to many possibilities without a single coherent intentionality. I shall talk more about the importance of functional incoherency to the toolkit's metastability in the following section on interpretative flexibility.

A highly transparent technical architecture, such as open-source software, presents an environment with an ideal level of details, since producers and consumers practically share the same toolbox. Nevertheless, while a transparent technical architecture conforms to the two-layer design framework, transparency is not a necessary quality of a two-layer design. In Chapter 1, I briefly describe the computer hobbyists' enthusiasm for holding open transparent access as a sacred design principle. Graeme Kirkpatrick provides a theoretical substantiation of this principle in *Critical Technology* (2004). He asserts the importance of recovering a sense of transparency in technology (p. 44). One of his arguments is concerned with the graphical user interface of a personal computer. He argues that the interface design of personal computer (PC) is hegemonic because of its lack of transparency (Kirkpatrick, 2004, pp. 51-54). Instead of associating the lack of transparency as "perfect like a work of art," as Steve Jobs did in the movie (see Chapter 1), he adopts the ideas in modernist art to critique the aesthetics of a PC's interface design (Kirkpatrick, 2004, pp. 50). Modernist art circumvents banality by incorporating ambiguity and contradiction. This modernist aesthetics opposes the dominant emphasis of interface design on "ease of use" (p. 52). Kirkpatrick's adoption of modernist art is similar to Eco's analysis of contemporary art. Aesthetically, he views the "user-friendly" technologies as vulgar processes that elicit comfortable, seductive illusions of 'pseudo-natural' experiences. They are not "perfect like a work of art," if we think of art from the perspective of modernist art. Furthermore, Kirkpatrick alleges that technology with an opaque interface is hegemonic. When a user interacts with a technology over an opaque interface, the interactions resemble a "'human' contexts of action." The interface hides technical details from users, inhibiting them "from having to think about what s/he is doing" (Kirkpatrick, 2004, p. 54). The abstraction exaggerates the technical power as a force independent of human knowledge and expertise. Technologies appear as objects in nature, giving the illusion of carrying mysterious powers beyond their technical designs. To Kirkpatrick, an opaque interface reifies human users by taking away their technical mentality and produces the effect of technological fetishism.

Nevertheless, Kirkpatrick admits, "it is not a simple matter to say where the line should be drawn between transparent and opaque, open and closed system" (p. 44). He realizes that certain professionals prefer technically opaque PCs because they have no time to become a computer scientist. This is evident if we consider the complexity of the computer design. Its technical layers include software applications, the operating system, device drivers, hardware components, integrated circuits, transistors, and semiconductors. Each layer represents a sub-discipline in computer engineering. Total transparency presumes open access to all these layers, but few computer engineers have mastered skills in more than one layer. For instance, no application programmer is also an integrated circuit designer.

In contrast, the two-layer design methodology does not require transparency in the technical architecture. For instance, the constellation of a digital image file, an image viewer application, and an image editing application does not reveal the technical structures behind their abstract meanings. The image applications do not need to be open-source. The image file format and compression algorithm may also be proprietary. But even with this lack of transparency, users can still manipulate digital images to create Internet memes or other derivative works. The logic also holds for open-source software and hacking activities. Access to the source code of a software application but not to the code of the operating system is a limited transparency. Discovering software vulnerabilities without source code access, such as "buffer overflow" attacks, is a hacking exploit based on programmers' malpractice since carelessly written codes often lead to security holes in the software. Appropriating the two-layer design for musical instruments, the top layer product is the music produced by musical instruments, which serve as the lower layer toolbox. The instruments grant musicians the capability to compose or to perform music in a wide variety of ways, even though they may not understand the internal mechanics of the musical instruments.

What are the potential sources of catalytic germs of a metastable and structurable product? I describe a few examples in Chapter 3. A hacker's idea transduces the Minitel as an information system into a messaging system. Social events prompt derivative works that transduce images into Internet memes. A hacker group, such as Anonymous, reacts to absurd political events and penetrates government websites. In these examples, the catalyst is either an idea from human imagination, or an event that inspires a human idea. Note that the possible emergence of a catalyst as a human idea presupposes an operational environment that is metastable and structurable like a craftsman's workshop. If the operational process is rigidly defined to the very details, there is little room left for human imagination. In other words, an open technical evolution depends on the metastability of both the product itself and its operational environment. Conversely, if a product with an open design subsists in a closed environment, it can only evolve linearly, in a unidirectional movement toward greater efficiency based on the incumbent set of values and metrics.

4.1.3. Interpretative Flexibility

The preceding section focuses on the openness in the physical form of a technical product. In this section I want to deliberate on a product's interpretative flexibility, which is the openness of its social concept or meaning. Interpretative flexibility is not the same as plurivocality. For a plurivocal technology, designers inscribe a plurality of intentions into the technology. Users are free to select from one of the inscriptions, but not necessarily free to interpret new meanings beyond the original design intentions. For a technology with interpretative flexibility, users can conjure up new meanings for the technology to resolve its tension with social demands. Certain characteristics of technology grant users with a greater degree of interpretative flexibility. I want to understand what these characteristics are.

I begin by revisiting the example about technological interpretations of a stone. We can perceive a stone as a technology in a variety of ways because a stone has multiple affordances that point to many directions without any coherency. Users can group a coherent selection of affordances to interpret its technical utility. Each technical interpretation corresponds to a corresponding group of affordances. Therefore, the flexibility of interpretations is correlated the possible groupings of coherent affordances. For example, a paperweight requires a stone with a flat surface, heavy enough to keep the paper from flipping over by wind, and light enough to be lifted up easily by hand. An Acheulean hand axe requires a stone with a sharp edge, which may be on the boundary of a flat surface. Its weight ought to be significant enough to produce a forceful strike. One of its sides ought to be thick enough for its user to hold the axe. A paperweight and an Acheulean hand axe share some common affordances such as heaviness. They also depend on different affordances such as a flat surface or a sharp edge. The affordances of a stone underdetermine the technology that it may represent. Similarly, the underdetermination is also an attribute of a software library, which typically lacks cohesiveness in its affordances. It underdetermines the applications that programmers develop.[34] Their interpretations of the software library depend on which affordances they choose when writing their programs. This is consistent with my claim in Section 4.1.2 that the lower-layer toolbox is more open if the technology providers do not inscribe it with any coherent intentionality.

Another factor that affects the interpretative flexibility of a technology is its degree of concreteness. In Simondon's theory of individuation, a technology evolves in a series of concretizations. A concretization involves the convergence of multiple functions in a single technical element. As a result, this technical element becomes functional overdetermined: It is determined both by the original function and by the extra function. Over a series of concretizations, a technology progresses toward cohesiveness between

[34] In contrast, a software framework, such as the plugin framework on a web browser, is a system with holes to fill. The designer inscribes clear intentions in the framework and leaves certain holes to be filled in by third-party developers.

functions and parts such that it supports fewer redundant affordances without any technical purpose. As I explain above, the redundant affordances are the basis of interpretative flexibility. Therefore, a more mature technology is less open to interpretation. A typewriter is such a mature technology. Its size is too large to be a paperweight. Its shape is too irregular to be footstool. It is difficult to conjure up another meaning for a physical object with its special form and functions.

The claim that more concrete technical objects are less open to interpretation seems to contradict my earlier argument. In Section 2.3, I suggest that a concrete technical object and an abstract object are equally likely to concretize. To address this contradiction, we need to differentiate two types of interpretative flexibility. One is about the interpretation of a static technical object without any modification, such as the technical meaning of a stone or of a typewriter. The other is the interpretation of what a technical object or milieu may become. For example, an inventor may reinterpret a typewriter as a computer keyboard, leading to the production and social adoption of the computer keyboard. The case study of the bicycle invention by Bijker, Hughes, and Pinch (see Chapter 1) presents another example. Different user groups have their own interpretations of what a bicycle ought to be. Negotiations between these user groups result in actual changes of the bicycle design. Recall that recurrent causality, a necessary condition of concretization, involves an imaginative leap beyond existing circumstances. This imaginative leap foresees the effect of the modified technical object on its associated social and technical milieux, and how the milieux with this technical object becomes a more suitable environment for adopting of the object. There is no recurrent causality in the open interpretation of a static technical object. But when an inventor simultaneously imagines a projection of technical modifications and reinterprets the conceptual meaning of the resulting technical object, the inventive act introduces recurrent causality between the technical and the social realm. This inventive process is a concretization.[35] Therefore, a more concrete technical object is less open to interpretation, but equally open to the technical progress of concretization.

[35] This does not mean that all inventions of social technologies are concretizations. Only inventions that actually change user behavior are concretizations.

This argument is consistent with Madeline Akrich's argument that users can circumvent designers' inscription of technologies. In *The De-Scription of Technical Objects* (2010), her case studies reflect changes made to the associated milieu of a technical object instead of the object itself. She differentiates between simple technological scenarios, such as a stone axe, and most scenarios of modern technologies that are associated with a milieu with complex relations "between technical choices, users' representations, and the actual uses of technologies" (p. 208). Hence users' interpretations of a technical object is not only "an individual and psychological approach" (p. 208), but they influence many social and technical choices during its deployment. Since there is no modification of the technical object, the deployment process does not represent technical concretization according to Simondon's definition. Nevertheless, users are free to interpret a technical ensemble consisting of a concrete technology and a constellation of extrinsic technical and social elements. In other words, it is the technical ensembles, not the technical objects, that exhibit interpretative flexibility in Akrich's case studies.

4.2. The Value of Openness

Throughout this thesis, I argue that a technology ought to co-evolve openly with its users. Otherwise, as social contexts continue to evolve, its form will not match the social changes and reify human users. But for prescriptive technologies such as a traffic light, interpretative flexibility is not a desirable attribute. An ambiguous design cannot fulfill the purpose of preventing car crashes. Therefore, we need to address, under what types of circumstances is openness a desirable attribute of a technology? When openness is desirable, what is the proper degree of openness?

As in the preceding chapters, I separate the analysis on technology as an evolving concept from the openness of a concretized technical product. Most modern technologies evolve in the midst of complex social and technological relations. Until the social meaning and the technical architecture stabilize as "black boxes," the technology will evolve by default. But even for technologies stabilized as "black boxes," they still need to evolve in order to adapt to society. This is true even for prescriptive technology such as traffic light. For example, for a society aware of disabled people's needs, its government is obliged to upgrade its transport infrastructure, such as traffic light enhancements, to address their needs. Upgraded traffic lights may produce audible signals, such as beeps or rapid ticks or human voices, to assist the blind or partially sighted pedestrians. As this illustration shows, the open evolution of the traffic light depends on a democratic operational process and politics of technology, with channels for policy makers to hear the marginal civilians. A perfectly closed capitalist system neglects the marginal voices in favor of profit optimization. Generalizing from this illustration, the value of an open operational process lies in the prevention of social hegemony and of the closure of obsolete "black box" technologies, in order to promote the co-evolution of technology and society.

With regard to the openness of a concretized technical product, I find its relevance mainly in technologies that enable engagement in social or cultural activities. The domain of such activities includes music, art, games, or communications. The technical platform ought to empower users with freedom in their activity engagement, rather than reducing their human capacities and reifying them to follow banal rules. Under these criteria, playing a piano is preferable to playing a music game on Nintendo because a piano is a more open technology. It affords variations in music making whereas game players strive for high scores in a Nintendo music game. We can also use the criteria to evaluate the recent extension on the "Like" button on Facebook. In addition to "liking" a post, users can also express other reactions: "Love," "Haha," "Wow," "Sad," or "Angry." When I use the enhanced mode, I find myself taking a few more seconds to consider which reaction to indicate. This new mode is relatively more open than the old mode because I no longer press the "like" button without thinking about how I truly feel about the post. Of course, limiting emotional expression to six emoticons is still a reification of instinctive bodily reactions, albeit to a lesser extent.

But perhaps prescriptive and activity-enabling technologies are not necessarily in opposition. We may consider a collection of prescriptive technologies as a technical ensemble that enables social or cultural activities. Consider the comparison between a traffic light and a piano. A piano does not prescribe users with specific actions like a traffic light. Even though it shapes the form of the users' activities, there is no limit on the variations in the music produced. At the same time, if we focus on each piano key, we can consider the key as prescriptive. A user strikes a piano key with her finger, not her fist, to produce the sound. Putting together a collective of prescriptive technologies may yield an open technology or technical ensemble. This collective is analogous to the lower layer toolbox of my proposed two-layer design. We may appropriate this argument to a traffic light and a transport infrastructure. Even though a traffic light is necessarily a closed design, we can still evaluate the openness of a city's transport infrastructure, which includes fixed installations including roads, railways, and airways in addition to traffic lights. For instance, if modifying the traffic light coordination helps reduce the constant traffic congestion in a city, then the modification improves the openness of the transport infrastructure.

Under the circumstances in which openness is desirable, we may still question, what is the appropriate degree of ambiguity or of transparent access in an ideal openness that optimizes the actualization of potentiality in the technological and the social realms? To address this question, I return to So-Young Park's methodology that I refer to in Section 1.3. The methodology is based on a particular sensibility for making an aesthetic judgement. We can appropriate this sensibility to the designs of open operational process and of open technical products. Even if designers have a clear conception of openness, they still need to make intuitive decisions about an appropriate balance of openness and closure throughout the development process. These decisions may oscillate back and forth in opposite directions while generally approaching a proper balance, in a pattern similar to Eco's dialectic oscillation of contemporary art.

4.3. Democratizing Innovation

The growing trend of user-centered innovation reflects growth in the social awareness of the value of openness. In *Democratizing Innovation* (2005), Eric von Hippel studies this trend. For von Hippel, users represent both firms and individual consumers. Based on his findings, even though the manufacturer-centric model still fits some fields and conditions, an expanding body of empirical works shows that users are the first to develop a significant number of new industrial and consumer products. Many users, from 10 percent to nearly 40 percent, are engaged in developing or modifying products (p. 4). This trend shares a lot of the aforementioned characteristics of openness. In this section, I briefly summarize von Hippel's study and then compare the user-centered innovation to my theory and design approach of open technology.

In user-centered innovation, users may bring innovation not only to information products, but also to physical products. Examples of user-centered innovation in physical products include the experimental windsurfing board with foot-straps. After some wind surfers discovered the technique of jumping on waves, they customized the windsurfing board so that they could jump on waves with better flight-control (von Hippel, 2005, pp. 1-2). While users tailor their customizations to their unique needs, many of these special features also appeal to other users. If product manufacturers recognize the popular appeals of these features, they may decide to commercialize the user innovation. Indeed, the attachment of foot-straps is now a standard feature on manufactured windsurfing boards. Von Hippel argues that user-centered innovation brings greater benefits to social welfare, but current government policies are not favourable to users engaging in innovation activities. Policies such as intellectual property law allows firms to "create 'patent thickets'—dense networks of patent claims that give them plausible grounds for threatening to sue across a wide range of intellectual property" (von Hippel, 2005, p. 12). This strategy allows them to "prevent others from introducing a superior innovation and/or to demand licenses from weaker competitors on favorable terms" (Shapiro, 2001). Hence the intellectual property law fails to achieve its intended effect in increasing the amount of innovation investment. Levelling the playing field would promote user-centered innovation. As users become an important source of innovation, manufacturers need to adapt by shifting away from product designs to developing product-design toolkits. In selling product-design toolkits, manufacturers would abandon their efforts to collect a detailed understanding of users' needs. Instead, they equip users with the appropriate toolkits and outsource innovation to users (von Hippel, 2005, p. 147). Product-design toolkits can ease users' innovation-related tasks and allow users to design, develop and test on their own (p. 14).

Von Hippel's suggestion to level the playing field and to provide users with product-design toolkits resembles respectively an open development environment and the two-layer design methodology. User-centered innovation flourishes in an open development environment, which requires technology providers and users to participate on a levelled playing field. In addition to intellectual property law and "patent thickets," many competitive strategies, such as the control of standards, are obstacles to user-centered innovation. Meanwhile, a product-design toolkit is an example of a lower layer toolkit in a two-layer design. It presumes a "pre-existing capability and degrees of freedom," which von Hippel calls the "solution space," built into the production system for user designs (p. 196). Since technology providers can control the degrees of freedom by their design of the solution space, a product design toolkit is an example of bounded openness. Von Hippel proposes five criteria for designing a high-quality toolkit for user innovation. These criteria are:

> (1) It will enable users to carry out complete cycles of trial-and-error learning. (2) It will offer users a solution space that encompasses the designs they want to create. (3) It will be user friendly in the sense of being operable with little specialized training. (4) It will contain libraries of commonly used modules that users can incorporate into custom designs. (5) It will ensure that custom products and services designed by users will be producible on a manufacturer's production equipment without modification by the manufacturer" (p. 154).

Most of these criteria are applicable to the lower layer toolkit of the two-layer design methodology. The criterion that needs further deliberation is user-friendliness. "In the sense of being operable with little specialized training," user-friendliness is tied to the dilemma of finding the proper balance between open access and concealment of complexities. As I argue in the preceding section, the proper balance is unique in each scenario, and it is discovered through a series of trial and error. Hence the appropriate level of required skills is situation-specific, and there are certainly cases where users are expected to have specialized training.

For instance, in the open-source software environment and Apple Inc.'s iOS development environment, the target users are skillful software developers. The source code of open-source software is available to the public. Each project provides minimal technical documentation, with the expectation that software programmers prefer directly reading the source code. Conversely, the iOS development environment does not expose the source code of its platform. Software programmers access the platform through its API and understand it by reading its documentation. The environment also supports a distribution channel for programmers to submit and publish their software applications in the App Store. To many programmers, the iOS development platform with all its supporting services and technical documentations is easier to use than the open-source environment. But to a computer hobbyist or to a hacker, the open-source environment is user-friendlier because they enjoy the process of reading source code more than words. Moreover, source code represents a precise depiction of all the details in a software program, whereas technical documentation may misrepresent details, requiring the programmers to discover the precise behavior by experimenting with the program.

Which of the two environments is more open? Which environment resonates better with users' capacity to innovate? Based on the number of applications on Apple's App Store and the novel ideas in many of these applications, it seems that the iOS development platform has generated more innovative software. In contrast, many open-source software projects are implementation of concepts derived from commercial software. For instance, the Linux operating system is based on Unix, which was first developed in the 1970s at the Bell Labs research. Open-source office software imitates the applications and the features of Microsoft Office. The article "Open source innovation on the cutting edge" (McAllister, 2010) describes this general feeling about open-source software: "Open source doesn't innovate – so goes the old saw." Even though the article goes on to argue that there are indeed innovation in open-source, the sentiment about its novelty seems far less convincing than the sentiment for iOS applications.

Nevertheless, we can attribute the more bountiful innovations in the iOS environment to the novelty of a smartphone platform, rather than to other characteristics of the iOS environment.[36] During the social adoption of the smartphone, the meaning of the new technology was still ambivalent. The iOS development environment shifts the negotiations of conflicting user demands from Apple designers to the realm of third-party developers and users in the App Store. The popularity ranking in the App Store represents a democratic voting system on which applications address the needs of most users. The App Store scheme simply speeds up the social adoptions and feature

[36] Note that innovation potentials also emanate from the contribution of the user community, but this is common to both environments.

negotiations of the smartphone platform. It does not actually generate more potentiality for innovation. The actual innovation emanates from the openness of “systemic conversion” as the user community adapts to a novel smartphone platform. In a slow adoption process, innovations are spread out over a long duration. In a fast adoption process, innovations are squeezed in a short duration, giving the illusion that the development environment inspires more innovative ideas than it actually does. As time passes by, the interpretative flexibility would stabilize, and the intensity of innovation in smartphone applications would dwindle correspondingly.

A fair comparison of openness between the two development environments presumes that they operate on equally saturated technology fields. On an equal footing, there are unique advantages to both environments. The iOS environment is easier for software programmers to master, and thus generally easier to translate user needs into software applications. The open-source environment is less restricted. If programmers need a function not supported by the API, they can directly modify the underlying code. If the milieu is metastable, a well-defined toolkit such as the iOS environment is more appealing to the developer community. If the milieu is already stable, filled with technological black boxes, the open-source environment allows developers or hackers to destabilize the milieu. The resulting metastability rekindles possibilities for innovation.

As the above comparison of the iOS and open-source environments shows, the specificity of complexity and of expected users’ skills is situation-specific. Von Hippel’s criterion of “[user-friendliness] in the sense of being operable with little specialized training” is susceptible to reducing product-design toolkits to a banal set of functionality, which curtails the openness of its product. The banal toolkit may be subjected to a critique similar to Kirkpatrick’s critique on the hegemonic interface of a personal computer.

4.4. Political Significance of Continuous Structuration

In previous chapters, I study the characteristic of continuous structuration in the openness of technology. Particularly, I compare the continuous structuration of dephasing with negative dialectics. In this section I want to discuss the significance of this comparison in the political realm. I focus particularly on the Cultural Revolution of China. An in-depth analysis of the Cultural Revolution is obviously beyond the scope of this thesis. Nevertheless, I want to distinguish the pattern of negations in the Cultural Revolution from the pattern of continuous structuration in openness.

Negative dialectics is the basis for the slogan of continuous revolutions in the Cultural Revolution of communist China. On the surface, the political program aims at liberating China from the hegemonic ideologies of traditional institutions and culture. Nevertheless, according to Xu Youyu (1999), Mao was using the program to bolster his political status after his failed economic policies. He manipulated people's passion for communism into hero-worships for Mao himself (Xu, 1999, p. 32). They blindly supported Mao and helped him exterminate political enemies (Xu, 1999, p. 18). The "bible" of the program is the "little red book," *Quotations from Chairman Mao Zedong*, which endorses extremist violence to combat institutional violence. This endorsement has a Marxist origin. In Western society, the New Left also argues that violence can be humanistic if it curtails the greater evil in institutional violence. Their intellectual argument contributes to the social awareness of repressive tolerance and eventually led to social movements and humanistic reforms such as environmentalism, feminism, or anti-racial discrimination. Yet in the Cultural Revolution, people in China witnessed and endured the obliterations of the most basic human values and life instincts. Not only did the Red Guards bring down institutions such as the hospitals or the police, they fervently burnt all cultural artifacts, from literature to philosophy books to religious architecture. They circumvented the legal institutions to criticize and execute one another in self-pronounced death penalties, even among the Red Guards themselves. In one story, a child accused her mother of being a counter-revolutionary for simply owning a small property, and she killed her mother with her own hands (Xu, 1999, p. 35). Such horrifying acts seem to be common occurrences during the Cultural Revolution.

The continuous structuration of openness resembles the continuous revolution of the Cultural Revolution. Both encourage challenges against traditional conventions to destabilize the milieu. Nevertheless, we can distinguish between the continuous structuration of Simondon's transduction, the historical revolutions in Hegelian dialectic, and the continuous revolution of the Cultural Revolution. In a transduction, new structures form on the basis of existing ones. Being the basis does not mean that the structure will not be destroyed. This structuration may consist of dialectic negations at a small scale, similar to the dialectic oscillation of contemporary art. The overall form remains stable at large. Continuous structuration corresponds to the socialist reform in the West during the past half-century. Just as contemporary art retains a degree of stability in conventional standards in order to communicate, for a society undergoing reforms, most of its cultural values and institutions remain stable. The macro-political systems stay put. In contrast, Hegelian dialectic negates at the systemic level. Politically, by usurping the macro-political systems, the entire social milieu is destabilized and the transitioning societies are free to re-establish new values until the milieu becomes stable once again. In Marxist theory, the political economy and its forces of production is the base that determines the superstructure of social institutions and cultural values. Changing the base leads to corresponding changes in the superstructure.

The Cultural Revolution took place seventeen years after the Communist Party took over China. So the movement was unlikely the natural consequence of a systemic conversion. Instead, it was the outcome of a political program through education and propaganda. For example, schools provided political classes that taught Mao's quotations (Xu, 1999, p. 27-28). This environment shaped an obscure ideology that perceives all institutions and cultural values as absolute evilness. Brought up in this environment, the Red Guards engaged not in a revolt against a corrupted political system, but in many micro-revolutions against institutions and cultural values. In this sense, its operation is more similar to the continuous structuration of openness than systemic conversion. But whereas dialectic oscillations fluctuate in the preservations of traditional conventions, the Red Guards were determined to obliterate every identifiable social structure that belongs to the old regime. In a movement without the basis of human values or any intellectual deliberation, they thoughtlessly refuted all traditional values and lost even the most basic human values along the way (Xu, 1999, p. 32). To justify their violence, they discredited international standards for humanity as the intrusion of foreign imperialist power (p. 32). The resulting society was in a state of formless chaos. In contrast, continuous structuration is a theory about the genesis of forms, not a theory of formlessness. In this sense, it is clearly distinguishable from the continuous revolution of the Cultural Revolution in China.

4.5. Conclusion

This thesis is a theoretical exploration about the openness of technology. I begin the endeavour by describing examples related to openness, from the open access of computer architecture to the closure of technological determinism. I then clarify what I mean by openness and closure in this thesis. Openness is the condition for liberating potentialities whereas closure suppresses them. Under this definition, I classify openness into bounded and unbounded openness. Bounded openness describes an open field within a well-defined boundary. Unbounded openness refers to a non-linear evolutionary path of an individual or a field that is beyond anticipation.

In the main body of this thesis, I develop a theory of openness by drawing on the works of Gilbert Simondon and Umberto Eco. I engage in a philosophical excursion into Simondon's theory of individuation, and analyze how the concepts of concretization, transduction, and pre-individual potentiality are related to openness. Two realities are in an open relation if an operation of individuation transductively traverses between their structuration. The operation typically goes through a series of resolution. Each resolution transcends the incompatibilities between the two realities such that they co-evolve in a reciprocal relationship. For instance, humans and technology in an open relation are in a reciprocal relationship. According to Simondon, when modern machines replace humans as "tool bearers," the new relation rectifies the imbalance between humans and pre-modern tools, and breaks down the duality between human and technology. For transductive structuration to occur, the milieu must be a structurable field that is metastable, waiting for a catalyst that shares its pre-individual being and resonates with the field. The encounter with such a catalyst transduces the pre-individual being into another phase. The dephasing of a pre-individual being is a different type of temporal movement from negative dialectic. Dephasing is a movement based on the resolutions of incompatibilities. Negative dialectic is a movement based on the negations of incumbent forms. In his critique, Simondon favors dephasing over negative dialectic, but I argue that Marcuse's dialectical theory has richer ramifications than the dialectic under Simondon's critique. I then explain Simondon's critique of cybernetics and differentiate between a machine that encodes and decodes information from one that transduces information.

Next, I survey Eco's theory on open works and compare his theory of aesthetic openness to Simondon's. I classify Eco's theory into three types of openness: interpretative flexibility, systemic conversion, and the dialectic oscillation of contemporary art. I compare these types of openness to Simondon's theory and appropriate them to the realm of technology. The dialectic oscillation is similar to the continuous structuration of an individuation. I distinguish two types of continuous structuration in a technological evolution. One is the transformation of a physical product. Examples include hockey skates, Lego toys, the hacking activities, and Internet memes. The other is concerned with technologies as evolving concepts, such as version upgrades. I then deliberate on the problems with Taylorism in common standards of operations, and explain the effect of Moore's law on the evolution of computer technology.

After my exposition on the theory of openness, I explore the significance of openness in practice. I begin by proposing a design approach for developing an open technology. The necessary attributes for an open technical process or product are structurability and metastability. One model for a structurable and metastable process is the craftsman's workshop. Hacking can also break open a formally specified operation and transform it into a workshop-like environment. For a product to be structurable and metastable, I propose a two-layer design methodology. The top layer is the original product. The bottom layer is a toolkit that hobbyist users can utilize to develop customized features. The toolkit needs to provide sufficient tools and options that do not follow any coherent design intentions, and requires no transparency of its technical architecture. This proposal is similar to the product-design toolkit that Eric von Hippel's suggest in *Democratizing Innovation* (2005). I examine the relative openness of different toolkits by comparing the Apple iOS development environment with the open-source environment. As a final note, I venture into the political sphere and distinguish the openness of continuous structuration from the concept of continuous revolution in the Cultural Revolution of China.

4.5.1. Final Remarks

The pivotal problematic of this thesis is concerned with the incoherency between technology and the living beings. The formal system of technology and its structures are attempts to stabilize the flux of activities of the living world. Rather than living in the wilderness, we are all accustomed to living in a technologically textured world. The contingencies of the wilderness may at times be spiritual refreshing (for instance, see Albert Borgmann's *Technology and the Character of Contemporary Life* (1987)), but very few people can deny the many benefits of technical advances in medicine, transportation, and communication. Most of these advances come from inventions in modern technology in the past couple of centuries. Perhaps due to the sheer quantity of technical inventions in this period, our dependence on technology seems to have intensified, affecting both our temporality and spatiality. While human beings have always lived in a technologically textured world prior to the modern epoch, there used to be more open space in between the stable structures. Within this relatively open space, human beings can act more or less according to their own agencies, and other non-technical beings can function within the contingencies of their physical laws. The more technologically advanced is a society, the deeper are the technical penetrations into the lifeworld, and the more suffocated are human beings or other living beings if technologies continue to reduce their open space of creative freedom.

The ever-increasing role technology plays in contemporary life is why the issue of openness in technology is becoming increasingly paramount today. The key to unlocking the issue lies in how to situate the stabilizing influence of the technical structure within the contingent flux of the organic living world. In this thesis, I suggest that, when technical structures and living beings are related to one another in a hybrid environment, openness is a desirable quality in this environment. Within this open environment, some of the relations are open while others are closed. Analogous to a toolbox, each tool has a unique, concrete functionality with little ambiguity, but the toolbox as a whole contributes to an open environment because its users can pick from the collection of tools to operate on various physical materials. Earlier in this chapter, I also give practical examples in the relations between piano keys and pianists, or that between traffic lights and car drivers. Each piano key and each traffic light is a closed technology. Yet, the ensemble of piano keys and the mechanics of a piano's construction is an open environment that empowers musicians to create a new musical world. A technical system coordinating the timing of traffic lights fosters an open transport environment for car drivers to go where they want with minimal temporal and spatial constraints. The idea is similar in a corporate environment. Good conventions allow project team members to collaborate effectively while bad conventions intrude on the creative freedom of individual team members.

Therefore, we want to develop technologies that contribute to open environments. Some of these technologies may be in closed form. Others may be an open technology as a layer on top of other layers of closed technology. A Windows operating environment is an open environment for activities, and it is built on top of layers of software libraries and hardware components that perform precise functionalities. Since openness is not a set of well-defined characteristics such as open transparency, designers and engineers cannot determine the degree of openness by following formal rules or stipulations. But they can develop a certain sensibility through experiences. This sensibility is similar to that of experienced engineering gurus who intuitively know what makes a good software platform for third-party development, or which design patterns can improve the quality of software code for future maintenance. Such sensibility may at times contradict the formal biases in the capitalist market and the legal system. For instance, a company may restrict the functionality of a software library in order to shape third-party developers' activities in a bounded openness. Some of these contradictions may lead to political struggles within a corporation or a legal system.

Another site of political struggle is the promotion of openness as a technical standard, similar to the already accepted standards in stability, usability, or extendability. This is not a remote possibility given the recent trends in technology development. The open source movement, the iOS App store, and the research by von Hippel on user-centered innovation are all representative of this trend. What would the world look like if openness became a commonly accepted technical standard? In this thesis, I present some of the benefits that openness may bring. Nevertheless, the crucial aspect to this question is whether it may bring more damages than benefits. One possibility of adverse effects is the incorporation of openness under the wrong circumstances. Naming the wrong Miss Universe is funny to the audience but not to Miss Columbia. Nevertheless, since most of today's standards for good design emphasize clarity and unambiguity, the possibility of this type of adverse effects is well under control. In the end, a developed sensibility of openness in the technical community can circumvent this possibility. Another possibility comes from vulnerabilities to malicious attacks. If a system is intentionally hackable, it may spawn creative activities. But it also empowers people with malicious intentions, such as terrorists, to conduct destructive activities. In addition, for any platform that encourages creative derivative works, some of these resulting works may be morally questionable. Critics of the Internet, which is an open system that generate many possibilities, have referred to similar criticisms in their discourses. Addressing the social ethics of openness as a technical standard is beyond the scope of this thesis and is a possibility for future research. What this thesis argues is that openness is a desirable quality of technology under certain circumstances, and it is possible to identify these circumstances, to cultivate a sensibility for distinguishing openness from closure, as well as to discern the benefits and adverse effects of openness in specific situations.

Another possibility for future research is to analyze openness within the domain of computer engineering. In this thesis, I make a number of allusions to the field of computer engineering. While I distinguish open transparency and open standard for interoperability from my definition of openness, the field nevertheless contains many examples of openness. The emergence of computer engineering signalled a turn of the tide in modern technical development, from the slogans of better control in industrial technologies and in scientific management to decentralizing networks and open architectures. Nevertheless, it remains a debatable question whether this change of tide indeed brings about openness in the way I define the term in this thesis. It may also be a revealing exercise to apply Simondon's philosophy to computer engineering. There are likely concepts in computer engineering that are not identical to the concepts in Simondon's philosophy. For instance, how is the design principle of decoupling in computer engineering related to Simondon's concept of recurrent causality? The two principles seem contradictory even though both decoupling and recurrent causality are examples of elegant designs. Nevertheless, I believe that their core ideas are similar and we can translate such design principles in computer engineering to Simondonian expressions. This translation is useful for recognizing where we may discover individuation, transduction, or concretization in computer engineering and analyze its openness in relation to Simondon's philosophy.

Other future research possibilities include empirical studies that may validate and improve on the theory. In this thesis, I briefly discuss the open-source initiative, hacking activities, Internet memes, the iOS or Android development environment, and political reforms or revolts. All these empirical sites are subjected to further studies on their respective openness and closure.

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