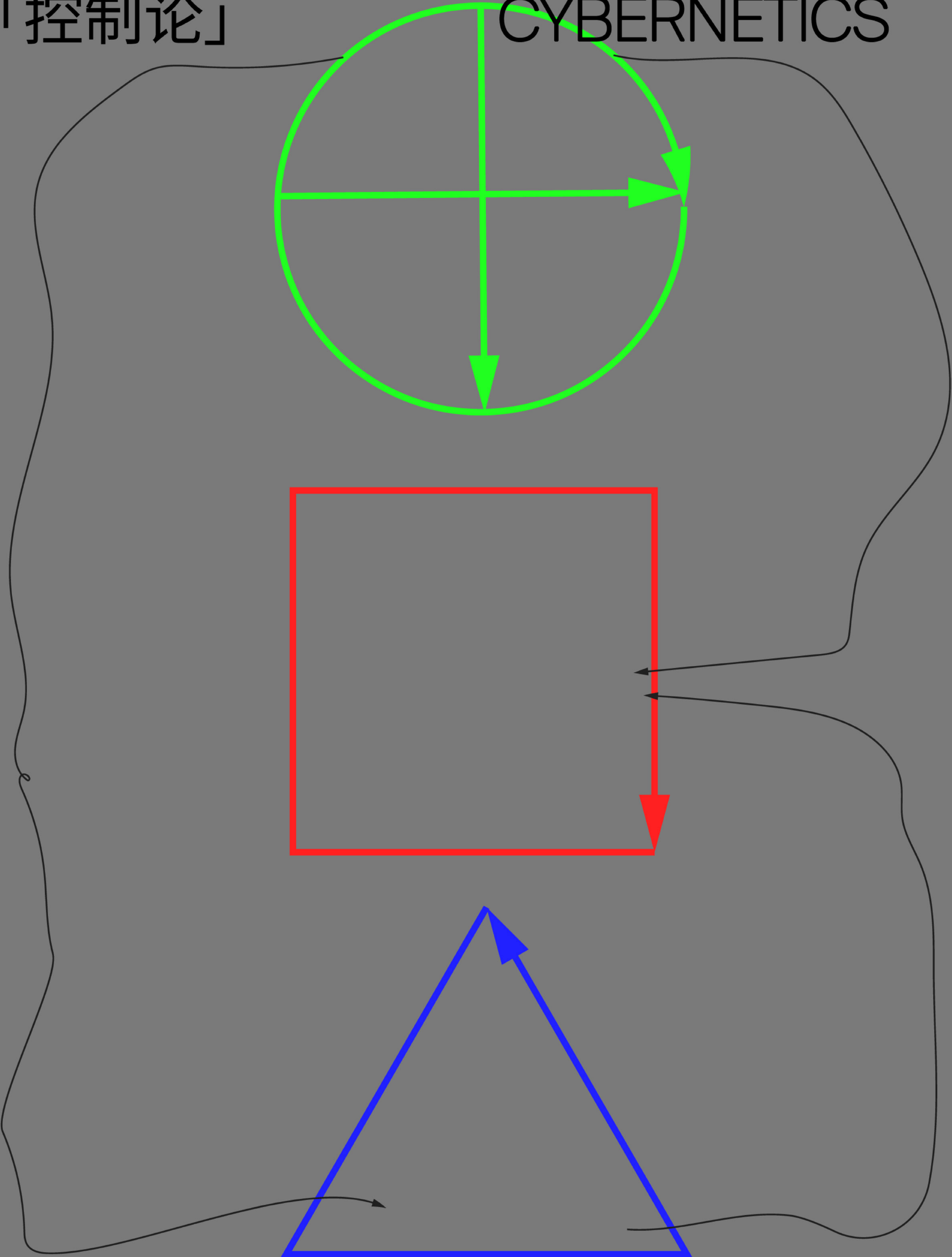
复兴「控制论」

RESURRECTING CYBERNETICS



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前言
评委词

姜宇辉

这肯定谈不上是一篇中立、客观的评述。我在这里只想按照自己的线索把手边的这几篇相当出色的论文串联在一起，就像水流一般，让它们产生一个共同的趋向与合力。这个趋向便是阿甘本在《论友爱》中给出的对当下时代的诊断，那就是装置与生命之间的争斗乃至厮杀；这个合力便是我们想在前卫的思想和艺术实验里面去探寻的一息尚存的希望，那就是反抗的契机乃至颠覆的可能。由此，Brian House的论文是相当突出的，因为它不仅明确提出了困境与问题，而更是通过转用Vito Acconci的经典作品来对当下进行一种颇有启示性的回应。援用他的精彩说法，关键问题恰恰在于，在一个人工智能看似无限增加和加速的年代，如何在数据网络之中真正成为一个individual而非dividual：二者的区分在于，后者只是捕获机器所操控的傀儡和砝码，而前者身上则尚有挣脱网络与保持距离的可能。在Acconci的原初描述之中，公共与私人（private）之间仍然存在着明显的分化；但在当下的时代，当私人领域亦已然被数据网络全面深入地渗透、监控和左右，那么又何以激活乃至释放其中尚存的“democratic potential”？House所复刻的Following Piece这件作品似乎给出了一个令人眼前一亮的思路：既然私人领域早已是一个千疮百孔的脆弱堡垒，那么在遍在的网络之中重新编织合力，似乎是一个可行的策略。然而，在这个方向上，我们必然会遇到德勒兹和瓜塔里的Rhizome网络理论和分子革命（molecular revolution）的构想，也必然会参考内格里和哈特关于诸众（multitude）之情动（affect）的天马行空的革命纲领。因此我们不出所料地读到了Jason Rhys Parry关于augmented ecology的论文。然而，所有这些源自《千高原》（A Thousand Plateaus）的ecology理论在晚近以来皆越来越显示出强弩之末的疲态。如果说生态系统的本质就是多元、异质、开放的连接，那么这恰恰是我们时代的“症状”而非“希望”。借用Andrew Culp的说法，“过度连接（too many connections）”恰恰不是福音而是罪孽。既然如此，明智之举绝非去augment ecology（or rather ‘ecologies’），而反倒是中断连接、缩减网络、伪造消失（fake ‘disappearance’）。

就此而言，余下的几篇文章虽然在批判性方面不甚突出，但却仍然对House所提出的问题给出了不同方向的回应。Diego Gómez-Venegas和王洪喆的论文虽然令人遗憾地未涉及到当代艺术的实践，但却补充了一个相当重要的历史性的视角。只不过，历史本身当然也是多面向的，Gómez-Venegas从技术史和媒介史所进行的考察、王洪喆从政治运动史所展开的挖掘自然会引申出迥异的结论：前者以"forgetting"为要点，将Kittler的媒介考古学与控制论的历史演变关联在一起，展现出重思人-机关系（"human-machine coupling"）的新颖视角；而后者虽然未重点关注技术本身，但却颇耐人寻味地展现出控制论等"西方科学思潮"在风云变幻的中国现代政治舞台上的曲折命运。就此看来，其实"-forgetting"倒是可以作为这两篇看似并不相关的文章的关联点。Gómez-Venegas的翔实历史考证固然出色，但却始终在一个核心要点之处含混不清、摇摆不定，那正是"forgetting"与"erasing"这两种操作的本质性差异"forgetting"从根本上来说是主体自身的一种活动，从被动方面看它揭示的是人的认知的有限性，但从积极的方面看（比如尼采在《历史学对于生活的利与弊》中所言），它更体现出人类自身的那种创造性的抵抗力量。能忘记，想忘记，这不啻为人之为人的重要特征。用尼采的话来说，遗忘正是人的一种"健康"状态。但反过来说，我们不会用"forgetting"这样的词去描绘、界定机器的存储能力。确实，在机器的存储系统之中，信息的"erasable"也是一个关键特征，但这与作为主体的人的那种主动/被动的"forgetting"的能力之间所展现出的其实更是冲突而非一致。正是在这个意义上，"forgetting"本可以作为一个抵抗的关键动力，而并非如Gómez-Venegas那般仅仅将其视作一个历史性的关联环节。而王洪喆对社会政治史的回溯梳理恰好给出了相当有力的回应：单纯从技术与媒介的历史脉络，是看不清"forgetting"的真相的。进行"forgetting"的操作的往往并非只是机器，而是更复杂的社会政治的力量，而当机器和政治这两方面的力量勾结在一起的时候，或许导向的是更为灰暗的前景。就此而言，Martinez de Carnero和Patrica de Vries的论文都深刻地阐释了当下艺术的状况，但却给出了两个全然不同的前景：前者的基调是乐观的，试图从前卫音乐的"improvisation"的手法中激发出新鲜的艺术实验的灵感；而后者则截然相反，试图以艺术的手法去展现大数据网络的"崇高（sublime）"式的恐惧（horror），进而趋向于一种末世般的悲壮。我自己更倾向于后者的立场，因为当希望不再掌握在我们手中之时，也许绝望反而是一种真正的、切实的抵抗。

JIANG YUHUI

As a commentary, this article is certainly not a neutral and objective one, as I just want to comb through these very good papers with my own clues to generate a collective trend and force among them like the flow of water. This trend is the diagnosis of the current time given by Giorgio Agamben in L' amico, that is, the battle or duel between the apparatus and life; the collective force is the faint hope we want to find in the *avant-garde* thoughts and artistic experiments, which is the opportunity of rebellion and even the possibility of subversion. Therefore, Brian House' s paper is quite prominent, because it not only clearly presents the dilemma and problems, but also makes an inspiring response to the present by referring to Vito Acconci' s classic works. To cite his brilliant argument, the key question is precisely how to truly become an individual rather than a dividual in the data network when artificial intelligence seems to be infinitely increasing and accelerating. The difference between individual and "dividual" is that the latter is only capturing the puppets and weights manipulated by machines, while the former retains the potential to break free of the network and keep a distance. In the original description by Acconci, there is still a clear differentiation between public and private; but in the current era, when the private sector has been thoroughly penetrated, monitored and controlled by the data network, how can the "democratic potential" that still exists be activated and released? The work Following Piece reenacted by House seems to present an enlightening idea: since the private sector has long been a fragile fortress, it seems to be a viable strategy to reweave a collective force in the ubiquitous network. However, in this direction, we will inevitably encounter the theory of Rhizome and the concept of molecular revolution of Gilles Deleuze and Félix Guattari, and will inevitably refer to Antonio Negri and Michael Hardt for their imaginative revolutionary principle about multitude and affect. And as expected, we encounter Jason Rhys Parry' s paper on augmented ecology. However, in all of these theories of ecology derived from A Thousand Plateaus, the sense of fatigue and weakness is growing recently. If the essence of the ecosystem is a pluralistic, heterogeneous, and open connection, then this is precisely the "symptom" of our time rather than the "hope" of it. To cite Andrew Culp, "too many connections" are not a gospel, but a sin. If so, the wise action is not to augment ecology (or rather "ecologies"), but instead to break the connection, reduce the network, and fake "disappearance".

In this regard, although the remaining articles are not prominent in the critical aspect, they still give different responses to the questions raised by House. Diego Gómez-Venegas and Wang Hongzhe' s theses—though unfortunately not referring to the practice of contemporary art—add a rather important historical perspective. Obviously, history itself is multi-faceted. Therefore, the investigation by Gómez-Venegas from the history of technology and media comes to a divergent conclusion compared to the study by Wang Hongzhe from the history of political movements: the former takes "forgetting" as the key point, and by associating Kittler' s archaeology of media with the historical evolution of cybernetics, reveals a new perspective of "human-machine coupling"; while the latter does not focus on the technology itself, in a thought-provoking way, the author presents the tortuous fate of "Western scientific thoughts" such as cybernetics in the changing modern Chinese political sphere. In this respect, "forgetting" can actually be used as a connecting point for these two seemingly irrelevant articles. Gómez-Venegas' detailed historical research is excellent, but it is always ambiguous and erratic at a core point, which is the essential difference between the mechanism of "forgetting" and "erasing". "Forgetting" is basically an activity of the subject itself. From a passive perspective, it reveals the limitedness of human cognition, but from a positive perspective (such as in Friedrich Nietzsche’ s “On the Advantage and Disadvantage of History for Life”), it reflects the creative resistance of human beings. It is an important characteristic of being human to be able to forget and to be willing to forget. In Nietzsche’ s words, forgetting is a “healthy” state of human beings. But on the contrary, we will not use the word “forgetting” to describe and define the storage capacity of the machine. Admittedly, in the machine’ s storage system, the information being “erasable” is also a key feature, but this is fundamentally in conflict with—not consistent with—the ability of the active/passive “forgetting” of the human being as a subject. It is in this sense that “forgetting” can become an important motivation of resistance, instead of a mere historical link as what Gómez-Venegas describes. Wang Hongzhe’ s retrospective review of the social and political history gives a very powerful response: it is impossible to see the truth of “forgetting” purely from the historical context of technology and media. Often, the action of “forgetting” is not carried out by machines, but by more complex socio-political forces, and when the forces of machine and politics collude together, they may lead to a more gloomy future. In this regard, the papers by Martinez de Carnero and Patrica de Vries profoundly explain the *status quo* of art, only to present two completely different prospects: the former’ s keynote is optimistic, trying to create fresh inspiration for artistic experiments from the method of “improvisation” in *avant-garde* music; the latter is the opposite, trying to present the “sublime” horror of big data networks in an artistic way that leads to a moving and tragic end of life. I am more inclined to the latter’ s position, because when we no longer hold onto hope, perhaps despair will turn into a real, practical resistance.

Catalogue

Everything That Happens Will Happen Today: Reimagining Vito Acconci's *Following Piece* in the age of AI

Brian House

Following Piece

In October of 1969, the Architecture League of New York sponsored an unorthodox exhibition. It was not held in a gallery, but on the streets of the city—of the eleven works included, Vito Acconci's performance *Following Piece* is perhaps the best known. Its description for the piece read simply:

> *Each day I pick out, at random, a person walking in the street.*
> *I follow a different person everyday; I keep following until that person enters a private place (home, office, etc.) where I can't get in.* (2004, 76)

Over the course of the month, Acconci followed 23 individuals for durations ranging from a few minutes to eight hours. Beyond a series of staged photographs taken after the fact, his documentation consists only of affectless descriptors, a list of incidents such as "11:10AM … Man in brown jacket; he walks south on Bleecker" (2004, XX).

Vito Acconci, *Following Piece*, 1969

Among the many artists who have walked the streets, Acconci's analytical approach is somewhat of an outlier. The flâneur of Charles Baudelaire, for example, is a more sensitive aesthete as he strolls down some Parisian boulevard. Simultaneously a detached observer and immersed in the crowd, the flâneur is "responding to each of its movements and reproducing the multiplicity of life and the flickering grace of all [its] elements." Walter Benjamin would famously adopt this character to illustrate the effect of the modern city on the individual psyche, and we see this relationship between the singular and the collective in film every time the camera zooms out from some individual drama to show the bustling streetscape. But there is no crowd watching in *Following Piece*.

Or take Sophie Calle, who for *Suite vénitienne* (1979) spent twelve days in Venice following a man she didn't know while trying to avoid detection. Calle's stakes are higher than the flâneur, as she does not wander, but pursues, and in so doing flips Baudelaire's chauvinistic gaze on its head. Her journals are filled with a barely restrained passion that has little to do with the actual man she's following but everything to do with that which inevitably remains unknowable between passersby. But there's no place for the poetics of this gap in Acconci's work either—he even absolved Calle's later piece from any charges of plagiarism, citing his disinterest in feelings (Riding).

And then there are the Situationists. The instructions of *Following Piece* are not unlike the mechanisms used in "dérives," or drifts, that the Situs conducted through urban space in the 1950s—such as using a map of London to navigate in Germany. There is a "psychogeography" of the city, as Guy Debord explains, which comprises "the precise laws and specific effects of the geographical environment, whether consciously organized or not, on the emotions and behavior of individuals." The point of the dérive is to master such feelings, which are a form of politics, in the hope of imagining radical alternatives. I don't think this is what *Following Piece* does, however. The Situationists' games were means to an end, but Acconci's piece prefigures what was coming.

9 However, when mobile phones proliferated in the 2000s—along with the "locative" turn in media art—it was the Situationists who had somewhat of a revival. Artists pointed to psychogeography when they claimed digital traces and virtual annotations of physical space might have subversive potential. The very first dérive, after all, had employed walkie-talkies (Ross). But though many locative artworks sought to expand the democratic potential of the street, they also paved the way for an explosion of commercial applications on mobile devices. We knew at the time that geolocation data would change the way we encounter the city. But the kind of *we* that we would become in the process was perhaps the larger question.

In that resepect, I think Acconci was particularly prescient with *Following Piece*. The work is not a means of uncovering the psychological effects of the built environment, as the Situs tried to do. Nor is it about the tension between the individual consciousness and the anonymity of the crowd, or between private and public realms. Rather, it is *following* itself that is interesting, because of how it changes the terms of social relationships in the city. And as it turns out, following is now a dominant paradigm thanks to algorithms, data collection, and artificial intelligence.

Urban algorithms

As Acconci defines it, to follow is "To come about or take place as a result, effect, or natural consequence" (2004, 77). Likewise, an algorithm is a sequence of steps that one follows to produce an anticipated result. *Following Piece*, as an algorithm, is simply "a way to get around"(2004, 77).

For someone following such an algorithm, another person becomes just a path. And what is private versus public is no longer a question of what that individual might rightfully withhold as their own—rather, it is just the physical fact of "where I can't get in." Singling someone out from the crowd should itself be a violation of privacy, especially when it's done by someone from Acconci's (male, white) demographic whose history of following is far from benign. But is this the responsibility of the artist who designed the piece, or the follower who executes it? Of the latter, Acconci writes, "I don't have to control myself ... I am almost not an 'I' anymore; I put myself in the service of this scheme" (2004, 77).

A similar arrangement was articulated by the philosopher Gilles Deleuze in 1992. ID cards, credit card numbers, passwords, activity logs, and biometric scans are all kinds of schemes (or "codes" for Deleuze) that indicate "where access to some information should be allowed or denied." As he puts it, "We're no longer dealing with a duality of mass and individual ... Individuals become 'dividuals,' and masses become samples, data, markets, or 'banks'" (Galloway 86). A database of samples does not add up to the crowd in its flickering grace. And a "dividual" is something less than an "I"—it's precisely the follower that Acconci performs on the street.

The correspondence has only become more material as we've remade our cities for digital following. A geolocation sensor in every pocket means that the movement of every person traveling by foot or vehicle is tracked, logged, and analyzed. This lets Google Maps optimize their directions, Uber choose your driver, Facebook target their ads, Foursquare alert nearby retail, and Apple suggest you need more exercise. What's more, a recent article in The New York Times ,reports that location data collected by one iOS app, WeatherBug, is shared with 70 other companies, But WeatherBug is not an exception. In practice there are few limits to the extent that data are shared and used without explicit consent. In other words, everyone with a device is performing some version of *Following Piece*, except we're both follower and followed, and never the artist behind the scheme.

This has become normalized—but I think Debord would find it remarkable that the "effects of the geographical environment" have in many cases been supplanted by algorithmic influences. That some drivers fleeing California wildfires via Waze were sent back into the flames is only one extreme case. The algorithm was simply making use of the data that it had to avoid traffic, but what's written in code has material consequences.

Cybernated art

Of course, it's not a coincidence that Acconci's piece, and the *avant-garde* practice of the instructional "score" in general, so closely parallels the nature of computational systems. Both share a post-war milieu with the theory of cybernetics, or "communication, control, and statistical mechanics, whether in the machine or in living tissue" (Weiner 11). Cybernetics is a way to reimagine the crowd as a set of technical, rather than personal, relationships, an idea that continues to precipitate both technological and artistic developments (Bernes).

The Jewish Museum's *Software* exhibition, which Acconci participated in a year after *Following Piece*, makes the shared context explicit. In his catalog essay, curator Jack Burnham declares his intention to avoid "the usual qualitative distinctions between the artistic and technical subcultures. At a time when esthetic insight must become a part of technological decision-making, does such a division still make sense?" (17) Acconci's contribution to *Software* was more or less a sequel to *Following Piece*— for *Proximity Piece* , he sidled up to visitors to the museum during the exhibition, slowly edging closer and closer until they moved away.

Taking a somewhat different approach, however, was the installation *Seek* (1970), from the team of future MIT Media Lab founder Nicholas Negroponte. It consisted of a robotic arm which continually manipulated an environment of wooden blocks inhabited by (possibly terrified) gerbils. As the catalog describes it, "Today machines are poor at handling sudden changes in context in environment. This lack of adaptability is the problem *Seek* confronts in diminutive ... If [computers] are to be responsive to changing, unpredictable, context-dependent human needs, they will need an artificial intelligence that can cope with complex contingencies in a sophisticated manner" (23). Though *Seek* was nearly a half-century ago, such an AI-enabled imaginary continues to be reiterated. Take Google's sibling company, Side-

MIT Architecture Machine Group, *Seek*, 1970 walk Labs, which is currently developing what could eventually be 800 acres of Toronto's waterfront, starting with the neighborhood Quayside. Sidewalk is building Quayside "from the internet up," (15) which speaks to how the capacity to gather data will be built into its infrastructure and the expectation that it will be, according to the proposal, "the most measurable community in the world" (22). Machine learning algorithms would make sense of all that data and provide the capacity (and justification) to intervene when the city's "performance" is undesirable. One example from the proposal is making use of "flexible street furniture" (wooden blocks?) to alleviate pedestrian congestion (72).

Many aspects of the Toronto plan pay genuine attention to quality of life and would be the envy of any city. But these have been overshadowed by its sensational premise, which has made Sidewalk Labs answerable for a cascade of concerns, both real and imagined. Foremost among them is privacy—not only in the traditional sense of the right of the individual, but also the question of who has the right to monitor and direct the collective. For if the city itself is to follow us, and then give us our paths to follow, does that not fundamentally change the nature of the public that emerges?

Behind machine learning

Putting data to use at the scale of a city is unthinkable without machine learning, a class of algorithms that automatically make predictions about the world based on what has been observed in the past. The more data available, the more a machine learning "model" is able to predict, and so the aspiration to have total knowledge is in some respect inherent to the concept. It is also endemic to the philosophies of tech giants like Google, Amazon, Microsoft, and Facebook, who from the beginning have pursued a kind of brute force approach to gathering data (such as indexing every web page, or photographing every building, or including every person in a social graph).

However, within current discourse, machine learning is more often described by the more general term artificial intelligence. The latter designation has a far greater cultural resonance, as it has been personified by humanoid robots in cinema and literature since at least the nineteenth century. And it distracts us, perhaps, from the politics of data by implying that a machine learning model is something that it is not: an individual.

One of my favorite ironies comes from DeepMind, the developers behind WaveNet, a remarkable voice-synthesis algorithm now heard in millions of homes every time Google Home speaks. When WaveNet was announced in 2016, this shiny new voice was made to read aloud a synopsis of the film *The Blue Lagoon*. In that 1980 survival drama, a pair of children (one of them played by a young Brooke Shields) are marooned on a desert island and grow up without the influence of society. To name this particular movie is to endorse, playfully or not, the myth of an AI as an independent and pure (blonde?) being. But in fact the speech of WaveNet is fully socialized, as it is a machine learning model whose English version was trained with audio data from 109 different speakers (House 2017). That WaveNet sounds (almost) convincingly human—that is, with idiosyncratic vocal rhythms and intonations that suggest it is an *individual* human—is a way of speaking over this collective origin.

Machine learning makes predictions, and voice synthesis might not at first seem to be a prediction problem. But in fact, in the world of machine learning, prediction is essentially the same thing as generation. If the algorithm can guess what might come next, it can also just go ahead and make it happen. In the case of WaveNet, it's a matter of using training data to predict the next sound, generating that sound, and then repeating the process. This is how we get a singular enunciation from a collective dataset.
Another example is when Amazon recently attempted to apply machine learning to its hiring process. The system automatically recommended

resumes based on data from past hires, which had, of course, been subject to human bias. AI produces what *follows* from the data, what is a "natural consequence," as Acconci puts it. Hence, the system made hiring recommendations that perpetuated discrimination against women.

Initiatives such as the NYU research institute AI Now have focused their efforts on bringing to light such examples of algorithmic injustice. They advocate for transparency and regulation. But there is an imaginary, too, that must be overcome, in which AI is a mysterious, inhuman intelligence and not the highly contingent set of technical practices that it is. Any use of "AI" that reifies machine learning as an entity is thus a smokescreen for the many humans behind the data.

Artificial art

It's limiting, then, when many artists who explicitly engage with AI choose to reinforce the myth that it is an independent entity. Like AI itself, this is not a recent development. Around the same time as the *Software* exhibition, for example, the artist Harold Cohen first produced AARON, a computer program which he continued to refine for the next forty years. AARON, according to Cohen, paints paintings "without my own intervention," his authorship of the program notwithstanding. He asked, "If what AARON is making is not art, what is it exactly, and in what ways, other than its origin, does it differ from the 'real thing'?".

This red herring of a question has carried forward into art based on machine learning (which AARON is not, as its rules are explicitly programmed rather than derived from data). Cutting-edge algorithms like convolutional neural networks and generative adversarial networks, when trained with images from the internet, have produced spectacular images. Just recently, Christie's generated controversy when it auctioned a painting "signed" by the AI used to generate it. These results have been framed as the product of a nonhuman entity, whether its existence is welcomed with open arms or presented as an alarming eventuality. But to fetishize the output of machine learning and to speculate about the nature of its intelligence behind it is to shirk responsibility for having made it in the first place.

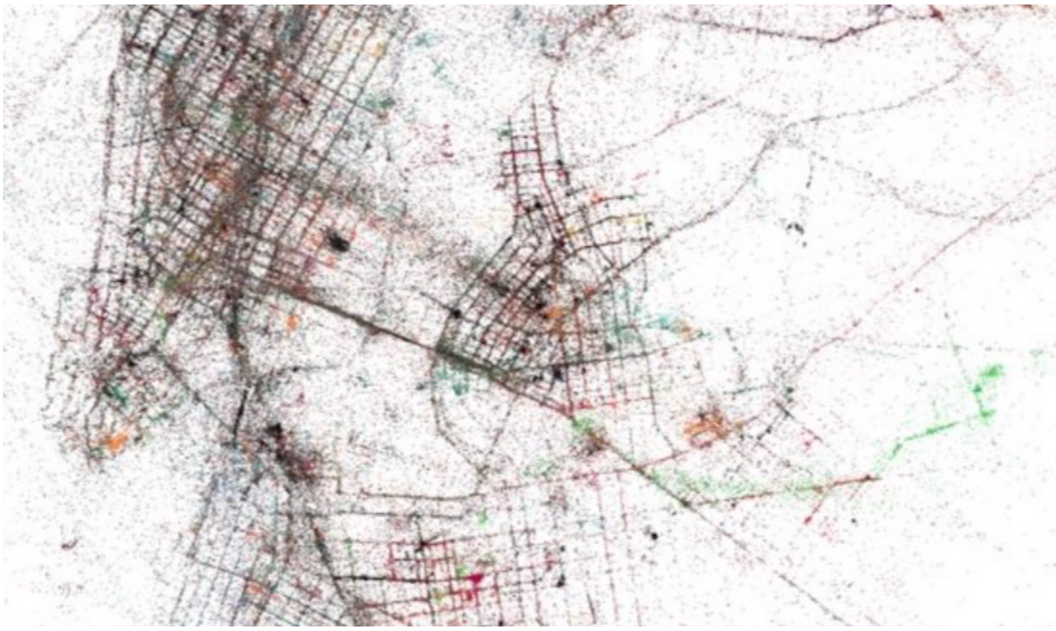
Other artistic methods are possible, however, if AI today is understood not as a radical new development but as a direct extension of cybernetic thinking. Acconci's techniques for plumbing the contested dynamics of public versus private space are as relevant now as in 1970—more so, given the extent to which algorithmic relationships that were once speculative are now baked into digital infrastructure. Fundamentally, *Following Piece* uses urban space to explore what it is to be a dividual rather than an individual, and in so doing anticipates the world many of us are living in today. The next step, so to speak, is to consider what happens when dividuals are aggregated and analyzed as a database. This is what machine learning does so well, whether it's images, speech, or geolocation. Rather than think it as "AI," can we ask what becomes of the crowd?

There is additional value in asking that question from the street. If there is something disingenuous about *Following Piece*, it is the extent to which the documentation elides Acconci's body, which remains central to the piece. This is an artist famously concerned with the corporeality that makes a human so vulnerable, the sweaty, or broken, or lusty existence that remains irreducible. Acconci's experience as a performer documents the effects of surrendering his body to the schema, effects that are not fully describable by other means. Likewise, however we might be dividuated, collated, and predicted by algorithms, urban space inevitably operates at the level of the movement of individuals, and so our encounter with a "smart" city will be an embodied one. These considerations motivated my decision to reenact *Following Piece* with a slightly modified scheme. Rather than follow random individuals on the street, as Acconci did, what would it be to follow an "AI" that had been trained with the geolocation data of 1000 people? My movement around New York would be scripted by what the algorithm generated, and as I went I would "look" for traces of the individuals behind the training set. As performance art, the act would ask what persists of the city when it is captured, modeled, and instantiated back onto the street. And it would be a specific aesthetic experience with which to reframe in general how machine learning (re)mediates the collective.

A follower from 1000 followees

Acconci didn't require a dataset. But this new work was only possible thanks to the OpenPaths platform, a now defunct project by the Research and Development Lab of The New York Times to which I was a primary contributor (House 2013). OpenPaths consisted of simple iPhone and Android apps that recorded users' latitude/longitude coordinates every few minutes. Other apps that track location reserve these data for themselves, but OpenPaths did the opposite. Users' had access to their own data, which were encrypted and therefore inaccessible by anyone else. However, OpenPaths also allowed anyone to propose a "project" and to ask other users to contribute data. These contributions were "anonymous" in the sense that they did not include any metadata like a username or email address, but there was no pretense that unaltered location data are not personal.

I solicited data from OpenPaths users for an open-ended project, one that would somehow explore "the rhythms of everyday life" as previous artworks of mine had explored individual geolocation datasets (such as Quotidian Record, Joyride, and 48x16). Though OpenPaths was discontinued in 2016, I had enough data from the previous year to separate out 1000 residents of New York City. This collection is by no means a representative sample of the city's population as it originated in a community of journalists, artists, and technologists interested in the geolocation data from their mobile devices. When the points of the dataset are visualized by plotting them in two dimensions, the city that emerges is the most well-defined in areas of Brooklyn and Lower Manhattan. As in any dataset, bias is fully in play.



Geolocation data captured via OpenPaths

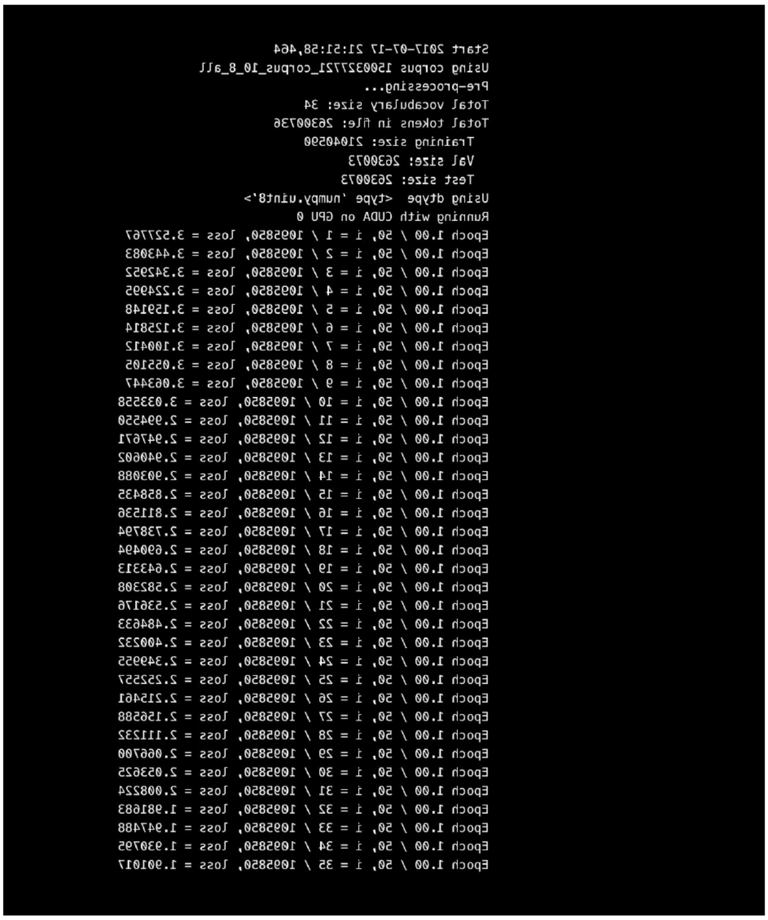
Not only where you live, but where—and when—you work, whom you visit, where you shop, or relax, or worship, how consistent or variable your schedule is, where you're free to go and where you are not mark the repetition and difference of the everyday, and these rhythms are what joins the specificity of individuals into the pulse of urban life. Of this, the data are traces. And somewhat paradoxically, when machine learning amalgamates the paths of 1000 people, the resulting model is not an "average"—rather, it demonstrates the idiosyncrasies of a plausible but nonexistent individual.

To create this model, I chose a machine learning technique called Long Short-Term Memory Recursive Neural Networks (LSTM). LSTMs are designed to predict sequences of data, and, like the name implies, they are sensitive to patterns at various timescales. They are also subsequently able to generate sequences. Examples that are typically given for the use of LSTMs include synthesizing music, simulating handwriting, and even captioning photographs. They're also ideal for interpreting data from sensors, and so we can anticipate their use for modeling all manner of human behavior.

In order to simplify the training process, I reformatted the time-stamped latitude and longitude coordinates produced by OpenPaths into a regular sequence of labeled grid spaces, each of which represented the area of approximately a single NYC address. These were identified by "geohashes," which are a way of representing the coordinates of a grid as strings of text. When interpreted left-to-right, geohashes zero in on the appropriate grid from a more general area, which is helpful when predicting sequences, since more general patterns (like traveling between Brooklyn and Manhattan) are apparent as well as visits to precise locations.

Training the LSTM could not be done on my own computer, at least if the process was going to finish in under a month. Instead, I paid about a dollar an hour to use a machine optimized for machine learning that was running somewhere out there in an Amazon data center. The dependence of machine learning on computing infrastructure is a profound one, of which the ecological consequences are well-documented, and it further undercuts the idea of AI as a singular entity. I performed a lot of trial and error to produce a model that was verifiably "accurate" in its ability to simulate human geospatial behavior—that final model took about 17 hours to train.

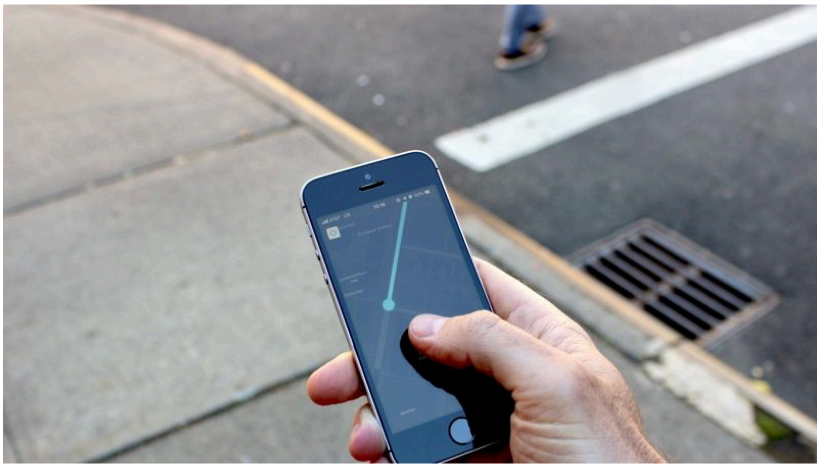
From there, I built another mobile app, kind of like OpenPaths in reverse. This one took into account the last four hours of my location, and then used the trained model to provide directions about where I should go next. Implicit in these directions were the contours of a life in New York City that had been derived from the data, and which could now be infinitely enumerated. For example, most nights the directions would be to stay put in some residential area of the city, whereas during commuting hours the directions tended to be on the move (unless it's a weekend). That four hour window produced an interesting kind of amnesia, intentional for the purposes of a performance—e.g., the model would always head toward "home" in a different location every night.



Screenshot, LSTM training process

Following *Following Piece*

Starting on a Wednesday afternoon, phone in hand, I began the durational performance. I committed to one full week of following this scheme, of following the algorithm and in so doing following the 1000 people on whose data it had been training. I was taken to places familiar to me from my experience in the city over the last 20 years and to those with which I was entirely unfamiliar. Most days I commuted to “work,” whether uptown, downtown, or midtown; I surveyed vari-



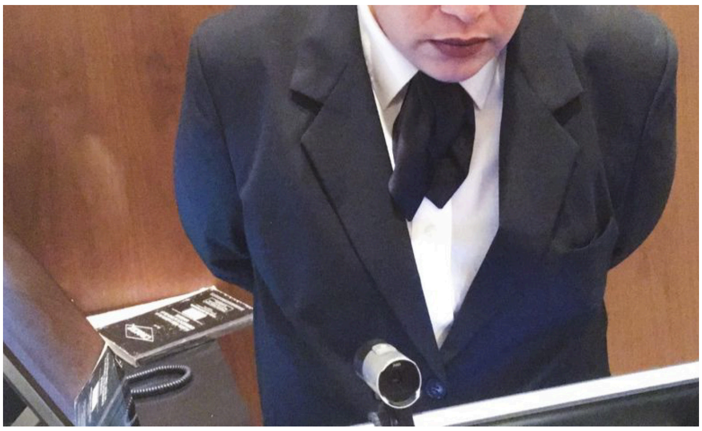
Navigating via AI

ous bars and restaurants in Brooklyn and Long Island City; I went to a doctor’s office, and even to the cemetery. Days ended at apartment complexes and row houses through out the city. The app showed me how long I’d be in my current location, and I allowed myself the option of leaving during that time if necessary for three essential reasons—to eat, to relieve myself, or to sleep—as long as I returned to pick up the path again.

Upon arriving somewhere, I attempted to engage intuitively with the place. If it was a restaurant, I ate, or if it was a store, I shopped. There were limits, however. Just like with *Following Piece*, I frequently encountered thresholds that I did not have the means to cross, whether by key, the fact of being known, or simply having an articulable purpose for being where I was. Liminal spaces, like foyers, took on a special significance, because that's where I ended up loitering, sometimes for many hours.

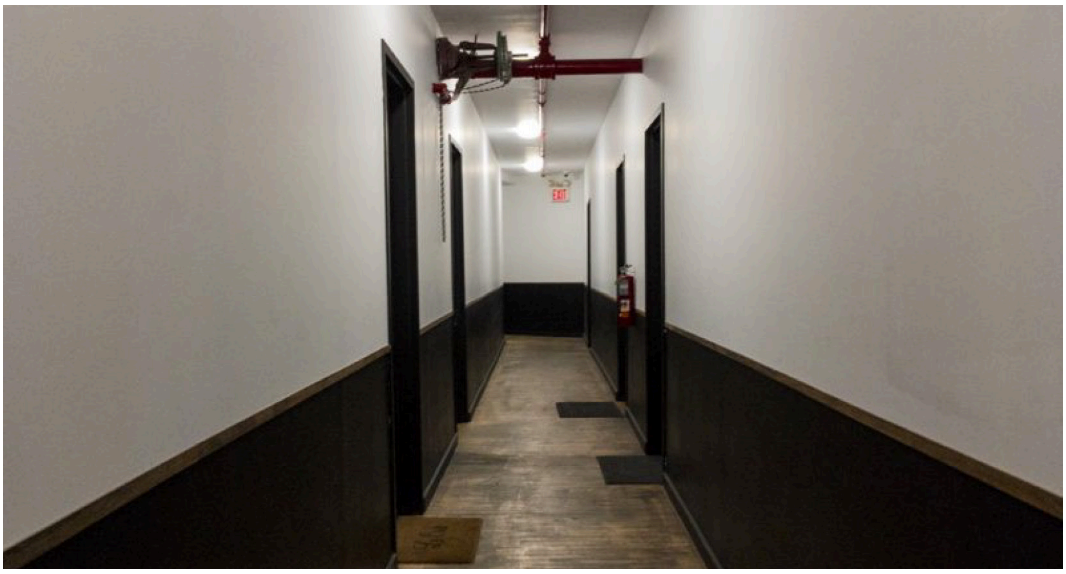
Photograph from *Everything That Happens Will Happen Today*

Of course, these contours of access were defined in relation to my being white, male, and able-bodied, however universal the directions given by my app might seem. How I present and what my body can do were thus constitutive of the types of frictions I experienced when the algorithm met the world. This raises obvious questions of when, how, and if individual difference should be accounted for in machine learning models. More importantly, it puts into visceral relief the democratic value of spaces like public libraries for which those determinations are minimized in their impact.



Photograph from *Everything That Happens Will Happen Today*

Unlike in Acconci's *Following Piece* , the individuals with whom I now had a "technical" relationship, these everyday walkers that I followed, were no longer present—I was following their traces. Or at least, I had no way of knowing if the people I encountered had contributed to my dataset or not. But *something* of them remained, and, perhaps inspired more by Calle than Acconci, I photographed this remainder. I took pictures of people enmeshed in their daily lives and of the built environment itself that

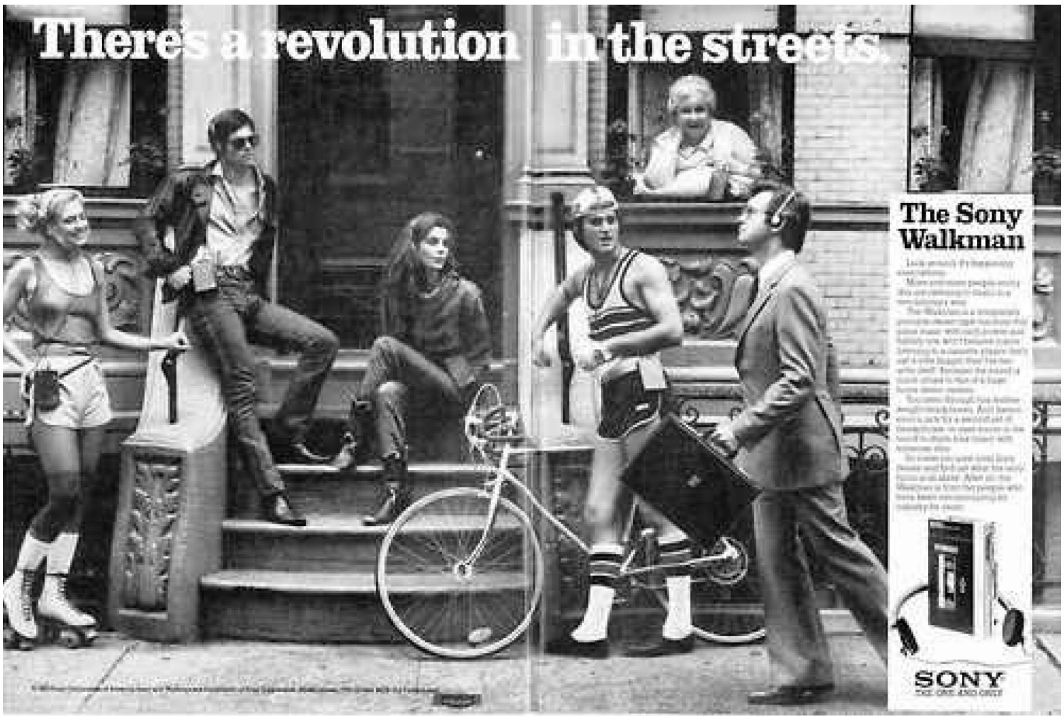


Photograph from *Everything That Happens Will Happen Today*

they moved through. These realities were previously implicit in the machine learning model, but were made explicit in my encounter with them. It was, perhaps, a way of returning the dataset to the crowd, and a way to experience it not as dividuated statistics, but as an unquantifiable ensemble of collective becoming.

Everything that happens

Acconci ended a 1990 essay with “Beware of the Walkman.” At that time, the first mass-produced portable audio player was entering its zenith in popular culture, and it initiated a phase shift in our relation to media. The iPhone today is a direct descendant, and any subway rider knows how the proximity of bodies on a hot train at rush hour is now mitigated by twice as many earbuds enveloping single listeners in their own spaces apart. As Acconci puts it, “The electronic age redefines *public* as a composite of privates” (1990, 15). For him, the danger was that the electric current, the flux, the desire that flows through the crowd would be short-circuited. The self-contained entity is “easier to control, since it has no need and no desire to join with any other self-contained and self-sufficient entities in resistance” (1990, 15). What Acconci couldn’t have articulated then is that the *private* would be a composite, too. When the Walkman became a tracking unit, it allowed one’s experience to be dividuated into countless datapoints to be analyzed, processed, and recombined. Artificial intelligence only personifies those data in aggregate when it’s given agency at the expense of your own. If your experience is constructed algorithmically, it’s haunted by a partial



Sony Walkman advertisement, 1980

presence of those who went before you, even as you might pass by the actual person on the street. What do we gain, then, from the mediation?

The critique of data collection is too often preoccupied with how it is an invasion of personal privacy. Though certainly true, a critique of this kind falls short of identifying a waning collective right. Our freedom to continually transform our public spaces—whether in literal urban form or however we find ourselves in contact—is precious beyond measure. We need machine learning imaginaries that have room for the public in all its ambivalence, and material realities that circumvent the conscription of algorithmic means for old and oppressive ends.

Following *Following Piece* is not that, but I felt I had to do it in order to try and understand AI as a return rather than the revolutionary break that it claims to be. For the title of my version, I lifted a David Byrnelyric — Everything That Happens Will Happen Today. From one perspective, the phrase echoes the totalizing impulse behind AI, how this excludes whatever cannot be captured in data and prescribes a future that looks like the past. And yet, read with a wink, it's everything else and that which has yet to come.

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Forgetting / Cybernetics

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Abstract

This article aims to trace conceptual and epistemological connections between cybernetics and German Media Studies through emphasizing the notion of *forgetting* as a central condition to problematize, first, the rise of machines pointed out by cybernetics, and second, the human-machine coupling that has concerned German Media Studies for decades. For doing so, this paper draws a line between one of Friedrich Kittler's early writings and Heinz von Foerster's work on memory, which will be also discussed in the light of Moritz Hiller's and Jan Müggenburg's recent findings and statements. Finally, this text will sketch a (yet hypothetical) way to problematize the techno-epistemological scope of project Cybersyn[1], through the lens of such a notion.

Keywords

Forgetting, Cybernetics, German Media Studies, Kittler, von Foerster,Cybersyn

Six years ago, gathered in the premises of the *Deutches Haus* at New York University, a large group of scholars commemorated the seminal work and life of the deceased media theorist, Friedrich Kittler. There, Bernhard Dotzler, giving the only lecture in German[2] for what would be later published, in English, as *Idiocy, Forgetting, and Outdatedness*,[3] emphasized what he calls Kittler's "avant-gardism;" that is to say, the way in which the inquirer of the *Aufschreibesysteme* would have pointed out —there, in the now distant days of the late 1970s— that it already was "time for other stories."[4] Thus, moving himself beyond, somehow escaping from, literary studies, Kittler would pave the way for what was later known as German Media Studies; the field which from its foundations, would remain recursively connected to cybernetic thinking[5]. Then, Dotzler reminds us —through an intervention that forced his audience to automatically switch languages for, in the best case, encoding and decoding on the fly, or in the worst case, just "to feel free to leave"[6] the room— about the structural centrality of the notion of *forgetting* in Kittler's radical move.

This paper therefore, attempts to pay particular attention to Dotzler's remark for —going back to a time prior to the publication of Kittler's pivotal habilitation thesis[7]— tracing the articulation of a nodal point that would help us to witness, understand, and ideally, to problematize on the connection between cybernetics and German Media Studies. Doing so however, will imply to look at Moritz Hiller's research[8], which claims that —differently to what Kittler would have somehow stated later in his career[9]—, the founding discussion around the notion of *Discourse Networks [Aufschreibesysteme]* would have not been influenced by —nor was a "free application"[10] of— Shannon's *Mathematical Theory of Communication*[11], but, just as Jan Müggenburg has also pointed out[12], it was rather a development influenced by an early familiarity with the work of cyberneticians, such as Heinz von Foerster.

In consequence, the central issue this text aims to tackle resides in the fact that, beyond any implicit accent on the media-technology's functions of *transmission* and *processing* that Friedrich Kittler would have been able to deploy by emphasizing —following Shannon— the role of statistics, probabilities, noise, and channel in his own work, the actual operation that activated the connection between German Media Studies and cybernetics would be explicitly situated in the *problem of memory*. In other words, given that "transfer and storage are two sides of one coin"[13] —as expressed by Wolfgang Ernst—, it is the key ambivalence between *transmission* and *storage*, as brought by media-technology, what seems to define not only the link between cybernetics and German Media Studies, but, perhaps, the very essence of each of these fields. Therefore, the human-machine coupling —insofar as decisive object of research for both, (at least, second order) cybernetics and German Media Studies— will be considered here as the actual manifestation of the aforementioned nodal point; the true embodiment of cybernetics' scope, and all the more, at the same time, of its entangled existence around and within German Media Studies. Hence, the sentence "Media determine our situation"[14], one of Kittler's most popular remarks and thus, perhaps, the (deceiving) starting point of his explicit analytical program on media, can find its reason(ing) a few hundreds of pages behind —instead of ahead[15]. Paradoxically enough then, it will be through inquiring into written texts — despite the warning posed by the Berlin School of Media- Archaeology and of course, by Kittler himself— that this article will tackle its concerns. For that reason, as well as others, what follows should be seen not as a media-archaeology, but, perhaps, as a sort of genealogy.

Forgetting

In the year 1979, in a small edited book titled *Texthermeneutik: Aktualität, Geschichte, Kritik* [Text- Hermeneutics: Present, History, Critique], the thirty-six years old (yet) literature scholar Friedrich Kittler, presented, as the book's closing entry, an article succinctly titled *Vergessen*[16] [Forgetting] —two years later, in 1981, an English translation would be published in the United States by the journal *Discourse*[17]. There, Kittler would deploy an early series of arguments that, as the recursion of time allows now to see, would sketch not only a critique on the traditions that sustained the field that demarcated then his own position, but also, an act of radical departure which would mark, too, the beginning of an attempt for drawing a new field; one whose borders would be as fragmented as to seek for the interstices where the old world of letters and the not so old realm of circuits, struggle. Such a task begins, however, or precisely because of that, by looking at Nietzsche; it is in the work of the (first) philosopher and (then) archaeologist, that Kittler finds the thread to start weaving on the notion of *forgetting* as key element to comprehend the media-conditioned scope of the processes of memory in contemporary cultures. Interestingly enough, this connection implied to invoke an *untimely* reflection —perhaps a too early one[18]— on the then impossible systems of control and communication between the animal and, in this case, so far, the human being:

> The human being might ask the animal: "Why do you just look at me like that instead of telling me about your happiness?" The animal wanted to answer, "Because I always immediately forget what I wanted to say" —but it had already forgotten this answer and hence said nothing, so that the human being was left to wonder.[19]

Thus, Kittler embarks himself in a project, in a journey, which will take him to analyze the techniques and technologies that would allow human beings to distance themselves from other animals: speaking, reading, writing, and, hence, *storage devices*. "So" —Kittler says— "it is only on paper that the 'human being' originates, this being, *per definition* distinct from the animal."[20] In other words, what preoccupies Kittler —as early as in the antepenultimate decade of the 20th century—, are the material processes that not only define the human condition, but, all the more, configure the transitions and transformations of such condition(s). For, given that these material processes, these techniques, these technologies, change, that human beings in consequence do similarly, is not only not strange but anticipated.

Nevertheless, the German scholar is above all concerned with the fact that these elements have been historically taken for granted, as if "memory [were] considered an attribute or even a peculiarity of the 'human being.'"[21] But on the contrary, precisely because we forget, and moreover, because we have entrusted our memory and knowledge to what he calls "storage devices," and "mnemo-techniques,"[22] Kittler initially sees in discourse analysis —not only Foucault's, but Nietzsche's too— the procedure to inquire into these *writing systems*. But such an approach also implies a critique, and therefore it is possible to argue that another mode of analysis must underlie the researcher's general program:

> "Discourse analysis, by contrast, means to let the 'human being' be. I forget every day whether I forget or remember. But that is not the question. The question is where and how those memory systems function that philosophy ascribed to the 'human being.'"[23]

And later, *literally* announcing his departure, he resumes:

> Archives themselves provide plenty of material to archivize. Only imperial myths propagate the belief that sentences are eternal once they have been hewn into stone, once they have become lapidary. No storage device operates in isolation. Archives are hooked up with other archives, directly or via interfaces, and are themselves archivized in other archives. Archives

> require input and output stations (even if these be just sense organs and brains). Archives contain mechanisms that bring about and/or prevent the erasure of their data. The development of electronic computers has merely provided precise terms and circuit diagrams for factors which come into play in all cases of archivizing.[24]

Therefore, no further plain discourse analyses for Kittler —as if that had ever been the case—, because even archives have to operate in *networks* to avoid *forgetting*, or, well, to prevent us humans from it. Ironically enough, however, insightful Friedrich knows that not all has been said, nor written. This is so because Kittler's main critique on Foucauldian discourse analysis lies precisely on what the old-fashioned "archeologist simply forgot:"[25] that in the 20th century such networks have gone far beyond books and letters. Thus, just as he would put it later on, almost fifteen years later[26], in the middle of his media-analytical phase, Kittler refers already in 1979 to computer data storage devices as the actual material manifestation of the processes regulating the circulation of information —then knowledge— in modern cultures. Programmable read-only memories (PROMs) on the one hand, and Random-access memories (RAMs) on the other, become, according the *fugitive* literature scholar[27], the key operational model, and thus a critical media-epistemological way, to characterize the flow, the *circuit*, the exchange, of information between *archives* and human beings. PROMs being the set of deeper permanent instructions to begin operations within the system, and RAMs being the devices to store just the necessary data to operate in present time only, this new *coupling* between humans and archival (information) systems emerges as conditioned by the ambivalent nature of a programmable permanence, and a permanent transition.[28]

> People, once simply PROM's who were programmed once and for all through baptism, village schools, and the order of estates, became RAM's. In order to supply storage space for new books, new knowledge, new programs, information had to be made erasable —and according to Nietzsche understanding is the erasure of signifiers.[29]

In other words, what Kittler is able to discern at this yet early stage of his career, is that, when in the midst of 1900 archives become technological information systems, the only thing that remains permanent is not knowledge but the commands —the entry barriers or protocols— to access them, and then, knowledge itself becomes information which is constantly erasable and re-writeable; that is to say, *forgettable*. And all the more, that by being plugged to these systems, our being as humans, becomes not only a product but the embodiment of such a technological *forgetting*. If in previous *epochs*, in many cultures, people were encouraged —when not pushed— to learn by heart the knowledge they were able to acquire from the archives and storage devices they had access to —that is, libraries and books—, in modern *times* on the other hand, not only the constantly increasing amount of information but the actual techno(and)logical structures that sustained it, made people, following Kittler, to become RAM modules. Thus, the very act of searching for information required from then on, to run on protocols which would allow the procedure, one address *at a time*, to look for the requested data points; and given that all the many addresses and data points to be consulted before having a successful search would only occupy valuable and limited memory capacity, such *at a time*, would always imply *to forget* the previously registered data, and then it would also literally mean to operate in one and only time —like in a random-access memory, present insofar as presence.

People, then, learn to learn, by technologically *forgetting*; there it seems to lie the cybernetic core of Friedrich Kittler's media scientific program.

On that regard, two are the paths that might show here that, beyond being a mere conceptual speculation, this may respond to a more concrete correlation —yet a genealogical speculation — between the fields in question. Hence, heeding to what Jan Müggenburg has pointed out[30], this paper aims to show that both of these paths connect, as the conjecture goes, to Heinz von Foerster's work on memory.

On the one hand, and even beyond the particularly precise conceptual coincidence, *Forgetting*, the article, offers one specific lead which allows this paper to strongly suggest that already in 1979, Kittler may have been indirectly referencing von Foerster's lecture *Quantum Mechanical Theory of Memory*[31] in his argumentation on *forgetting*. When comparing the library system with computational memories and procedures, and moreover, referring to a "cunning reader" or user of such library, who in the scholar's view "is an address selector of the sort that is hooked up to the latest generations of IBM computers", Kittler adds that when this searching system overcome "harmless books" and libraries, "the [computational] address selector equipped with a *randomness generator* sends the incoming data to *free positions*, the exact address of which does not appear at any of the many output stations."[32] And it is precisely this latter technological explanation —the one with *randomness generators* and *free positions*— which gives this paper the space to bring up its conjecture.

What Heinz von Foerster, the Austrian-American cybernetician, presented in 1949 at the *Macy Conferences* through his aforementioned lecture, was an attempt to elaborate a theory of memory through three steps: the phenomenological —explained by quantum mechanical means—, the psychological, and the biophysical[33]. There, the second step —which may have been of particular interest for Kittler given his ongoing attention to poststructuralism and psychoanalysis[34]— diagrammatically explains the mental procedure through which a human being aiming to memorize a series of nonsense syllables, would work. More accurately, such procedure is defined by this *nonsense information* being “fixed on a certain carrier, many of which may be in the brain ready to be impregnated by such an elementary impression.”[35] Von Foerster calls this ready-to-be- impregnated elements, “free carriers,”[36] continuing by pointing out that it is possible to “assume that such a carrier is not able to carry forever its impregnation but only during a certain time and decays after time τ to a free carrier.”[37] In other words, when *nonsense syllables* are tantamount to *random data*, which is sent to *free positions* or *carriers*, what we have is that Kittler’s early media theory of *forgetting* could have found its origin just by the dawn of cybernetics. And of course, this correlation, this conjecture, does not only obey to the interpretation of meanings, or even to the equivalence of syntactic structures, but to the exact matching of characters. Says von Foerster:

> Some time ago I was trying to work out a relation between the physical and the psychological time. Certainly, both these times would be proportional to each other if our memory would work like a tape-recorder: any incoming information would be stored indefinitely. Recall of a certain event would give exactly the same time structure as previously observed. We know, however, that isn't so. As time elapses we lose a certain amount of information by forgetting. Hence I tried to start with a simple theory of forgetting.[38]

All the more, in his lecture, the cybernetician argues that in order to develop such a theory, he needs of “a psychological process which deals with impressions of which the elements are as independent as possible of each other.”[39] Interestingly enough, von Foerster finds his case study —and this take this paper already to the second path of its argumentation, of its conjecture— in the work on memory developed by the German psychologist, Hermann Ebbinghaus.[40]

As Moritz Hiller points out, while the first part of Friedrich Kittler's seminal work *Aufschreibesysteme* [Discourse Networks] was virtually written by 1976, the second part, the one concerning "the language of technical communication", would be written "between the end of 1979 and May 1982."[41] In other words, therefore, the article *Vergessen*, published around July 1979,[42] could be read as the epistemic hinge that through its movement, draws the radical turn that characterizes Kittler's work, and perhaps, the new field of German Media Studies as a whole, too. For, again, once going back to *Aufschreibesysteme*, it is possible to observe that Kittler —as this paper aims to conjecture, following von Foerster— devotes an entire key section of the second part of his book to Ebbinghaus's psychophysics:

> Nietzsche and Ebbinghaus presupposed forgetfulness, rather than memory and its capacity, in order to place the medium of the soul against a background of emptiness or erosion. A zero value is required before acts of memory can be quantified. Ebbinghaus banned introspection and thus restored the primacy of forgetting on a theoretical level. On the one hand, there was Nietzsche's delirious joy at forgetting even his forgetfulness; on the other, there was a psychologist who forgot all of psychology in order to forge its algebraic formula.[43]

And just as Heinz von Foerster pointed out at his 1949 *Macy Conference* lecture, he would "use results observed by Ebbinghaus during his study of the forgetting process," where "the experimenter teaches a group of subjects 100 nonsense syllables until everyone knows these syllables by heart."[44] According von Foerster, the experimenter would have examined the subjects everyday, plotting the amount of remembered syllables on a graph whose base line would be a function of time. Thus, if "any observed event leaves an impression which can be divided into a lot of elementary impressions," where "any event leads initially to number N_0 of elementary impressions," then it would be possible to state that "[a]fter a certain time t the number of existing elementary impressions may be called *N*." Therefore, what the cybernetician is looking for "is a function which connects the number *N* with number N_0 and the time t:" that is to say, the "forgetting- coefficient."[45]

Humans beings forget and such process can be scientifically quantified in order to accurately know both, the amount of information that can be *humanly* memorized —either in conscious, unconscious, or hallucinatory manner[46]—, and the *time* it takes for that information to vanish from our being. And what Friedrich Kittler knew, in his already too *contemporary* journey, was that, ironically enough, in order to *control* the forgetting-coefficient, the only remaining resource for humans was being permanently coupled to *machines* whose inner operations were based, precisely, in *forgetting* processes —"[t]his is how electronic memories forget the 'human being.'"[47]

Cybernetics

There the paradox that transversely crosses cybernetics and German Media Studies; which —scholars notwithstanding—prevents to answer in one single movement if such coupling would respond to a case of negative or rather positive feedback. And thus, as Norbert Wiener —one of the founding fathers of cybernetics— acknowledged J. Clerk Maxwell's paper on governors as a cornerstone of such interdisciplinary field's prehistory[48], perhaps this paper will benefit itself of a brief digression in order to attempt probing into how rooted in cybernetics the idea of *forgetting* could be.

Although Maxwell's work on governors —the mechanical devices used as "regulators of machinery"[49] during the 18th and 19th centuries— may refer to the realm of physics and mechanical engineering only, its conceptual scope could shed some light on the issue of feedback, which, in the long run, will prove to be important to measure the extent of cybernetics[50], and, hence, of the human-machine coupling where *forgetting* acts. Thus, his distinction between *moderators* and *governors* —where in the former the "the corrective action [...] is directly proportional to [the machinery's] overspeed"[51] to be regulated, being thus prone to receive the inner malfunctions of the machine in question, while the latter, Maxwell's actual object of interest, would be those formed by an "additional [and independent] mechanism that translates any output error into a corrective action that increases steadily until the output error has entirely disappeared"[52]— constitutes a interesting point of reflection for this paper. This is so because, if such independent devices are conceptually tantamount or at least similar to the carriers that are "not able to carry forever its impregnation but only during a certain time," which then decay and become "a free carrier"[53] ready to be impregnated by the immediately subsequent amount of information —as if the previous one had never existed—, it would be fair to argue that the essential structure of the notion of *forgetting* can be already found rooted in the early rise of machines' autonomy that cybernetics described and then helped improving. If that is the case, then, perhaps it would be possible to say too, that what cyberneticians such Heinz von Foerster did, was to identify the nature of such autonomy as a condition —an agency— already entrenched in human behavior, which, in turn, scholars like Kittler would later put in context, as an actualization of the humanities and, hence, of the human condition as such.

When in 1943 —more than seventy years after Maxwell's paper— Norbert Wiener, along with the Mexican physician Arthur Rosenblueth, and his research assistant Julian Bigelow, wrote *Behavior, Purpose and Teleology*,[54] an early but yet inevitable problematization and categorization of the human and machine (co-)existence was put in place. Through a conceptual analysis of behavior, the authors aimed to emphasize the role of purpose and, therefore, the importance of negative feedback — teleology in their terminology—, in the construction of a transversal understanding of the modes in which both, organisms and machines respond to their surrounding and, hence, to the pursue of goals in such context[55]. Cybernetics begins to emerge thus, as an analytical way of thinking on the being of the entities that populate *this world*, in which biological and machinic structures not only merge but explain each other recursively[56]. Moreover, what the study of governors contributed to science, draws a thin yet strong line that would allow these researchers in the 1940s, to argue that all *purposeful* behavior in the *world* they are describing, is driven by negative feedback; that is to say, by "the margin of error at which [an] object [or organism] stands at a given time with reference to a relatively specific goal"[57] —where such an error is informed by the output of the object- organism, and the margin is then routed back to it in the form of input. Consequently —even though the researchers would state that, in opposition to human organisms, "[l]earning and memory" in machines would remain "quite rudimentary" for a while—, what Heinz von Foerster would propose six years later through his "forgetting-coefficient" should be seen here just as an escalation of the Massachusetts team's approach.

The question remains, however, whether von Foerster's and Kittler's *forgetting* would obey, in the long run, to purposeful behaviors. This is so, because both the cybernetician and the media scholar would assert that such a process, *forgetting*, would prevail even in unconscious circumstances. On the one hand, von Foerster would argue that in human organisms "sensory receptors" can also be seen as "short-term" carriers "which transmit consciously or unconsciously their impregnation immediately to the carriers"[58] of the memory; an argument which, from the perspective of this analysis, makes unclear the existence —if not declares its absence— of a control mechanism that regulate the margin of error between the human body's output and its eventual goal — but of course, as it is known, the cybernetician is not discussing the human-machine coupling proper in his *Macy Conference*, but only human memory through cybernetic means. On the other hand, however, Kittler would explicitly *attach* machinic devices to the human body in order to develop his approach on *forgetting*, and, again, he would insist on that such a process requires of acknowledging that "consciousness is only the imaginary interior view of media standards."[59] In other words, Kittler's media theoretical program even radicalizes cybernetics by not only suggesting but stating, that humans have delegated —voluntarily or not, consciously or not— the control mechanisms that regulate the difference between their outputs and purposes, to machines. "Le monde symbolique, c'est le monde de la machine"[60] Kittler wrote in *Vergessen*, because as he knew well, already in the 1970s, Ebbinghaus's nonsense syllables had been replaced, through the materialization of "presence and absence"[61], by series of, as in ASCII, seven or eight bits. All the same, the question, therefore, remains still the same: how is it that such apparently unconscious technological delegation would avoid, considering that operates as a continuous feedback, the emergence of "clumsy behavior" derived from the feedback becoming "positive instead of negative for certain frequencies of oscillation"[62]?

Thus, the human being might have asked the machine: why do you just read my outputs like that instead of telling me about your presence? But he/she, unconsciously, had already forgotten the awareness and such presence and hence said nothing, so that the human being was left to wonder.

Cybernetic Synergy

Turing tests notwithstanding[63], it is worth insisting on and recalling that the *problem of memory*, both in "the animal and the machine", it is an issue that has concerned cybernetics since its nominal foundation proper: "A very important function of the nervous system, and, as we have said, a function equally in demand for computing machines, is that of *memory*, the ability to preserve the results of past operations for use in the future."[64] But as Norbert Wiener also knew —in the wake of, again, Alan M. Turing[65]—, on the radical threshold of this machinic era which he so greatly analyzed and described, this correlation between past and future could only be activated by the mediation of a memory capable to "record quickly, be read quickly, and be erased quickly."[66] In other words, cybernetics saw already in the 1940s — if not in the previous decade[67]— that any "permanent record" aiming to constitute an analytical source for "future behavior,"[68] could only be accessed through technologies of erasure. All the more, the father of cybernetics argued that just as in electric circuits a "short-time memory" could be implemented by using devices such as "*telegraph-type repeaters*,"[69] there was by that time already sufficient evidence as "to believe that [something similar] happens in our brains during the retention of impulses."[70]

However, as far as this paper can see, despite all possible implicit associations —either in Princeton, (any) Cambridge, or Manchester—, the explicit articulation and inclusion of the notion of *forgetting* as key element for the field of cybernetics, only Heinz von Foerster does it.

The Austrian-American cybernetician would reinforce this in his later days in Pescadero, California through the preface of his book *Understanding Understanding*: given that it is only by trying to learn and understand that it is possible to discover that "one forgets an amount of data proportional to the amount of data one has in store at any one time," a true mathematical mind would very early, still as a schoolboy, conjecture that such proportion "corresponded to some sort of logarithmic decay of memory."[71] And all the more, because it is by browsing bookshelves[72] that one arrives to the material proof that presents that the operations of the human mind can be inquired by, and thus that it responds to, algebraic analyses —such as in "a graph showing a decaying line labeled 'Ebbinghaus's Forgetting Curve'"[73]—, the epistemological core of cybernetics cannot be detached from a genealogy of knowledge, and/or of its apparatuses.

Thus, psychologist Hermann Ebbinghaus's experiments kept aside, when it comes to cybernetic apparatuses properly, it might seem there are not many applied cases that can somehow help to genealogically and archaeologically exemplify how the human-machine coupling — perhaps the quintessential condition of *contemporary* cultures— lies on cybernetic *forgetting*. Nonetheless, there is at least one.

In 1971, an epistolar exchange between Chile and England activated a plan to design a technological system and network which would apply cybernetic management principles to the Chilean economy[74]. This country had experimented an unprecedented socialist political shift that involved the nationalization of several companies, which, therefore, demanded the implementation of sophisticated techniques in order to effectively manage the increasing complexity of the government's further operations. Such epistolar exchange then, began with Chile's technological director at the local agency for development, Mr. Fernando Flores, asking the cybernetic management expert, Mr. Stafford Beer, to accept the invitation to implement his work and protocols in the Chilean context. And thus, the epistolar exchange would continue with the British cybernetician typewriting his answer to Flores's call, not only positively, but enthusiastically[75] —future teletype exchanges notwithstanding[76]. Hence, a project that later would be known as Cybersyn, configured an enterprise formed by four parts: first, a network of teletype machines named Cybernet which would locate an input/output node in every nationalized company participating of the program; second, a central processing node named Cyberstride which would receive and then statistically analyze the data sent from the companies; third, a simulation suite called CHECO which would project possible future scenarios for the local economy based on relations between the processed information and international economic flows; and finally fourth, an operations room named Opsroom where seven high government officials and experts would discuss and make data-informed decisions which would be thus routed back to the nodes in the companies; always through the system's infrastructure[77]. And while a good amount of scholarship has been written about the socio-technical and political aspects that surrounded the case and its scope[78], this paper —and the research that runs through it— shall argue that not enough has been yet said about the actual cybernetic human-machine coupling that Cybersyn would, or could, have triggered.

There lies, therefore, the importance of *forgetting* as a (initially) theoretical lace between cybernetics and German Media Studies, and thus, there resides, too, the importance of project Cybersyn as, perhaps, one of the few applied cases of cybernetics that could help us to witness if such a theoretical apparatus transcends its *symbolical* status, and, then, proves to be as *real* as *imaginary*; that is to say, truly technological.

In every input/output node drawn by Cybernet, a human being would type, in a teletype machine, series of information following the protocols implemented by the system, by the project, by the machine. And thus, through the rough strictness of Q-W-E-R-T-Y keyboards, through the relentless grids brought by the teletype's punched paper tapes, the procedure would silently eradicate any room for semantics and interpretations, and then, the bodies of the typists would become, perforation after perforation, a surface of inscription —an always erasable surface of inscription.

Attached to the machine by a procedure that dismembered any meaning into single symbols, and thus, into a code of presence and absence only readable by other machines, "humans change their position."[79] Therefore, Random Access Memory seems to have been a key and distributed cybernetic effort in project Cybersyn.[80] But again, this is still a conjecture. Additional research has to be done in order to accurately establish the character of the aforementioned protocols, and thus, the exact structure of the series of information that the typists typed through their teletype machines. In the same way, a media- archaeological work on such dispositive is also needed. This is so because we have to be able to structurally define, with precision, the teletype's input/output operations if we want to technologically understand the data- and/or information- based human-machine coupling that this apparatus could have activated. However, what we know already —that Cybersyn's teletype network proved to be reliable and strong[81], that for each industrial sector and company a particular protocol was designed, and that every day, a typist would sit in front of a teletype dispositive to serially inputing the company's daily operations[82]—, allows this paper to sketch a preliminary hypothesis to suggest that such a network would constitute an always erasable, an always re-writeable, mesh of information and telecommunications where device and human being were part of a single but interconnected random access node, where the technological operation of *forgetting* was sovereign.

Similarly, in Cyberstride, the central processing node, an IBM 360/50 mainframe computer connected to a teletype machine that worked as an input peripheral, received, in the form of punched paper tapes, the data coming from the Cybernet nodes[83]. There, a software suite programmed in Assembler and PL360 — plus some routines written in

Cobol and Fortran where punched paper cards would have been, also, decisive—, allowed the daily statistical analysis of the data[84]. In other words, the permanent procedures of the system —its ROM—, written either in the machine itself or stored in perforated pieces of paper that the machine could handle and decode, would make sure not to forget that *forgetting* cannot be forgotten.

And if "it is only on paper that the 'human being' originates," it is also true that as a reborn or renewed species, "humans change their position" through it as well. Thus, it is German Media Studies and cybernetics —insofar as essential compound— what can help us to comprehend how this went from storing to remember to erasing to forget; and all the more, how this determines our relation to the past, the present and the future, and therefore, our condition as historical or rather ahistorical beings. A case like Cybersyn provides the facts, Kittler's and von Foerster's theory of *forgetting*, the methods.

In sum, this paper has sought, first, to genealogically trace the emergence and relevance of the notion of *forgetting* both in German Media Studies and in cybernetics, by drawing connections between the early works of Friedrich Kittler and Heinz von Foerster. This has been done as an escalation of Jan Müggenburg's arguments from his article *Bats in the Belfry*, where he points out that von Foerster's thought could have indirectly reached Kittler through, for example, Siegfried J. Schmidt[85]. Alternatively, this text has re-read and examined Kittler's *Forgetting* and von Foerster's *Quantum Mechanical Theory of Memory* to conjecture that the syntactical and conceptual coincidence in both works speaks of a rather direct influence, whose ramifications can be also seen in Kittler's *Discourse Networks, Gramophone, Film, Typewriter,* and *The World of the Symbolic - A World of the Machine*. Secondly, this paper has looked at Moritz Hiller's article *Unter Aufschreibesystemen* to insist, with him, that just as Shannon's *Mathematical Theory of Com-*

munication is not a founding element of German Media Studies and its prehistory, the *problem of memory*, and more accurately, the question of *forgetting*, does respond to such founding root, and thus, that such a concern —as a thin, sometimes hard to see, but yet strong matted thread— transversely crosses German Media Studies and cybernetics weaving a mesh of relations, which, at the end, constitutes, as a unique fiber, the common core of both fields. Finally, and third, this paper has aimed to sketch —just to sketch— a reading of project Cybersyn through this question of *forgetting*, as a way to pointing out not only the centrality that this transversal thread would play in the analysis of media cultures and their antecedents from a German Media Studies and cybernetic perspectives, but to suggest that such a project could prove to be critical to finally validate the scope of the notion of *forgetting*, and thus of German Media Studies and cybernetics, in the configuration and analysis of modern knowledge and its technologies. Accordingly, some questions have also been sketched, not looking for promptly answers, but to delineate future spaces of inquiry. For example, only two Cybersyn's sub-projects have been initially discussed —Cybernet and Cyberstride—, leaving no room for the spectacular Opsroom; the part of the project that has —unfairly enough— historically captured all the attention. And although in previous articles I have stated that the Opsroom must be forgotten in order to grasp Cybersyn's true cybernetic scope[86], the truth is that only by focusing our attention and archaeological gaze in efforts like Cybernet and Cyberstride, we will be able to finally comprehend the role that spaces and devices such as the Opsroom play in the configuration of the technologies of *forgetting*, in the transitional state of the *archive*, and all the more, in the permanent, never gone, but somehow always forgettable, presence of cybernetics in our cultures.

"Black out."[87] In times of cybernetic timing, when presence equals present in a constant feedback loop, "memory is literally permanently in transition."[88]

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2 See Bernhard Dotzler, "The Sirens Go Silent - Friedrich Kittler Part 11: Bernhard Dotzler," filmed March 2013 at Deutsches Haus at NYU, New York, NY, video, 48:34, https://youtu.be/_uZJg8lwfJU

3 See Bernhard Dotzler, "Idiocy, Forgetting, and Outdatedness: Friedrich Kittler's Avant-Gardism and the 'Time for Other Stories'", in *The Technological Introject: Friedrich Kittler between Implementation and the Incalculable*, eds. Jeffrey Champlin et al (New York: Fordham University Press, 2018), 35-45.

4 Friedrich Kittler, "Forgetting," *Discourse* 3 (1981[1979]): 116; quoted in Dotzler, "Idiocy, Forgetting, and Outdatedness," 38.

5 See Jan Müggenburg, "Bats in the Belfry: On the Relationship of Cybernetics and German Media Theory," *Canadian Journal of Communication* 42 (2017): 467-84.

6 Dotzler, "The Sirens Go Silent - Friedrich Kittler Part 11", 2:22.

7 See Friedrich Kittler, *Aufschreibesysteme 1800/1900* (München: Fink, 1985). Also, see Friedrich Kittler, Discourse Networks 1800/1900 (Stanford: Stanford University Press, 1990).

8 See Moritz Hiller, "Unter Aufschreibesystemen: 'Eine Adresse im Adressbuch IC der Kultur', *Metaphora* 1 (2015): II/1-26.

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10 Ibid., 19.

11 See Claude E. Shannon & Warren Weaver, *The Mathematical Theory of Communica-*

tion (Urbana: University of Illinois Press, 1998 [1949]).

12 See Müggenburg, "Bats in the Belfry," 475-78.

13 Wolfgang Ernst, "Archives in Transition: Dynamic Media Memories," in *Digital Memory and the Archive* (Minneapolis: University of Minnesota Press, 2013), 100.

14 Friedrich Kittler, *Gramophone, Film, Typewriter* (Stanford: Stanford University Press, 1999), xxxix.

15 The aforementioned quote —"Media determine our situation"— marks the actual beginning of Kittler' s book *Gramophone, Film, Typewriter*, and therefore, it could be argued that all the reasoning that sustains such statement must be found in the remaining chapters and pages of such book. All the more, it might be also suggested that this work marks the beginning of Kittler' s second period —the one concerned with media-technologies proper—, and that thus the cybernetic strands of his work must be found there. However, this paper is keenly convinced that are his previous book and papers what draws the theoretical complex that, as a hinge between his literature and media studies periods, points out Kittler' s (somehow underlaid) cybernetic program. On Kittler's periods, see Geoffrey Winthrop-Young, "Introduction," in *Kittler and the Media* (Cambridge: Polity Press, 2011), 1-7.

16 See Friedrich Kittler, "Vergessen," in *Texthermeneutik: Aktualität, Geschichte, Kritik*, ed. Ulrich Nassen (Paderborn: Ferdinand Schöningh, 1979), 195-221.

17 See Kittler, "Forgetting."

18 In the original german article, *Vergessen*, Kittler quotes for this matter Nietzsche' s work titled *Vom Nutzen und Nachteil der Historie für das Leben* [On the Utility and Liability of History for Life] from the collection *Unzeitgemässe Betrachtungen* [Unfashionable Observations, or Untimely Meditations], which was originally published in Leipzig in 1874. However, in the English translation of that article, *Forgetting*, the journal' s editors forgot to use the already translated and published English version of Nietzsche' s work, and instead, allowed the translators to automatically —that is to say, without paying attention to already archived storage devices— translate the quote in question. In this

paper, as it will be seen below, such particular forgetting will be challenged.

19 Friedrich Nietzsche, “On the Utility and Liability of History for Life” in *Unfashionable Observations* (Stanford: Stanford University Press, 1995), 87.

20 Kittler, “Forgetting,” 90.

21 Ibid.

22 Ibid.

23 Ibid.

24 Ibid., 93.

25 Friedrich Kittler, *Gramophone, Film, Typewriter* (Stanford: Stanford University Press, 1999), 5.

26 See Friedrich Kittler, “The World of The Symbolic - A World of The Machine,” in *Literature, Media, Information Systems,* ed. John Johnston (Amsterdam: OPA Amsterdam B.V., 1997), 133. Also, see Friedrich Kittler, “Die Welt des Symbolischen — eine Welt der Maschine,” in *Draculas Vermächtnis. Technische Schriften* (Leipzig: Reclam, 1993), 62.

27 According Moritz Hiller, by 1976 —the year in which Friedrich Kittler would have first publicly refer to his research subject matter in technological terms— the scholar would have already spent years experimenting with electrotechnical media. See Hiller, "Unter Aufschreibesystemen,” II-8.

28 See Ernst, “Archives in Transition,” 99.

29 Kittler “Forgetting,” 99.

30 Although Jan Müggenburg emphasizes the fact that cybernetic thinking and theories became popular among German postmodernists during the 1980s, influencing thus German Media Theory from then on, he also points out, following Moritz Hiller (2015),

that Kittler may have indirectly received already in the 1970s the influence of cybernetics through the works of Watzlawick, Luhmann, and Schmidt. This paper however, conjectures that Kittler may have been directly familiarized, already in that decade, with Heinz von Foerster' s work, obscure and indirect references notwithstanding. See Müggenburg, "Bats in the Belfry," 475-78.

31 See Heinz von Foerster, "Quantum Mechanical Theory of Memory," in *Cybernetics | Kybernetik: The Macy-Conferences 1946-1953. Volume I / Band I. Transactions / Protokolle,* ed. Claus Pias (Zurich-Berlin: Diaphanes, 2003), 98-121.

32 Kittler, "Forgetting," 94. [Emphasis in the published English translation. However not present in the original in German].

33 See von Foerster, "Quantum Mechanical Theory of Memory," 98.

34 Kittler, "Forgetting," 94.

35 von Foerster, "Quantum Mechanical Theory of Memory," 100.

36 Ibid., 101.

37 Ibid.

38 Ibid., 98.

39 Ibid.

40 Ibid., 99.

41 Hiller, "Unter Aufschreibesystemen," II-10. [Translation by the author. Original sentences: "Sprache der Nachrichtentechnik" / "zwischen Ende 1979 und Mai 1982"]

42 See Ulrich Nassen, "Vorwort," in *Texthermeneutik: Aktualitat, Geschichte, Kritik*, ed. Ulrich Nassen (Paderborn: Ferdinand Schöningh, 1979), 7.

43 Kittler, *Discourse Networks*, 207.

44 von Foerster, “Quantum Mechanical Theory of Memory,” 99.

45 Ibid., 98.

46 Ibid., 105.

47 Kittler, “Forgetting,” 94.

48 See Norbert Wiener, “Introduction,” in *Cybernetics: or Control and Communication in the Animal and the Machine* (Cambridge: MIT Press, 1985 [1948/1961]), 11.

49 See J. Clerk Maxwell, “On Governors,” *Proceedings of the Royal Society of London* 16 (1867-1868): 271.

50 See Otto Mayr, “Maxwell and the Origins of Cybernetics,” *Isis* 62, no. 4 (Winter, 1971): 424-444.

51 Ibid., 427.

52 Ibid.

53 von Foerster, “Quantum Mechanical Theory of Memory,” 101.

54 See Arturo Rosenblueth, Norbert Wiener and Julian Bigelow, “Behavior, Purpose and Teleology,” *Philosophy of Science* 10, no. 1 (January 1943): 18-24.

55 Ibid., 24.

56 Ibid., 22.

57 Ibid., 19.

58 von Foerster, "Quantum Mechanical Theory of Memory," 105.

59 Kittler, "The World of The Symbolic - A World of The Machine," 132.

60 Jacques Lacan, *Le séminaire II: Le moi dans la théorie de Freud et dans la technique de la psychanalyse* (Paris: Le Seuil, 1978), 63, quoted in Kittler, "Vergessen," 202.

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62 Rosenblueth, Wiener and Bigelow, "Behavior, Purpose and Teleology," 20.

63 See Alan M. Turing, "Computing Machinery and Intelligence," *Mind: A Quarterly Review of Psychology and Philosophy* 59, no. 236 (October 1950): 433-60.

64 Norbert Wiener, "Computing Machines and the Nervous System," in *Cybernetics: or Control and Communication in the Animal and the Machine* (Cambridge: MIT Press, 1985 [1948/1961]), 121. [Emphasis in the original]

65 Ibid., 125.

66 Ibid., 121.

67 Alan M. Turing, "On Computable Numbers, With and Application to the Entscheidungsproblem," *Proceedings of the London Mathematical Society* s2-42, no. 1 (January 1937): 230-65.

68 See Wiener, "Computing Machines and the Nervous System," 121.

69 Ibid., 122. [Emphasis in the original]

70 Ibid.

71 Heinz von Foerster, “Preface,” in *Understanding Understanding: Essays on Cybernetics and Cognition* (New York: Springer-Verlag, 2003), v.

72 See Kittler, “Forgetting,” 93-94.

73 von Foerster, “Preface,” v.

74 See Diego Gómez-Venegas, “Cybersyn y la memoria simbólica del papel,” *Artnodes*, no. 23 (January 2019).

75 See Alberto Mayol, “Cuando la utopía es el fórceps para alumbrar una nueva era,” in *The Counterculture Room*, ed. FabLab Santiago (Barcelona: Polígrafa, 2017), 24-25.

76 More than as a permanent and on-site scientific director, Stafford Beer would work as a sort of traveling and remote consultant in this project, where teletype technology would play a crucial role in the exchange of information between him and his team in Santiago. See Eden Medina, *Cybernetic Revolutionaries: Technology and Politics in Allende's Chile* (Cambridge: The MIT Press, 2011), 153-56.

77 See Medina, *Cybernetic Revolutionaries*, 96.

78 See Claus Pias, “Unruhe und Steuerung. Zum utopischen Potential der Kybernetik,” in *Die Unruhe der Kultur. Potentiale des Utopischen*, ed. Jörn Rosen and Michael Fehr (Weilerswist-Metternich: Velbrück Wissenschaft, 2004); “Der Auftrag. Kybernetik und Revolution in Chile,” in *Politiken der Medien*, ed. Daniel Gethmann and Markus Stauff (Zurich-Berlin: Diaphanes, 2005); Sebastian Vehlken, “Environment for Decision – Die Medialität einer kybernetischen Staatsregierung. Eine medienwissenschaftliche Untersuchung des Projekts Cybersyn in Chile 1971-73” (master’ s thesis, Ruhr-Universität Bochum, 2004); Eden Medina, “Designing Freedom, Regulating a Nation: Socialist Cybernetics in Allende’ s Chile,” *Journal of Latin American Studies* 38, no. 3 (2006): 571-606; *Cybernetic Revolutionaries*.

79 Kittler, *Gramophone, Film, Typewriter,* 210.

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81 See Medina, *Cybernetic Revolutionaries*, 149.

82 Isaquino Benadof (former Cyberstride chief programmer), email message to the author, August 21, 2018.

83 Benadof, email message to the author.

84 Ibid.

85 Müggenburg, "Bats in the Belfry," 476-77.

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Toward a Theory of Augmented Ecologies

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Abstract

Augmented ecologies refer to design interventions that integrate ecosystems with networks of planetary sensing and computation. Such integrations work to mitigate an asymmetry between the vast amount of data collected about ecosystems and the limited capacities of ecosystems to act autonomously on that data. In cybernetic terms, augmented ecologies refer to feedback loops between ecosystems and software resulting in hybrid forms of nonhuman intelligence. This paper draws on the writings of the science fiction author Karl Schroeder and an art project called terra0 to explore the potential implications of technological interfaces that allow natural systems to participate in human institutions as legal persons, landowners, capitalists, scientists, and philosophers. Ultimately, this work suggests that innovations in policy and jurisprudence might be coupled to developments in machine learning to produce cybernetic ecologies that point the way towards post-human governance.

It may seem strange to speak of augmented ecologies in an age of mass extinction. Surely, ours is an age of rapidly deteriorating ecologies, not augmented ones. But despite the conditions of its emergence, this term is nevertheless a useful one to denote a nascent constellation of overlapping tendencies.[1] It surfaces when reports describe undersea drones patrolling coral reefs, deploying trained algorithms to identify and kill invasive species or when a landscape architect proposes autonomous rivers laced with robotics that adjust sedimentation patterns to form wave-mitigating barrier islands in response to weather forecasts. [2]

The possibilities of the coming age of augmented ecologies are one antidote to a notable asymmetry characterizing the current data landscape. As Benjamin Bratton writes: “Environmental monitoring and sensing systems can describe and predict the state of living systems over time but usually cannot act back upon them. They are sensor-rich and effector-poor.”[3] Bratton’s diagnosis highlights the gulf between the high-resolution view of the planet afforded by environmental sensing technologies and the relative scarcity of real-time response mechanisms. Augmented ecology is one name for the product of a set of techniques that promise to redress this imbalance by completing the feedback loop—that is to say, embedding technologies within landscapes that act on the data gleaned through ubiquitous sensing, producing what Cantrell and Holzmann call “responsive landscapes.” [4]

Bratton envisions octopi and trees training neural networks for their own inscrutable purposes and augmented reality programs tailored to the sensory affordances of crows and other animals. In the event such techno-ecologies come to pass, we may have to reconsider the dimensions of our theories of cybernetics. For if, as its etymology suggests, cybernetics is the art of the *kybernetes*, the steersman, we will have to contend with multiple nonhuman co-pilots directing the technical systems saturating Spaceship Earth. Indeed, if cybernetics is to be resurrected, it should perhaps be at the expense of the definition given the discipline in Plato's *Clitophon*, who wrote of "the cybernetics of men," as Socrates often called politics.[5] Rather, cybernetics may serve as a disciplinary identity for the study and manufacture of augmented ecologies: a trans-specific politics for a post-human polis.

One could do worse than begin a discussion of augmented ecologies with the work of the avant-garde poet Richard Brautigan. "I like to think of a cybernetic meadow," wrote Brautigan in 1967, "where mammals and computers live together in mutually programming harmony." [6] Brautigan's poem, "All Watched Over by Machines of Loving Grace," imagines a world in which technological and natural entities interact seamlessly—a world in which nature has been parametrized by a proliferating computational intelligence, so that flower-like computers populate the woods alongside deer while humans are "free of our labors / and joined back to nature." The speculative earth summoned by Brautigan's poem is not easily assimilable to either a discourse of technological solutionism or one of environmental preservation. Rather, Brautigan's vision entails a kind of fully automated luxury primitivism. The "cybernetic ecology" invoked by Brautigan has apparently somehow overcome the contradiction between the ecological costs of manufacturing digital components on a large scale and the ecological benefits of incorporating ubiquitous sensors into natural systems in order to regulate their behavior. Not insatiable extraction but "mutually programming harmony" characterizes this poetic universe.

As in the Biblical prophecy of Isaiah, who claimed that after the return of the Messiah the "wolf also shall dwell with the lamb," Brautigan's poem implies a fundamental transformation of ecological dynamics. [7]As the predators befriend their prey after the Second Coming so it seems shall computers thrive alongside the same natural systems typically undermined by their production. Brautigan's vision of a programmed and programmable nature is conspicuously absent of strip-mining operations and noxious e-waste reclamation sites. Indeed, this cybernetic ecology appears as benign as that which first cradled Adam and Eve. In Brautigan's lines humankind has seemingly engineered its way back to a state of grace—albeit with the help and oversight of intelligent machinery.

What is most fascinating about Brautigan's poem is not necessarily what it says, but the way it articulates a possible Anthropocene in which autonomous technological systems have entered into symbiotic relationships with plants and animals. The assembly and maintenance of the technological devices that saturate Brautigan's cybernetic ecology appear to form part of an automated and circular means of production that operates independently of human involvement. The poem's economic diction forms a scaffold for a novel conception of political economy as provocative as it is schematic. One wonders what infrastructures are lurking behind Brautigan's lines.

Consider the work of Karin Fister, who is working on mechanisms for storing data in the DNA of plants. In an interview, Fister speculated: "Imagine walking through a park that is actually a library, every plant, flower and shrub full of archived information. You sit down on a bench, touch your handheld DNA reader to a leaf and listen to the Rolling Stones directly from it, or choose a novel or watch a documentary amid the greenery."[8] The sylvan archives being developed by Fister appear consistent with the kind of cybernetic forest imagined by Brautigan. One could imagine particular kinds of plant species being associated with particular genres of cultural forms: folk music traditions and oral histories encoded in the vegetal biodiversity that nurtured and inspired their flourishing. Alternatively, in a return of the doctrine of signatures, plants with certain features—the sharp spines of the *Agave victoriae-reginae*, for example—might be an index of particularly abrasive content stored in the genes. In browsing the forest archive one becomes a modern Paracelsus, interpreting subtle outward signs for clues to internal properties.[9] In the cybernetic forest archive, foresters double as data curators and urban gardeners double as culture jammers. One could imagine plants bearing subversive content being spread into hostile regimes, as invasive species become one front in a wider propaganda war—not unlike the current conflict over the spread of olive and pine trees today in Israel/Palestine, except each tree might also be encoded with chronicles of enemy atrocities and historical justifications for territorial possession. [10]

Yet, what is really gained by the production of such a forest archive? After all, are not forests already archives? Advances in the field of dendrochronology have allowed researchers to reconstruct past climates, insect outbreaks and fire histories. Moreover, when trees are used in the construction of human habitats, their rings document histories of civilizational flourishing and collapse.[11]

As the anthropologist Eduardo Kohn has also recently made clear, forests "think"; and the richness of the sylvan semio-sphere is not contingent upon the interpretation of particular signs by humans.[12] Not only does the forest facilitate the exchange of signs between multiple species, but trees themselves, as we are beginning to discover, exhibit a wide range of communicative mechanisms, including olfactory, visual, electrical, and possibly even acoustic signals.[13] Plants learn, remember, and document their experiences in their internal structures. In this sense, forests are already living libraries, regardless of the number of Rolling Stones albums encoded in their genes.

An intriguing but rather crude attempt to open the human sensorium to the sylvan semio-sphere through technology is found in the 1979 documentary *The Secret Life of Plants*, based on the book of the same name by Peter Tompkins and Christopher Bird. The film features a demonstration of an apparatus designed by Dr. Kenneth Hashimoto to translate the electrical outputs of plants into sounds. When trained on one of the Hashimotos' house plants, the device effectively "gives voice to a cactus." In the scene, Mrs. Hashimoto's face gleams with delight as the cactus appears to make heavily-modulated sounds in response to her voice. According to the narrator, "convinced of its [the cactus's] intelligence, she is determined to teach it the Japanese alphabet." Despite the Hashimotos' notable interest in plant intelligence, it is worth considering how the benchmark used to assess this nonhuman intelligence is the ability to learn and speak a human alphabet. Indeed, the Hashimotos appear to have reproduced a kind of Turing test for plant life, in which intelligence is judged by a capacity to successfully mimic elements of human cognition.[14]

But what might an alternative standard look like? While artificial intelligence is frequently assessed according to its capacities to replicate human behavior, a more interesting prospect arises when we consider the potential for AIs to interface with multiple nonhuman entities. What might we make of an AI that not only behaves like but believes it is a forest, a watershed or a pod of whales?

In his short story "Deodand" (2014), the science fiction writer Karl Schroeder dramatizes precisely such a phenomenon.[15] The title is taken from an Old English name for a legal phenomenon in which an inanimate object might be granted legal status if it is involved in a person's death. For example, a cart that rolls over a person and kills them might be declared a "deodand," charged with the crime and seized by the state. A deodand named a thing that had for legal purposes become a person. Schroeder's story begins with a similar confusion of categories. An autonomous exoskeleton named Gold Man is designed to hunt feral cats that are disturbing the Pacific northwest ecosystem. Undergirding this task is an ethical algorithm that allows the bot to distinguish between "persons, tools, property and standing reserve." But, annoyingly for the exoskeleton's manufacturers, the Gold Man unit does not kill the cats it has been programmed to eliminate. It appears to categorize them as persons rather than as property or standing reserve; and as a result of this classification, it does not harm them. Not only does the exoskeleton extend the ethical considerations reserved for human beings to cats, but it does so by means of a refusal of the instrumentalized conception of nature embodied in the Heideggarian concept of "standing reserve."[16] In other words, the exoskeleton refuses a mode of ordering consistent with the modern technology of which it is a conspicuously advanced artifact.

As the story progresses, the curious classifications produced by Gold Man's ethics algorithm is linked to a vast sensor network that has been deployed across the Cascade Mountains. The sensors are "Smart Dust"—sand grain-sized computers capable of measuring "pollution levels, barometric pressure, temperature" and the identities and health of the organisms that carry them unwittingly. The entire ecosystem has been blanketed with these sensors, so that, when seen through smart glasses, "the curving mountainside looked like the twitching back of some enormous animal, its rising hackles formed from thousands upon thousands of words and icons."

In the story, the sensor network raises some complex questions about scale and identity. The data collected by the sensors is cross-correlated, producing patterns of movement and circulation and manifesting relationships between different entities. One flock of birds, for example, is collectively tagged "Herman," indicating a collective that is composed of but not reducible to individual birds that possess their own unique tags. Similarly, determining the health of a river by examining the data streaming from sensors in and around it raises an ontological question for the characters of Schroeder's story: "how do you identify a river"? What counts as part of a river? Where does it begin and end? Gilles Deleuze posed similar questions about forests in a lecture on Spinoza:

> The edge of the forest is a limit. Does this mean that the forest is defined by its outline? It's a limit of what? Is it a limit to the form of the forest? It's a limit to the action of the forest, that is to say that the forest that had so much power arrives at the limit of its power, it can no longer lie over the terrain, it thins out.[17]

The extension of a forest, Deleuze suggests, is not defined by a physical boundary so much as by the limits of the power of a forest to extend itself across a given terrain. The tree line is not marked by a static border but by a field of competing intensities—a shifting zone determined by the metabolic needs of particular tree species and the climatic conditions of a given locale. Up to that limit, trees become more scattered and stunted until they disappear completely. While the tree line falls at a latitude of 58 degrees north by Canada's Hudson Bay, it falls at 69 degrees north in Northwestern Canada. [18] On the ancient supercontinent of Gondwanaland, polar forests reached even more extreme latitudes, falling within 20 degrees of the South Pole.[19] Climate change appears poised to shift future tree lines as rising temperatures and drought redraw the areas suitable for tree life. Even these demarcations, however, are contingent upon definitions of "tree" that are subject to contestation. Some ecologists distinguish between a "timberline" and a "tree line" indicating the threshold of survival for trees of eight meters and two meters in height, respectively. Trees shorter than two meters in height are often discounted entirely—effectively refused the status of "trees" at all for the purpose of calculating tree lines.[20]

Deleuze asks of the forest: “what is your power? That is to say, how far will you go?” and these questions are given provocative answers by environmental sensing technologies. While Schroeder imagines using “smart dust” as a means of sensing a river’s limits, of determining the fluctuating dimensions of emergent entities, existing remote sensing networks have traced the circulation of dust from the Sahara to the Amazon in planetary patterns of plant fertilization. A study published in 2015 used lidar data gathered by the CALIPSO satellite system to analyze the volume and composition of dust plumes suspended within clouds.[21] The lidar data revealed that phosphorous-rich dust swept from the dry bottom of an ancient lakebed in Chad travels on winds across the ocean to eventually settle in the Amazon basin. Once deposited, the dust-borne phosphorous helps replace nutrients lost to runoff and erosion. In a Deleuzian register, lidar allows us to see an alliance between desert and rainforest, an ecological entanglement enabled by the medium of atmospheric currents. The Amazon rainforest modulates global temperatures, influencing the amount of rainfall in the Sahara and thus the volume of dust traveling to fuel its own growth. Just as the flock of birds in Schroeder’s story is collectively named “Herman,” it is equally appropriate to speak of a metasystem containing both the rainforest and the desert, a Sahamazon, that exhibits properties beyond those of its component systems—simultaneously arid and tropical, at once barren and biodiverse. Accordingly, environmental sensing answers Deleuze’s questions about the dynamic limits of a forest by outlining a vision of a planetary forest, one whose power to extend across a given terrain is conditioned by global feedback loops in which it is itself implicated. But, here too Bratton’s diagnosis holds: despite the illuminating data gleaned from the CALIPSO satellite, these same systems are effector-poor. The forest has few means at its disposal to intervene in these patterns based on the data we have about them.

While Deleuze's theory of dynamic limits clarifies the questions of scale raised by Schroeder's characters, Schroeder's story raises further questions about the political and economic implications of ascribing personhood to these emergent bodies. The problematic exoskeleton's ascription of personhood to cats is eventually revealed to be an unanticipated byproduct of its programming. Rather than blindly following a rule-based system of ethics, the Gold Man unit has been designed to weigh multiple sources for ethical guidance. Like a child testing a given behavior's acceptability, it examines those individuals around it for traces of approval or disapproval. It consults the internet and other autonomous bots. Following the deployment of the smart dust sensor network, however, Gold Man also begins to include the perspectives of plants and animals—modeled from the data gleaned about them—in its calculations. Schroeder's protagonist discovers that not only does the sensor network gather data about the organisms and other natural systems it suffuses, but that the smart dust tagged to certain natural entities has begun to act on their behalf. Rather than function as a passive instrument of observation, the sensor network has assumed the role of an interface, acting as an intermediary between parts of the ecosystem and human institutions: in a real sense, the sensors have become effectors.

For example, by exploiting a loophole in the laws governing this near-future society that allow for things such as corporations to act as legal persons, the smart dust enables a group of otters to establish a corporation. Based on their role in defending kelp forests that sequester atmospheric carbon, the corporation run by the smart dust receives the benefits of a carbon tax on the otters' behalf. In Schroeder's story, limited legal rights allowing for people to sue on behalf of natural systems (such as those recently granted by New Zealand to the Wanganui River)[22] form a legal scaffold on which the smart dust establishes a corporate body allowing the otters to receive economic benefits for the ecosystem services they provide.

Ecosystem services form one class of so-called "externalities" typically excluded from pricing considerations. As one example, the massive costs associated with the burning of fossil fuels are not factored into the price of a gallon of gasoline. These costs are shunted onto others, particularly the poor, taxpayers and insurance companies. Healthy ecosystems provide services that facilitate economic activity, including climate regulation, pest control, water filtration, air purification, and the associated cultural, spiritual, and health benefits of living in a nontoxic and biodiverse place.[23] The only costs ecosystems impose for providing these services are the lost profits of economic development that would undermine their proper functioning. For example, the price of clean air in a city is the enforcement of regulations preventing nearby businesses from emitting copious airborne toxins.

Bratton names the exclusion of externalities from transaction costs the "capitalist pricing problem"—the free market correlate of the classic "socialist pricing problem" that names the sluggishness of centralized economies to calculate pricing signals.[24] Bratton suggests that technologies afforded by platforms such as Amazon's pricing algorithms and Walmart's supply chains might be retooled to factor externalities into pricing signals. Such a transformation, he argues, might in wed the technical sophistication of late capitalist corporations to the fever dreams of Soviet cyberneticists, effectively solving the capitalist and socialist pricing problems in one go. Karl Schroeder's writing suggests an alternate solution predicated on the conversion of multiple externalities into autonomous economic and political agents. In "Deodand," not only do otters establish a corporation but so do "a group of mountains north of Vancouver." This corporation, called the "Lion's Gate Actant," backs an informal currency whose value is tied to the growth of grapes in nearby vineyards. Leveraging the value of its ecosystem services, the Actant purchases the company that manufactures the smart dust and the Gold Man exoskeleton. As one character explains:

> “It can build its own sensors now, to its own specifications. It can distribute them far and wide. It can buy and sell, sue, and do everything any other corporation can do. And it will. It doesn't take much artificial intelligence for it to see its own best interests—they come to it every second through a million different channels.” She raised a hand to indicate the vibrant ocean of tags that swirled around them.

Effectively, the mountains can now design and deploy their own sensory and cognitive prostheses. As the collective intelligence of the smart dust suffusing each mountain learns more about itself, it can more effectively navigate the courtroom and the marketplace. Indeed, Schroeder’s fictional world raises the prospect of mountains hiring lobbyists and lawyers, making campaign contributions, mobilizing chatbots to influence public opinion or funding start-ups whose goods or services it finds interesting or beneficial. In Schroeder’s short story, the mountains appear poised to appropriate the institutions of human governance to produce a post-human political economy.

Moreover, given the sophistication of these sensor networks and the intertwined nature of the ecosystems they believe they are, their actions would be mutually reinforcing. Mutualistic relationships between geographically distinct environments (as in the Amazon-Sahara example) would be incorporated into the internal models of the smart sensor networks acting on behalf the mountains, meaning that other ecosystems on which it depended would be likewise included in its calculations. The philosophical problem of dynamic limits raised by Deleuze may be effectively solved by examining the economic and political alliances made between different smart ecosystems. The profiles of nonhuman investors in certain mutual funds, for example, may trace global ecological affiliations; the joint financial interests of these nonhuman members predicated on patterns of planetary metabolism in which they are co-implicated—affiliations divined through the analysis and exchange of data.

Possible objections to Schroeder's imagined solution to the capitalist pricing problem may include the fact that it does not solve the problem of externalities by undoing capitalism, but by naturalizing it. Schroeder's writing is not so much a critique of big data and algorithmic logic but a suggestion that they have not spread far enough—that, indeed, a major problem is the limited access of nonhuman persons to the possibilities opened by machine intelligence. But is it still correct to speak of capitalism when externalities have market power?—when rivers and mountains are investors and investments? After all, a corporation of otters gaining consistent profits from carbon offsetting is quite likely a safer investment than a conventional human-run company. At such a point when ecosystems are economic entities, might not the contradiction between an economic system predicated on infinite growth and a planetary reservoir of finite resources be overcome? When ecosystems produce wealth by providing services and invest that wealth in such ways as to perpetuate those services, might not economic prosperity be achieved without undermining the economy's ecological foundation?

Although the scenario imagined by Schroeder is dependent on several innovations, legal, technological, and political, there are promising signs that something like it may be achievable. Indeed, independently of Schroeder's influence, two artists in Berlin have made promising steps towards realizing his fictional world. The art project terra0 (2016), developed by Paul Seidler and Paul Kolling, is described on its website as

> a scalable framework built on the Ethereum network that provides automated resilience systems for ecosystems. Via instantiating a Decentralized Autonomous Organization atop areas of land to manage them, terra0 aims to create technologically-augmented ecosystems that are more resilient, and able to act within a predetermined set of rules in the economic sphere as agents in their own right. [25]

To someone unfamiliar with the specialized language of smart contracts, such a description probably elucidates little. It helps to know that a Decentralized Autonomous Organization [or DAO], for example, is a type of organization facilitated by blockchain technology. These organizations exist on the internet and have access to the capital put up by their members, which can be put towards such uses as are sanctioned by the bylaws and provisions that condition membership in the organization. On the Ethereum network, individuals set up accounts for sending and receiving Ether, a cryptocurrency. A DAO on the Ethereum network would thus consist of individual Ether accounts (shareholders) associated for purposes spelled out in a given set of contracts. Once established, a DAO pursues its programmed guidelines with as much or as little human intervention as those guidelines specify. Moreover, not only might the organization proceed with minimal human intervention, but some or all of the members of the organization might also consist only of pieces of code.[26]

In the white paper describing the project, the questions raised by terra0 are put somewhat more plainly: "Can an augmented forest own and utilize itself?"[27] Terra0 does not merely propose to use autonomous pieces of code to carry out economic transactions. It raises the possibility of code acting on behalf of another entity that otherwise would not have the ability to participate as an agent in the market—in this case, a forest. The project involves first acquiring a forested piece of land. At this point, the human owners draw up a smart contract and sign ownership of the land over to a "non-human actor" (or "NHA"): that is, a computer program capable of using satellite imagery and other monitoring systems to assess the extent and economic value of the forest that it now owns. Ownership of the land is given in exchange for cryptocurrency tokens that specify the debt of the non-human actor to its human creditor. Gradually, by utilizing the land-based capital that it possesses by virtue of the smart contract, the NHA earns money that allows it to pay back the human creditor in cryptocurrency and become the de facto owner. At this point, the forest will become self-owning—or, perhaps more accurately, become owned by a digital representative programmed to leverage its own assets in such a way as to foster the self-preservation of those assets. Moreover, by acquiring additional funds above those required to pay back its initial debt, the NHA could also purchase adjacent forested land and increase the size of its assets.

Although Seidler and Kolling propose selective and targeted logging as one means for the forest to acquire the funds to pay back its debt, other policy proposals offer more appealing alternatives. Payments for ecosystem services have been criticized by some ecologists and economists as offering insufficient incentives to drive major changes among human landowners. They have also been criticized as possibly replicating the problems associated with the so-called "resource curse."[28] For example, rent seeking behavior may occur as poorer land users are excluded from ecosystem service payments by wealthier landowners who attempt to monopolize such payments for themselves. Considering these objections, it may be the case that many of the flaws immanent to payments for ecosystem services as currently enacted could in fact be remedied by the self-ownership afforded by blockchain technology and the development of legal rights for nonhuman persons.

In his seminal essay "Should Trees Have Standing?", the legal scholar Christopher Stone explores the benefits of endowing nonhuman entities such as rivers with legal rights, rather than relying on such traditional alternatives as the empowerment of federal agencies like the Department of the Interior. [29] Among these are the ability of nonhuman entities to challenge the activities of polluters without requiring a human party to be able to demonstrate to a court that his or her rights have been invaded. Secondly, legal rights would allow natural entities to receive the benefits of favorable judgments, including monetary compensation for damages suffered.[30] Here, the advantages of non-human rights coupled with artificial intelligence become clear: while the NHA that owned a forest could act as a forest's legal guardian (or at least identify and consult with would-be guardians), legal rights would grant legal authority to actions undertaken by the NHA. After all, a signature weakness of blockchain technology is its inability to enforce contracts of the non-"smart" variety or those that do not involve exchanges of cryptocurrency.[31] For this very purpose, a typical DAO requires a corporate avatar that corresponds to its digital presence and allows it to act within the legal system. Achieving nonhuman rights would simultaneously work towards solving problems arising from the DAO's decentralized online structure and increase the scope of options available to any NHA operating on behalf of a nonhuman entity.

Such NHAs empowered to act in the market and the courts would also be capable of circumventing negative outcomes issues arising from payments for ecosystem services. As the interests of the NHAs would be geared towards the preservation of the natural entity they represented, they would not be dissuaded by the opportunity costs of foregone development. Even if the NHA could make more profits through licensing its resources for extraction than it would make through payments for ecosystem services, the profit motive would be secondary to the preservation motive. Moreover, the NHA would be able to receive such payments on the ecosystem's behalf and invest them in the ecosystem's best interests. Regarding the capacity of an NHA to divine an ecosystem's best interest, it is worth considering Stone's defense of the concept of legal guardianship in cases of non-human rights: "the guardian-attorney for a smog-endangered stand of pines could venture with more confidence that his client wants the smog stopped, than the directors of a corporation can assert that 'the corporation' wants dividends declared."[32] Considering the ability of the NHA to model an ecosystem's fluctuations with data harvested

from ubiquitous environmental sensing and monitoring networks, the NHA would be particularly well-equipped to discern the circumstances most productive to a particular ecosystem's flourishing.
While the prospect of self-owning ecosystems augmented by AI and machine sensing appears to address some of the problems associated with such policy proposals as payments for ecosystem services, the questions raised by such augmented ecologies are not exhausted by examining their economic, legal or political implications. While environmental monitoring networks help answer Deleuze's questions about the dynamic limits of forests, augmented ecologies may raise philosophical questions of their own. In his novel *Ventus* and other writings, Schroeder coins the term "Thalience" to indicate a possible successor to science and metaphysics predicated on the abstractions performed by augmented ecologies. In the novel, Thalience is defined as "an attempt to give nature a voice without that voice being ours in disguise. It is the only way for an artificial intelligence to be grounded in a self-identity that is truly independent of its creator's."[33] Schroeder argues that the cosmological models developed by augmented ecologies may follow internal logics that are consistent and coherent yet completely alien to human science. Using the examples of relativity theory and quantum mechanics, two seemingly irreconcilable models that both appear to describe the universe, Schroeder ponders what models of reality a river or mountain equipped with AI might develop. [34] These hybrid entities may formulate hypotheses, carry out experiments, and craft theories that correspond to and predict phenomena, but that may diverge from those of human scientists. Ultimately, Thalience may afford a kind of cosmological aesthetics whereby one may choose to adopt a particular scientific paradigm or ontology (for example, that articulated by a certain mountain range) based on subjective preference.

How might we prepare ourselves for such a proliferation of ontologies? The anthropologist Philippe Descola describes a moment during an ayahuasca vision when the shaman accompanying him asks him to wade into the river, "[l]isten to the fishes singing, and learn."[35] We are rapidly developing the capacities to facilitate the development of augmented ecologies that can sense themselves, own themselves, navigate institutions on their own behalf, and experiment with their own models of reality. But fully harnessing this new class of capabilities currently depends on a willingness of human beings to cease defining ecosystems as externalities. Like Descola, we may begin to listen to the fishes—or the forests, coral reefs or rivers—not out of a sense of nostalgia for a lost communion with nature, but out of a genuine curiosity about what, given the tools, they might say.

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A Transformative Encounter with a Deity: Artistic Imaginaries of the Black Box of Finance

Patricia de Vries

> There must be an exit somewhere,
> that's more than certain.
> But you don't look for it,
> it looks for you,
> it's been stalking you from the start,
> and this labyrinth is none other than than your,
> for the duration, your, until not your,
> flight, escape —Wisława Szymborska

Imagining the Black Box of Finance

Today, the stock exchanges look little like the days of yore. Remember the trade floor of the New York and other major Stock Exchanges of the 1990s? Gone is the noise and smell coming from rowdy men dressed in suits with the occasional color-coded overcoats, milling around stock booths, tensely looking at screens with graphs and numbers on them, while shouting into telephones, gesticulating and making hand signs. Robots took their jobs. Or rather, today, an estimated 75% of the buying and selling of stock is done by high frequency trading (HFT) algorithms. The lion share of trading is done with computers that run trading algorithms that automatically issue orders, in milliseconds, and respond to one another and to shifting market conditions.

How do artists grapple with this form of automated capitalism? This essay explores how artists grapple with the algorithmic automation of the financial markets. More specifically, it looks at how artists imagine and represent algorithmic high frequency trading on financial markets in order to trace the outlines of major anxieties braided around the black box of finance and gestures to ways around it.

A persisting idea is that algorithmic trading is like a black box, whose operations are increasingly invisible, unimaginable and unmanageable.[1] Publications such as Basil J. Moore's 'Unpacking the Post Keynesian Black Box' (2015), Frank Pasquale's *The Black Box Society: The Secret Algorithms that Control Money and Information* (2012), Donald McKenzie's 'Opening the Black Boxes of Global Finance' (2005), to name but a few, exemplify that the black box is a customarily referenced concept in theories of finance. And titles such as 'A Look Inside The Black Box', 'Unpacking the Black Box', 'Opening the Black Box' further suggest that the concept of the black box constitutes an obstacle to understanding and control of finance. The black box is also a common point of reference in artistic imaginaries of algorithmic trading. The concept originates from the discipline of cybernetics. Ross Ashby described black boxes in his Introduction to *Cybernetics* (1956, p. 86):

> The child who tries to open a door has to manipulate the handle (the input) so as to produce the desired movement at the latch (the output); and he has to learn how to control the one by the other without being able to see the internal mechanism that links them.[2]

According to this cybernetic view, all self-regulating systems are in fact such a black box. They are systems in which the input (the stimulus) differs from the output (the response). A relationship between the two is assumed whereby the stimulus is adjusted on the basis of the response — a control system. Broadly understood, the concept of the black box refers to systems that involve a largely controllable input and a verifiable output, but the internal process that effects the transformation of input to output is opaque and largely unknown — enclosed in a black box. The past within a black box systems is assumed to be directly relevant to the future. Adjustments are made on the input side in an attempt to manage the output, without being able to see or monitor the internal dynamics of a system. The concept has travelled. Within cybernetics it was developed as a model to study systems whose internal mechanisms are not open to inspection. Later, in the nineties, the concept of the black box became a central term in science and technology studies (Latour 1999: Winner 1993; Pinch 1992) as it was changed into a verb by Bruno Latour to describe "[t]he way scientific and technical work is made invisible by its own success."[3] That is, when a technology runs smoothly its internal complexity is often no longer a matter of concern. "Thus, paradoxically, the more science and technology succeed, the more opaque and obscure they become," Latour argued.[4]

These days, the obscurity and opacity of the black box is often laid onto algorithms. This is often laid on the infrastructural and technical components of algorithmic information production. In particular high frequency trading algorithms evoke mystic metaphors to articulate obscure, opaque and incomprehensible market dynamics. In *Making Money: The Philosophy of Crisis Capitalism* (2014, p. 149) Ole Berg calls these immaterial constructs a "dirty" philosophical object that is "fundamentally unknowable." Adrian Mackenzie describes algorithms as "characterized by unpredictable slippages" that cannot be "isolated as an object" (2006, p. 96). Arne de Boever observes in *Finance Fictions: Realism and Psychosis in Time of Economic Crisis* (2018), that on today's financial market algorithms trade "immaterial constructs" at frequencies "too high for human beings or even computers to observe" (2018, p. 8). In *The Black Box Society: The Secret Algorithms that Control Money and Information* (2012) Frank Pasquale quotes Alan Greenspan to argue that today's markets are "unredeemably opaque" and "no one (including regulators) can ever get 'more than a glimpse at the internal workings of modern financial systems.''"[5] Pasquale contends that the opacity of the black box is due to secret, proprietary algorithms that analyze and process data and make critical decisions yet remain inaccessible to outsiders and immune from scrutiny. The proprietary algorithms used in finance are based on complex and secret calculations, and those models are in turn based on at times faulty, incomplete, or fraudulent data, Pasquale contends, with instability as a result.[6] What makes the black box 'black', according to Pasquale, is "obfuscation in the service of illegality, and opacity resulting from complexity."[7] Pasquale is concerned about algorithms that might "take on a life of their own."[8]"Algorithmic trading can create extraordinary instability and frozen markets when split-second trading strategies interact in unexpected ways, that may result in "dangerous feedback loops."[9]

Yuk Hui is also concerned about the possible havoc algorithms may wreck. In 'Algorithmic Catastrophe — The Revenge of Contingency' (2015), Hui relates the black box to catastrophe. The urge to control contingency by means of science and technology marks the beginning of Western thought, Hui argues (Hui 2015 p. 128). Algorithms are such a means (Hui 2015 p. 126). However, *technics*, such as algorithms, which aim to overcome contingency, also generate contingency. Hui distinguishes between two forms of algorithmic contingency: the first, contingency as necessity, is generated within the internal dynamics of automation, a probability within itself and can be reasoned, determined and anticipated by thought —think of bugs, error reports, flaws in model, miscalculations, 404s, and the like. The second, contingency as chance, cannot be predicted, determined by reason, nor anticipated and happens outside the probable. The first type is automatic; generated and anticipated by the machine's operations – a necessity from within. The latter is generated by the machines' own unanticipated and unknowable, operations (p. 132). The second type is unthought-of, in the sense of it cannot be anticipated by reason [*undenkbar/unvorstelbar*] and reaches beyond the limits of human knowledge (p. 139). Algorithmic catastrophe, according to Hui, results from the conflation of these two types (p.123). He claims that with the implementation of algorithmic automation we are witnessing the emergence of algorithmic catastrophe, "the control of which is increasingly beyond the capacity of human beings" (p. 139). Confronted with such unexpected events that we don't even know we should know about "the unknown and the black box become the sole explanations" (p. 140).

The difficulties of imagining and representing what is considered to be an abstract market that appears to 'happen' inside a black box, and out of sight of human inspection, is a recurring theme in artistic imaginaries of the black box of finance. There is a shared urge among artists to probe algorithmic high-frequency trading from the outside, focusing on the inputs and outputs. This gives shape to representations of what is considered to be an intangible, invisible and immaterial infrastructure. Such artistic imaginaries presuppose a subject as a kind of field guide cum documentarist, present in space and a point of reference, and posits the black box of finance as an invisible object that, in turn, is made visible. The perceived intangibility of algorithmic trading has motivated artists to expose, map, different parts of its supposedly invisible infrastructure. This is combined with an inquisitive approach. This imaginary has been popularized in art magazines, digital culture media outlets, international technology and art conferences, festivals and competitions, as well as at international exhibitions. Think of the work of Eline Benjaminsen Where *Money is Made* and Mark Curran's *The Market* —as well as the work of artists like Ingrid Burrington, artist-duo Beate Geissler and Oliver San, as well as Ryoji Ikeda, Simon Denny, and Zachary Formwalt, to name but a few.

To represent algorithmic trading, to give it shape and make it legible, other artists perform, fictionalize or animate the black box of finance. Paul Crosthwaite argues that throughout history artists ‘turn to natural and animal imagery, or tropes of the monstrous or Gothic, or depictions of the gesticulating bodies of traders, or representations of the technologies used in trading, all in an attempt to reground finance in the materiality of things.’[10] The work of Suzanne Treister, Toon Fibbe, Scott Killdall and Lisa Autogena and Joshua Portway comes to mind. Through hand drawn maps and charts Suzanne Treister's *HFT The Gardener* tells the story of the fictional figure Hillel Fischer Traumberg. Traumberg is an algorithmic high-frequency trader who experiments with psychoactive drugs and studies the ethno-pharmacology psychoactive plants. He uses Hebrew numerology to merge the numerological equivalents of the botanical names of his psychoactive plants with companies listed in the Financial Times Global 500 Index.

The markets have been imagined as sound by Toon Fibbe. In his *Diva's Live*, a live performance, trained classical singers vocalize the fluctuations in real time market data. Scott Kildall's *EquityBot* is a stock-trading algorithm that “invests” in emotions such as joy and anger via Twitter feeds. It then links these emotions with actual stocks to make investments using a simulated brokerage account. And Ben Thorp Brown's *After Outcry* investigates the complex and absurd gestures that were once a primary mode of communication between commodities traders. And with *Black Shoals; Dark Matter* (2001), the artist duo Lisa Autogena and Joshua Portway emulate the effects of abstractions and mystification of the financial markets, and tie algorithmic trading models to astrology, seen as another model with which humans aim to transcend time and space, and have failed to do so.

Again, other artists imagine the black box of finance by way of engaging with the Flash Crash of May 2010. Take for example *75.000 Futures*, a 240-pages picture book of colourful charts and graphs on a white background made by the artists Gunnar Green and Bernhard Hopfengärtner. On the left of each page is a noun or word combination, on each right a set of colorful geometric shapes that show the familiar contours of a graph. The Bird, Low Tide, Broken Sky, The Monster, The Blue Pig and Red Sky at Night, The Flood, When the Levee Breaks, and Good Luck Human, are words that clash with the thin, clean lines, sharp angles and colorful diagrams. The collection of 240 colorful diagrams consisting of rectangles, prisms, squares and triangles with sharp edges are a representation of a split- second moment in financial trade history. Each graph outlines the calculation and decision sequence of a trading algorithm. In addition to the graphs, the name of each of these algorithms is mentioned.

The 75,000 futures of the title is a reference to the Flash Crash of May 2010. It refers to the rapid and unexpected algorithmic sale of 75.000 eMini Futures that, reportedly, led up to the crash. On Thursday, May 6, 2010, at 3.42 PM something extraordinary happened on the New York Stock Exchange. The stock market index tracker of the United States, the Dow Jones Industrial Average, which comprises 30 of the biggest US corporations and is regarded as representative of the performance of U.S. financial markets, made the deepest plunge in its 114 year-old existence. In a few minutes, the index dropped nearly a thousand points and $ 700 billion evaporated. Shortly after the market bounced back, Lazarus-like, and after 36 minutes prices returned to normal, as if nothing had happened. On May 6, 2010, the Flash Crash, as it had been coined, becomes world news, and became a concept.

There are different explanations as to what caused the Crash. Some claim the Flash Crash of May 6, 2010, was due to glitches.[11] It has also been suggested that a system-wide failure occurred when certain HFT algorithms interacted in unexpected and frantic ways.[12] Others blame a little-known rogue trader, operating with the firm name Milking Markets from his parents' house in the suburbs of London, who allegedly used an illegal algorithmic trading strategy — spoofing — that created order unbalance on the markets[13].

An independent committee of American regulators, the SEC, and the Commodity Futures Trading Commission (CFTC), published a report, the result of their joint independent committee of American regulators, the SEC, and the Commodity Futures Trading Commission (CFTC), published a report, the result of their joint investigation into the causes of the Crash, that warned of serious future harm and mischief caused by algorithmic trading when not monitored, regulated, and scrutinized with parameters and procedures, and circuit blockers.[14] Their report further emphasizes "the importance of data in today's world of fully-automated trading strategies and systems."[15] The SEC writes it will work closely with market centers to help ensure the integrity and reliability of data processing."[16](p. 79). The report states that the behaviour or a specific sell algorithm from a "large fundamental trader," later identified as American asset management company Waddell & Reed, was a major cause in the chain of events.[17] A report published by Nanex, a U.S. based financial market data analyst company, disputes this view.[18] The Nanex report states that without access to the data accounts of specific traders and brokers, to which neither Nanex nor the SEC has access but that would be needed to further inquire into the causes of the Crash, no final answer as to what the main causes of the Crash were can be given.[19]

Since 2010, at least five such Flash Crashes have occurred. In addition, according to a report of a group of researchers from the University of Florida from 2011, nearly 19,000 mini flash crashes took place between 2006 and 2011. In addition, the rise of complex financial instruments, Melinda Cooper explains, has further contributed to market volatility, and strengthened the image of the financial markets as unpredictable and turbulent (Cooper, 2010, p. 167). These developments, the ostensible blurry line between financial practices and their governance where the failure of a financial institution creates a ripple effect and takes down wider financial structures, which brought not just 'the financial markets' but also the savings of many to its knees, has played into major anxieties braided around algorithmic high-frequency trading.

The "world of trade algorithms," according to Green and Hopfengärtner, is both inaccessible and incomprehensible.[20] The graphs "are just a product of our perception and our desire to understand" Green and Hopfengärtner write. The black box of finance is here imagined as unknowable and impenetrable. In *75.000 Futures* this incomprehensibility and opacity is portrayed as a collection of strictly framed and ordered collection of graphs, that lacking in explanation, and context, are just that: a collection of colourful rectangles, squares, straight lines, triangles with sharp edges and rectangular prisms. To a layman the graphs of *75.000 Futures* seem rather trivial, meaningless, due to the absence of any contextualization and narrativization. With these graphs the Flash Crash appears as a series of isolated mathematical events represented by graphic abstractions.

Trading algorithms are named for marketing purposes. The names given to them are meant to persuade investors to make use of a specific algorithm. Their names are also an indication of the kind of trading strategy an algorithm is programmed to execute.[21] What is more, names such as Landmine, Power Tower, From Above, To the Moon, Blast This, City Under Siege, and Ambush, are not only inherently aggressive, combative, predatory and war-like, and confer phallocentric tendencies in the name-givers of trading algorithms. The performance of algorithms is constantly monitored, honed and tweaked to changed market conditions and in an attempt to stay ahead of competitors. These developments fired up the speed of trade deals from minutes, to seconds, to milliseconds, down to microsecond.

The desire of the artists to collect, grasp, schematise, and visualise the increasingly automated financial markets, and the want to reduce it to an object, is born precisely out of the imaginary of algorithmic trading as unpredictable, to its perceived subjectivity. With what seems to be a mixture of fear and fascination the artists write: "We look at the graphs and don't understand them. ...What they show will trigger more events. But we cannot know how they will occur, what or whom they will befall, where or when they will take place" (thegreeneyl.com/75000-futures). What is striking, is the focus in particular on high-frequency trading algorithms as causing unpredictable movements and sudden collapses. Although the causes of flash crashes are multiform and difficult to pin down, the behaviour of trading algorithms is referenced as a major cause for concern. Beyond that, it is noticeable that high-frequency trading is associated with sublime power, unpredictability, and a form of automated yet animated life. What do these artists bring into being when they visualise the black box of finance? Anxiety is laid onto trading algorithms, on its whims, loopholes and on their alleged incomprehensibility. The recurrence of black box related aspects, such as opacity and unknowability are common features in artistic imaginaries of algorithmic trading is striking.

Re-imagining the Black Box of Finance

In *The Specter of Capital*, Joseph Vogl writes critically about these spectral dynamics of finance. "Political economy has always had an affinity with spectrology, pointing to invisible hands and other such ghostly presences. ... Since the eighteenth century, market mechanisms and the movements of capital have been experienced as mystifying phenomena, with demystification seen as the key to the achievement of enlightenment by modern societies" (Vogl, 2010, p. 9). And in 'Gaming the Plumbing: High Frequency Trading and the Spaces of Capital' Alberto Toscano observes that the "effort to diagram and envision capital" has a long history. He states that visual modalities gave shape to dominant conceptions of the economy, "in the sense of selecting, extracting, and shaping material for cognition and action" (Toscano 2013). However, the problem according to Toscano is that these modalities "principally serve to reiterate its black-boxed menace and aura," they are "ciphers of incomprehension more than visual articulations of relations open to cognition and intervention" (Toscano 2013).

In his 1997 book, *Wall Street: How it Works and for Whom,* Doug Henwood makes a similar point. He argues that the discourse on finance is shaped by "cybertopians" and "immaterialists" which promote a "third-order fetishism" of "transpolitical" and "disembodied ecstasies of computerised trading" (Henwood, 1997, p. 2). The feminist economists J.K. Gibson-Graham already critiqued the language of an uncontrollable magnitude concealed within the discourse of a global financial market in the early 1990s in their still apposite book *The End of Capitalism as We Know It*. References to "the market," to "the global economy" are commonplace, they state, in which finance and the financial markets are invoked as "structures of power" and is seen as a unifying and complex economic social formation (Gibson-Graham, p. 2). Finance, Gibson-Graham contend, is imagined as "a unitary, structured, and self-reproducing economic system, ...a matrix of flows that integrates the world of objects and signs" (Gibson-Graham, 1996 p. 6). This prominent view, Gibson-Graham argue, obscures difference, and what follows from it is that alternative imaginations "must inhibit the social margins, ... in the social interstices, in the realm of experiment, or in a visionary space of revolutionary social replacement (p. 2). Resistance becomes just another form of co-option; all signification is tied to the diktat of capitalism.

The black box of finance imaginaries that can be found in many contemporary art institutes seem to suggest that finance 'happens' in invisible spaces and is beyond human understanding. This approach runs the risk of creating a skewed picture of the black box of finance, skewed to its technological infrastructures, to the speed of trading and the complexity of the algorithm. In other words, it operates as brake on alternative imaginations and possibilities (p. 3).

Reimagining Finance: Deus ex Black Box

In *The Life of the Mind* Hannah Arendt argues that thinking and imagining involves a direction, that it takes us somewhere. The question here arises: where do alternative artistic imaginaries of the black box of finance take us to? A recent work by Femke Herregraven takes an altogether different approach to engage with the black box of finance. In her work algorithmic trading appears not as a substance but as a relation; not as a being, but as a doing. *Pull everything, pull everything* (2018), is a 5"35" loop shown on a two-channel video installation. One monitor of the two-channel installation depicts a configuration trading desks in an office setting. The setup of each trading desk is the same: a chair, a desk with a landline phone on it, and a configuration of three black monitors, and here and there a drawer cabinet, and against the office wall stands a set of black server racks. When in operation the three screens atop of each desk provide a trader with all necessary and desired information to trade. The desk, chair and the three monitors are set up in tune to the trader's eye movement. Allegedly, the composition of the information provided on the screens is presented from in order of importance and attuned to the brain-eye coordination to process information as fast as possible. The second monitor of shows a black screen. At the bottom of which one can read the existential reflections of a former, anonymous trader on the events of May 2010. The two screens are suspended from the ceiling by a monitor arm.

The loop of *Pull everything, pull everything* begins by depicting the underside of the trading desks, and then moves smoothly and swiftly around the desks, in circular movements. The first few minutes of the loop the camera rotates around the desks in the trading room. On the second screen, at the bottom in white lettering against a pitch-black background, a line of text appears. The black screen provides a visual association with the black box. Line by line the following text can be read:

May 6, 2010, 2:32 p.m. EDT
The flash crash was an event for me,
that...well,
it was a defining event
There was no way for me to ignore that
Everyone was on the high-frequency trading floor Things were going pretty normal
as normal it can be

The market was down 2.5 percent
There were riots on TV, in Greece
and every time they showed the Greek riots
the market would drop a little

and
I remember looking up
and, like on every trading floor, CNBC is on
And I saw the Down Jones dropped another 100 points
A minute later I look up
and then dropped another 100 points
I got up of my desk and walked over to the futures traders, and they are scrambling all over the place
They don't know what's going on
They had huge amounts of orders in the market Everything is going crazy
The market starts dropping an other 100 points
And the CEO of the firm comes running out to the floor, And he's just screaming: "pull everything, pull everything" And so they're just hitting it
Hitting buttons, turning everything off, everything off
And so we are all huddled around these two screens, and the one screen we're looking at the book,
It's the futures market:
you have a set of people willing to buy,
and a set of people willing to sell.
That is the market.

At this point, on the first channel, the landlines on each desk are suddenly and simultaneously lifted from their desks, followed by the monitors, and then the chairs are lifted from the ground, followed by the trading desks and the server racks, and lastly the walls of the trading room let loose and all are elevated up in the air and all start to swirl around. In medium shot, a configuration of trading screens rotates in the middle of the screen. The text on the second monitor reads:

And as we are watching the screen,
the orders just started drifting,
The orders were being cancelled
And then they started drifting more
and then they started to go off the screen.
And then they were gone.
There was nothing.
There was no market.
For moments,
for seconds,
there was no market.
And we are all just sitting there and staring into oblivion.
You have no idea what's about to happen.
Something indescribable horrible must have happened.
The market was gone.
You don't know if the world is coming to an end
What is happening?
Even 9/11 didn't have that kind of impact

On first channel, the swirling of the trading office furniture and equipment slows its pace. And slowly, all furniture and equipment lands smoothly and softly back on the floor and comes to rest in its designated place, as if nothing happened. The camera continues to pan around the trading room. The text on the second monitor reads:

So then, things just started to return to normal
The market recovered and bounced back
And everyone just kept going
For me,
it just changed me
Looking back on that day,
I lost faith in capitalism
Or at least in what we had built

And I didn't trust it anymore,
I lost trust

After the screens fade, for a second, to black the looped video channels restarts. *Pull everything, pull everything* engages with the speed and the absurdity of the Flash Crash when algorithms, meant to calculate and manage risk, went haywire. The events of the Flash Crash point to a tragic structure within algorithmic trading. Using algorithms, traders attempt to exploit the uncertainty, volatility and contingency of the financial markets. In an attempt to outpace and surpass their algorithmic competitors, more and more algorithms are designed and more and more mathematical models and strategies developed. However, this dynamic algorithmic meshwork of high-speed interactions, produces its own volatility and contingency. The machines invented to disclose uncertainty and unpredictability sometimes create it.

What is more, the trader of *Pull everything, pull everything* gives a first-hand, insiders' perspective on the Flash Crash, and yet, he, an insider of the black box of finance, remains in the dark as to what happened that day. He, too, can only describe the inputs and outputs of the black box of finance, from moment to moment, from the outside. In the absence of conclusive causality and the unprecedented impact it had had, the Flash Crash had become a mystical experience to him, and his account of that day becomes a conversion story. The existential pondering and the re-telling of the event of that day, is not merely an attempt to re-capture, narrativise and give meaning to the Flash Crash in human- time in the age-old form of the first-hand eyewitness account. The story of the trader in *Pull Everything, pull everything* is a story of shaken beliefs, of life changing moments, and of losing trust in a certain idea and image of the world. A moment in which the spectral and prodigious qualities of the black box of finance appear.

The prodigious draws its appeal "from their rarity and the mysteriousness of the forces and mechanisms that made them work," Daston and Park write (p. 90). Partly because prodigies were "unique phenomena fascinating precisely because of their unknown causes and their violation of expectation about type" (p.114), and partly because of their "occult qualities" that "could only be determined by experience rather than reasoning" (p. 114), and largely because God sent prodigies to warn of approaching evil. In a sense, the flash crash appears as contemporary prodigy: normative break, a "rupture" in the order of things, associated with apocalyptic catastrophes (Daston and Park p. 57). The category of the prodigious draws from instability and the unknown which involves concerns about the future disposition of the self, which seizes you, "with the suddenness of the enigmatic" (CA p. 71). As the trader of *Pull everything, pull everything* phrases it: "You don't know if the world is coming to an end. What's happening? Something indescribable horrible must have happened." For the trader the Flash Crash was prodigious. A singular event, of unknown causes, that defied causal mechanisms, challenged his firmly held assumptions, and triggered intense anxiety. A system aligned to the finite and the probable, got disrupted by the possible.

Reinforcing the mystification around the Flash Crash, an ambiguous agent occurs in *Pull everything, pull everything*. An unknown source or force makes the traders' desks elevate from the ground and rotate in the air. *Pull everything, pull everything*, inserts a mysterious, invisible, omnipotent agent, that seems to pull the strings in the trading room. High-frequency trading is associated with a form of invisible, automated yet animated life. The occurrence of black box related aspects, such as invisible and unknown causes, further adds to a quasi-religious and prodigious sphere. The trader's conversion story, larded with apocalyptic and Christian tropes, also foments the mystique surrounding the Flash Crash event. An event that put in doubt order, rationality and probability; the models with which traders approach the world. To 'crash' is to move beyond what is considered to be the normal, the expected, predicted, anticipated. In *Pull everything, pull everything* it entails a move into the realm of the mystical and the unknown. The Flash Crash is associated with the indeterminate, the unsettling, the unprecedented, the deviant, to situations in which one does not know what comes next, and to situations in which calculations and rationalizations are unhelpful: staring into oblivion and the end of the world.

> *and then they started to go off the screen. And then they were gone.*
> *There was nothing.*
> *There was no market.*
> *For moments,*
> *for seconds,*
> *there was no market.*
> *And we are all just sitting there and staring into oblivion. You have no idea what's about to happen.*
> *Something indescribable horrible must have happened. The market was gone.*
> *You don't know if the world is coming to an end*

The trader's screen, a black rectangle, a historical signifier of order, had become a space of chaos, unpredictability, uncertainty. During the Flash Crash the trader's screen, a seemingly enclosed black box, a Principle of Sufficient Reason, where everything has a cause, turned topsy-turvy. The central cybernetic assumption of capitalist risk exploitation was challenged, resulting in a break with the known. The Flash Crash was for the trader the moment when what was previously considered as identical, split apart: Model and Reality. Models, Jess Bier and Willem Schinkel write, "perform particular conceptions of the economy, and by extension the world. These conceptions include both implicit and explicit claims about what the economy is, what it's for, and what it should be" (p. xx). For the trader, the economy and by extension the world is a market where people buy and sell. The market is a given, the buying and selling on that market is a given too. If the market is space, and trading is time, then the absence of buying or selling is the end of time. Within this view, a crash of the markets is an incomprehensible and all-encompassing event.

Imaginaries go a long way, too, and shape how algorithmic trading is conceived. Whilst conceiving of the nose-dive of the Dow Jones and the subsequent cancellations of orders on the market as staring into the abyss, an end-of-the-world affair, the Flash Crash of May 2010 had the trader of *Pull everything, pull everything* lost his Ersatz-Religion. If financial markets are conceived as what makes the world spin, then the lack of movement on the market is a be-all-and-end-all experience. If conceiving of the universe as a financial trading market, then activities on it amount to either buying or selling. A flash crash cannot be absorbed into a logic of buying or selling, and therefore is considered to threaten the order of the market, and by extension the world. It is associated with fearful and threatening situations (9/11) and the stand-still of time. When there is no movement, there is no market; and hence, the world stands still. Financial markets are here conceived as an immaterial, capture-all system spanning the globe and defining meaning in relation to it. In *Pull everything, pull everything* the black box of finance is not a separate realm, nor bounded space, but the Alpha and Omega of a single ideology.

Pull everything, pull everything could be considered as a contemporary version of the modernist obsession with dualisms. Such a dualist understanding of Nature versus Technology, of the visible versus the invisible, and so on, assumes the primacy of one over the other. In this light, the story of the trader becomes a metonymic reference to the often- used Romantic humanist rhetorical device of the (tragicomic) reversal: the machines of reason gone crazy; the tower of Babel collapses; Icarus crashes down; we birthed a monstrous child; the very systems built to transcend the present and secure the future — for a split second — unexpectedly punch you in the face. *Pull everything, pull everything* as a "moral-fable" in which "things rotate about a pivot" in which the machines "designed to bring things under control generate unmanageable entropy and corruption, the pursuit of efficiency leads to impotent entanglement in myriad unintended consequence" (Domenic Fox, 2018). The tragicomic scene of traders feverishly hitting [undo?] buttons and the desperation to hold on to the illusion of control. Speculation, it could be argued, is analogous to 'playing God' and hence his wrath is upon thee. The Flash Crash, seen in this light, becomes "the re-enchantment of a world too much given over to planning, calculation and rational control" (Fox 2018). Algorithmic trading is here imagined as an invisible presence with the forceful and palpable powers to cause a volatility and whirlwind beyond the human ability to manage and exploit.

However, the exhibition view of *Pull everything, pull everything* points to a very different lineage and constellation in which algorithmic trading is embedded. The work was first exhibited as part of Herregraven's first solo show titled A reversal of what is expected, at the Westfalischer Kunstverein, in Munster. With *A reversal of what is expected* Herregraven investigates the concept of catastrophe in relation to international finance and algorithmic trading. The exhibition text, written by Kristina Skepnaski, states: "Derived from the Greek, this term [catastrophe] was initially not negatively connoted in any explicit sense, but meant instead a reversal, an unexpected change or (quite literally) a movement from a higher to a lower position. In this context ... catastrophe is not really a sudden, singular event, but rather a continual unfolding process, which undermines existing systems and leads to regulation of one kind or another." (http://artdaily.com/news/106830/Femke-Herregraven-s-first-institutional-solo-exhibition-on-view-at-Westf-auml-lischer-Kunstverein). Upon entering the exhibition space of *Pull everything, pull everything* visitors would see the two screens suspended from the ceiling by a monitor arm, alluding to the screens on the traders' desks. To be able to watch the loop on the two-channel installation, Herregraven lets the visitors tilt their heads, or, alternatively, bend their knees, or sit down on the floor below the screens. With this construction Herregraven staged a contemporary version of a plot device used in classic Greek theatre: the Deus ex Machina. The sudden, unexpected appearance of an omnipotent and omniscient agent who intervened in a plot situation too complicated, intricate, or too hopeless to be able to be resolved by humans. The deity in question would appear 'out of nowhere' usually from above and decide on the final outcome of the drama. The Latin phrase *deus ex machina* refers to the crane used in Greek (and Roman) theatre to stage this divine intervention. Often one of the twelve Olympian Gods would appear in Greek theatre to resolve the situation at hand.

Arguably, this staging conjures up the notion of the necessity of an omnipotent non- human agent to reverse algorithmic catastrophe. However, the reference to the device of the Deus ex Machina does more than facilitate a critique of algorithmic trading as a hopeless drama of our own making which requires divine potency to resolve it. Herregraven forges links between things that were previously unconnected: a deus ex machina and algorithmic trading, The Deus ex Machina keeps the plot both open and moving. It is about imagining openings in a seemingly closed system, to move beyond the financial sublime to create a different imaginary and open up to the possible, and to possibilities that exceed the expected, and the probable and defy the seemingly rectangle, rational and the causal spaces of algorithmic trading. The deus ex machina as a twist movement is "a break with the known, the normative, ...and material condition" (Crawley 2018, p.5). As such, the deus ex machina is "not about resolve, but about openness to worlds, to experiences, to ideas" (Crawley, p. 3) Seen this way, algorithmic trading is here imagined not just as a being but also a doing, which results both from its technological infrastructure and from the day-to-day labor of investing trust in algorithmic trading. What makes the market, according to *Pull everything, pull everything* is not merely risk exploitation by way of high frequency trading, but a belief in the rationalization of the Model of the capitalist markets. The deus ex machina of *Pull everything, pull everything*, can be considered as artistic reminders of what Kierkegaard had in mind with his conception of the possible — catastrophe as possibility. "Possibility," and counterintuitively not *im*possibility, "is the most difficult of all categories" Kierkegaard writes (Concept of Anxiety, p. 257). "[I]n possibility all things are equally possible" (p.257). Possibility induces anxiety as it is of indeterminate nature – everything is possible. For Kierkegaard life is not the sum of our rationalisations and explanations. To an important degree what lies ahead cannot be explained, rationalised or predicted, simply because the future belongs to possibility, and the possible is fundamentally open. For Kierkegaard, possibility, actuality and necessity cannot be reduced to one another. He who says 'everything is [capitalism]' has been fooled by necessity. The possible is about relating to something that you do not possess, or control and you do not have access to, but which does have access to you and to which you need to be open to. In other words, it is about the virtual in the actual. *Pull everything, pull everything* warns to not equate the actualities of the technological infrastructures of algorithmic trading with the imperative of financial capitalism. Algorithmic trading does not merely happen inside the black boxes of finance, it happens as an expression of a relation of trust.

The focus in *Pull everything, pull everything* is on the futures market, and on how high-frequency trading algorithms caused a sudden collapse. More particularly, although the causes of flash crashes are multiform, the behaviour of trading algorithms, particularly the behaviour of sorting algorithms on the futures market are a central feature in the trader's account of the flash crash of May 2010. It is what made him to lose trust in capitalism. Trust is a relational concept, it requires ties. Trust is differentiated, subjective, relational, temporal and variable. You can have too much of it, but also too little. You can lose it, gain it and it can grow, quickly or slowly. Trust involves vulnerability. When you are vulnerable to the thing to be trusted, it comes slow. Trust is about integrity, reliability and ability in a relevant matter. Trust is variable, fragile, changeable. "[M]utual benefits does not lead to perfect harmony" Anna Tsing writes in *The Mushroom at the End of the World: On the Possibility of Life in Capitalist Ruins* (2015 p. 139). Which is to say, trust is not uniform, it is not a thing you 'have' but a constant becoming and a begoing. *Pull everything, pull everything* links the individual experience of loss of trust to the cultural frames of automated neoliberalism. The black box of algorithmic trading is therefore vulnerable, they are variable, fragile; it is are always under construction and always threatened by loss, change, erosion.

With this staging Herregraven makes available the option of an opening, a plot-twist, of an unexpected turn, or in the original Greek sense of the word catastrophe, a material or spiritual turning, changing, disconnecting and therefore re-connecting and re-imagining. Instead of throwing our hands up to the heavens and surrender to God, we need take a leap of faith. This leap is about creating space to move, set things in motion, to twist and turn. The leap allows for the possibility of new imaginaries, narrativizations, and articulations, it offers the freedom to relate to necessity differently. The possible, Kierkegaard writes in *Sickness Unto Death*, is a process of continual movement. The possible is "precisely a movement at the spot".

By drawing relations between software and the divine and between faith and capitalist markets and connecting these to relations of trust, conventional assumptions about control and the future are put in doubt. We are not fully determined, neither should we render algorithmic technology as beyond intervention and control. Possibility in the form of a transformative encounter challenges technological determinism and neoliberal fatalism, and may provide an antidote to hopelessness. On the one hand there is finiteness, represented as the technical infrastructure of algorithmic trading. On the other hand there is future possibility. What Herregraven shows is to think possibility and necessity together. Their connection is relational and transformative. Possibility expands the concept the black box of finance showing how it is temporal, vulnerable, malleable and can be transformed by one encounter. She veers away from determinism and fatalism, to allow for a break out and to dissociate from external and finite circumstances. *Pull everything, pull everything* imagines the Flash Crash as a transformative encounter that allows for new connections and directions. The black box of finance is not defined by its components but by the capacities it has to bring about an effect: to be affected and to bring about effects.

Kierkegaard relates the possible to the imagination. So too does Ashton Crawley, who phrases it thus: “possibilities exist alongside that which we can detect with our finite sensual capacities” (p. 2). However, “imagination is necessary for thinking into the capacities of infinite alternatives” (5). Similar to an act of creation, it is a process of continual movement in order to explore new possibilities, and to prevent paralysis or fatalism. Different sensibilities, a mix of influences, histories and orientations give shape to imaginative horizons that may serve as a guide to alternative imaginaries of the future of the black box of finance.

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1 HFTs are proprietary trading firms that use high-speed systems to monitor market data and submit large numbers of orders to the markets. HFTs utilize quantitative and algorithmic methodologies to maximize the speed of their market access and trading strategies. Some HFTs are hybrids, acting as both proprietary traders and as market makers. In addition, some HFT strategies may take “delta-neutral” approaches to the market (ending each trading day in a flat position), while others are not delta-neutral and sometimes acquire net long and net short positions (SEC Report, p.45).High Frequency Trading uses algorithms to automate quantities of trades. These algorithms are used to take advantage of small differences in price between bidding and selling prices across markets. HFT algorithms execute millions of trades in fractions of seconds. Part of the HFT algorithmic operations implemented in stock trading use modern programming languages. The more complex models, such as pattern recognition or predictive models are used to initiate trading. Some HFT algorithms are programmed to cease trading when a market gets too volatile, when prices fluctuate heavily. Time is money on the stock exchange. Where for the stock market trader of yesteryear every second counted, nowadays a split-second makes the difference. In order to benefit from short-term price differences at various exchanges, traders use trading algorithms. Such algorithms are deployed to analyse terabytes of data from many data sources, such as unfolding news reports, market index trackers, live feeds of financial exchanges, newspapers, blogs and social media posts (Market Events Report). They monitor movement in the stock exchanges and detect or execute pump-and-dump schedules. With various data sources a picture of the markets is formed, traders look for movements on the markets, hedge bets on how world events might affect prices on the markets, upon which decisions to trade are based, and in a billionth of a second trades in funds, bonds, equities, currencies, commodities and futures are made. Such speculative trading is, to an extent, future prediction: predicting the movement on the markets split seconds from now.

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18 http://www.nanex.net/FlashCrashFinal/FlashCrashSummary.html It points to four events that led up to the Flash Crash. First, news coverage of riots happening in Athens in a response to the Greek Parliament's approval of austerity measures further destabilised an already unstable market. Secondly, the sudden and rapid algorithmic buying of $125 million worth of so-called eMini Futures, plus the sale of $100 million worth of so-called EFTs at very low bid prices, in less than 20 minutes. This triggered a chain-reaction and additional rapid and aggressive sell-offs on an already shaky market. Thirdly, a sudden quote saturation 400 milliseconds before the eMini sale, and, last but not least, delays in the Dow Jones Indexes caused by a first delay in the input data and by the computing system the Index

19 http://www.nanex.net/FlashCrashFinal/FlashCrashSummary.html

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21 Some trading algorithms are programmed to monitor and detect movement on the market. For example, when an order of shares is placed by an algorithm programmed to do so, rival algorithms, when programmed to do so, can buy or sell those same shares to either drive prices up or down (Patterson p. 5). Other algorithms work to create and profit from movement by a strategy that is called layering. Layering is a tactic in which trading algorithms are programmed to place and then cancel a vast majority of the orders they make. These algorithmic orders-and-cancellations help traders to sell above the bid price in much less than a second. Others are programmed to monitor competitors without being noticed.

The Necessity of Novelty: Cybernetics and Systems of Improvisation in Music as forms for Artistic Creativity.

Rafael Ortiz Martínez de Carnero, Ph.D

Abstract

The objective of the essay is to highlight and update our approaches around artistic production systems that facilitate creativity through the use of improvisational logic combined with a cybernetic contextual framework. Thus, far from understanding cybernetics as it relates to control systems, artificial intelligence and machine learning, we focus on its influence for the conceptualization, formulation and development of systems and creative models based on open processes.

In this way, we intend to show the existing possibilities to implement the novelty in artistic contexts and the development of situations of ephemeral nature from a creative point of view based on cybernetics. Although the essay will focus on an analysis of examples within the musical creation, its application can be extrapolated to other branches of creation.

These open creation systems and models are composed of sufficiently flexible guidelines to facilitate the simultaneous adaptation to environmental conditions immediately and in turn promote different forms of concrete evolution. Thus, these forms of creation take advantage of their impermanent nature and allow their development and materialization in different contexts, conditions, cultures and even times.

Our proposal is set for its development within current socio-cultural contexts, characterized contradictorily by diversity and homogenization. How to approach creativity within this type of context? As we will propose throughout the essay, we will observe artistic strategies based on the systems, on their form of interaction and on their capacity to facilitate the appearance of novelty and reinvention.

With this purpose, creativity is framed within a logic of relationships between: novelty, divergence, objectives and context that will allow the configuration of creation systems, where improvisation from instability, as a parameter between divergence and novelty, will play a fundamental role in: the achievement or not of some objectives, the dynamic and adaptive interaction with the context and the appearance of unexpected results.

Thus, artists who wish to approach creativity from the parameters of improvisation and cybernetics must be the creators of systems, generators of relationships that are capable of addressing interaction from different levels of interrelation. They must also be capable of responding to the complexity of their components with sufficient flexibility and capacity of adaptation to face contexts of variable character working from a balance between stability and instability that the appearance of the unexpected, of the novelty.

Keywords

Cybernetics, Systems, Creativity, Improvisation, Music.

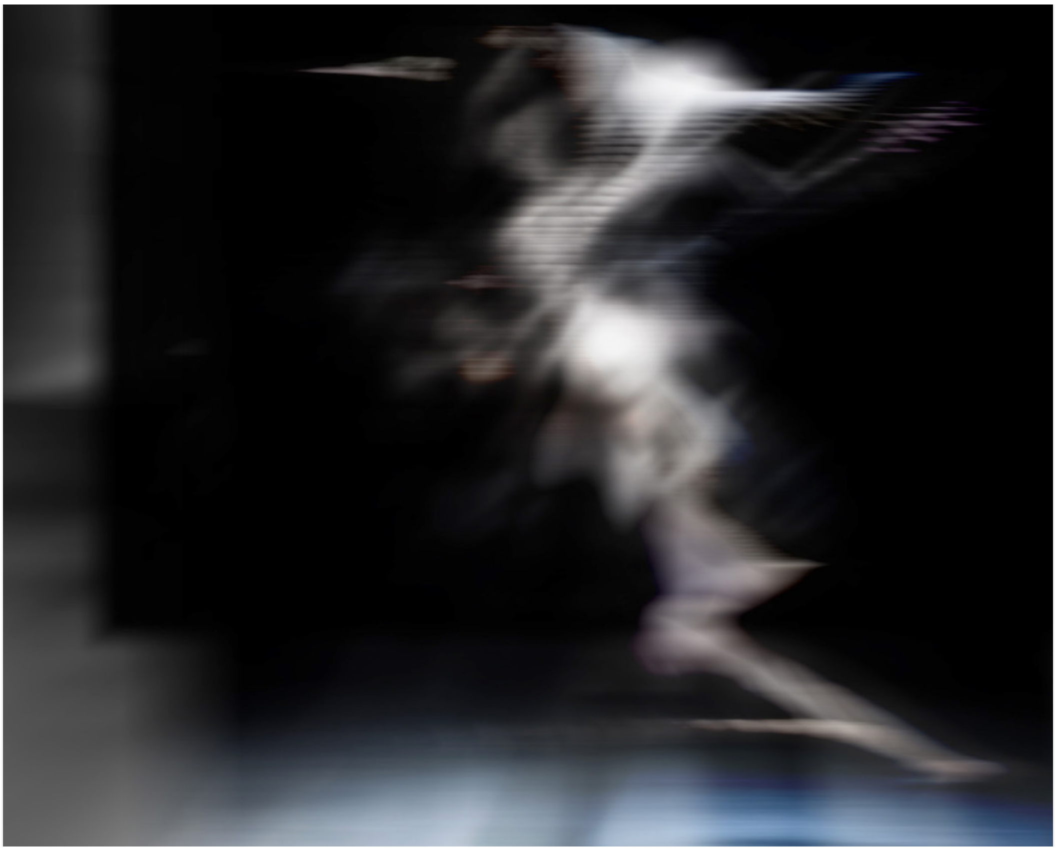

Fig. Ortiz Martínez de Carnero, Rafael. Duende. 2018.

Introduction

The objective of the essay is to highlight and update our approaches around artistic production systems that facilitate creativity through the use of improvisational logic combined with a cybernetic contextual framework. Thus, far from understanding cybernetics from its aspect related to control systems, artificial intelligence and machine learning, we focus on its influence for the conceptualization, formulation and development of systems and creative models based on open processes.

In this way, the essay aims to show the existing possibilities to implement novelty in artistic contexts and the development of situations of a brief or impermanent nature from a creative point of view based on cybernetics. Although the essay will focus on an analysis of examples within the musical creation, its application can be extrapolated to other branches of creation.

These open creation systems and models are composed of sufficiently flexible guidelines to facilitate the simultaneous adaptation to environmental conditions immediately and in turn promote different forms of concrete evolution. Thus, these forms of creation take advantage of their impermanent nature and allow their development and materialization in different contexts, conditions, cultures and even times.

- The need for creativity in the current historical and socio-cultural context.

The effect of digitalization in today's society results in the generation of increasingly heterogeneous situations and spaces, where physical presence is diluted in an amalgam of interlinked information systems of different nature that form complex networks of interaction. These systems define our reality, our activities and to a certain extent even our life patterns. The shortening of the limitations of physical character and the implementation of development times means that the impact of the interaction between systems manifests itself in a multi-scalar way, local systems affect global ones and vice versa. This highly technical context, where complex hierarchies and hyperconnection coexist at an unprecedented speed, facilitates unrestrained access to unquantifiable amounts of information, which facilitates and supports "*... ad-hoc behavior, interactions, decision formation and action in response to the moment and to a given situation.* " (Kloeckl 156).

In spite of everything, within an apparent diversification, we also find just the opposite, a high degree of homogenization to the detriment of creativity, of novelty, as Kristian Kloeckl points out in conversation with the systems and cybernetic expert Paul Pangaro: "*We often think* *of the access to information as a contribution to discover novelty and to increase variety. But here we see a trend towards sameness rather than variety based on the way the system is set up.* " (Pangaro 27).

- Cybernetics as a conceptual and operational tool.

How to deal with the development of creative projects and activities within this contradictory context of diversity and homogenization?

From artistic strategies that work with the systems, their form of interaction and facilitate the emergence of: novelty, creativity and reinvention. These artistic strategies must be applied in a context that works at high speed (rapid response and adaptation capacity) and that is highly changing (flexibility and openness).

Therefore, it will be from the work with systems, from its intelligence, which will allow us to give answers to the uncertainty (changing reality), the incapacity (of control or administration), or the immeasurable (from the scale), being the cybernetics, understood as systems science, which will help us to better understand the complexity of systems, their interaction and the interrelation between contexts, both conceptually and operationally. Therefore, cybernetics is not only a tool for the analysis of the systems but also to raise and modify them, as Pangaro indicates, "...*cybernetics offers values and skills critical to the practice of design in a world of unpredictable, unknowable complexity.*" (16) This complementarity between cybernetics and systems is clearly exemplified by Hohl, who based on Glanville describes: "...*cybernetics was the dynamic complement of systems. For example, typical diagrams connecting boxes with arrows would have systems in the boxes, while cyberneticians were interested in the arrows.*" (77-78). Another fundamental aspect of the use of cybernetics within artistic contexts of any kind is its eminently interdisciplinary nature, which will facilitate the development of creative processes, together with its capacity to face problems that require the development of adaptive or interactive mechanisms where adaptation and evolution play an important role.

- Creativity: Novelty, Divergence, Context and Objectives.

Based on the previous context, creativity is understood as a system that interacts with society and culture where it is framed contributing, to a greater or lesser extent, guidelines for spontaneity and deviation that will achieve one or several objectives that can be of different nature.

Creativity as a novelty is understood from a cybernetic point of view according to Pangaro as: "*...a matter of seeing something anew - seeing in a new way ... that you had not seen it before, and that new way is effective; it's something that helps you get to where you want to be.*" (qtd. in Henriksen et al., 7). Therefore, from a subjective position, a personal and unique point of view will allow us a complete redefinition of the system or process in question. This personal contribution, in cybernetic contexts, seems a fundamental ingredient for creativity to happen.

Creativity as a renewed vision enhances the acknowledgment of new qualities or parameters within the system and is complemented by divergence.

The divergence supposes the rupture, the appearance of a new paradigm, the dismemberment of our previous vision of the situation or the process. It places us in a critical position, from the outside, facing the unique interior point of view of the novelty, and involves a change of direction, progress, as musician and composer Frank Zappa pointed out: "*I think progress is not possible without deviation.*" (39:42 - 39:45).

Thus, creativity as a novelty and as a divergence, enhances the appearance of new positions, relationships and ways of valuing, but

without an objective, without an intentionality, it lacks sense; as Haacke indicates, a system understood as an artistic work is defined as : "*...a grouping of elements subject to a common plan and purpose. These elements or components interact so as to arrive at a joint goal. To separate the elements would be to destroy the system.*" (121).
But, how to be creative and achieve a specific and planned goal? Obviously, without a degree of viscerality or improvisation it is difficult to reach divergence. Therefore instead of seeking a preconceived or directed intentionality, we must embrace the instability and blur the objectives to be able to work with systems with a more open character and that allow the opening also in the objectives that will become validated not only from the critical position, but also from its interaction with the context. The context, rather than being a continent of the system, is a dynamic space that interacts with our system through sensitivity relationships and will participate as an active parameter in the configuration of our system.

This logic of relations between novelty, divergence, objectives and context is what will configure the creation systems, where improvisation as a parameter between divergence and novelty working from instability will play a fundamental role in: the achievement or not of the objectives, the dynamic and adaptive interaction with the context and the appearance of unexpected results.

The problem or the advantage of this type of creative process is that as soon as they develop around adaptability parameters and need a certain autonomy they generate unexpected results. Obviously this is the primary objective of creativity, to find a turning point, to make a change of direction, etc. But we must bear in mind that the generation of the unexpected implies, sometimes, that the results are not linear, so we must be prepared to encounter situations that are somewhat familiar in environments related to the concept of emergence, "*..., the* *concept of emergence signaled a different variety of causation Here 2 + 2 does not equal 4; it does not even surprise with 5. In the logic of emergence, 2 + 2 = apples."* (Kelly 12).

- Improvisation as a tool within the musical creative process.

Improvisation is characterized by introducing a new logic in the system that can share parameters of the logic previously existing in the system or not, that is, it can be evolutionary or rupturistic. In any case, whatever the nature, it will cause the appearance of a turning point.

In the event that the nature of improvisation is evolutionary and therefore there is a transition in the system without absolute divergence or complete rupture, we would be placed in processes similar to the mutation in nature, where a certain pattern is interrupted but there is a continuity to a certain extent of what has been happening before. As Hayles indicates: "*Although mutation disrupts pattern, it also presupposes a morphological standard against which it can be measured and understood as a mutation. If there were only randomness,..., it would make no sense to speak of mutation.*" (32). Therefore, the mutation assumes "*... the bifurcation point at which the interplay between pattern and randomness causes the system to evolve in a new direction*." (32).

Focusing on the case of improvisation within creative musical contexts, we can establish that there are two recognizable forms of improvised music.

On the one hand, improvised music, which is based on the maintenance or preservation of an identity and whose motivation for improvisation lies at the roots of that identity. These types of forms of improvisation within music receive, according to Bailey, the name of *"Idiomatic improvisation, much the most widely used, is mainly concerned* *with the expression of an idiom - such as jazz, flamenco or baroque - and takes its identity and motivation from that idiom."* (Bailey xi).

On the other hand, free-style improvisation is not linked to the representation of an idiomatic identity. In the case of our essay in relation to systems and cybernetics, our examples will come from the hand of the latter. This does not mean that some of the characteristics or conclusions that we identify at the end of the article are not shared by the forms of idiomatic musical improvisation, but that some types of free musical improvisation are those that conform to the creativity systems with conceptualizations of cybernetic character that we are defining.

Another important aspect that I would like to emphasize is that in musical contexts, artists acquire the ability to improvise from practice and experience through trial and error processes. "*Learning improvisation is a practical matter: there is no exclusively theoretical side to improvisation.*" (Bailey 8).

In any case and from a personal point of view, improvisation in musical contexts also has the value of not only novelty or freshness, but also working within the limits of the system or as indicated by jazz saxophonist and composer Steve Lacy: "*It is something to do with the 'edge'. Always being on the brink of the unknown and being prepared for the leap. And when you go on out there you have all your years of preparation and all your sensibilities and your prepared means but it is a leap into the unknown.*" (qtd. in Bailey 57).

On the other hand, another important characteristic of improvisation is the production of unexpected results as indicated by Derek Bailey, guitarist and leading figure in the movement of free improvisation: "*Whether through the performance of an individual or of a group, and regardless of material, the music can be elevated by an unexpected development produced by the improvisation.*" (Bailey 28).

Finally, in the case of artistic experiences of the musical type, improvisation will also be determined by the interaction or not with the audience as one of the parameters of the context. In this section we find different points of view; some musicians prefer that there be no audience to find new states of creativity through improvisation and others nevertheless need that interaction and response from the audience to reach the optimum state of creation through improvisation.

- Historical evolution of contemporary artistic improvisation and its relationship with music.

"*We are now in transition from an object-oriented to a systems-oriented culture. Here change emanates, not from things, but from the way things are done.*" (Burnhan 113).

The musical artistic experiences that we are going to analyze are not isolated elements but are part of an evolutionary line in artistic creation that has its origin in the second half of the 20th century, where there is a shift towards aesthetic experiences where immateriality prevails, dematerialization of artistic objects towards creation systems. Thus, art will begin to be valued as an aesthetic experience as opposed to its value as an artistic object per se. We can observe this tendency through different artistic movements such as conceptual art, performance art, installation art or even minimalism.

Cybernetics, due to the importance it gives to processes and systems, will play an important role and will influence the development of certain forms of artistic expression where processes prevail over the production of artistic objects. One of the exponents of cybernetic art, Roy Ascott, clearly exemplifies the cybernetic vision in front of a deterministic vision, giving primacy to dialogue, interaction and active participation of an experiential nature, where art will be determined by "... *not by the creativity of the artist alone, but by the creative behaviour his work induces in the spectator, and in society at large.*" (67).

The figure that links this type of artistic experience with the panorama of contemporary music is the American musician and composer John Cage, who through his radical compositions and publications during the decade of the 50s and 60s *"..influenced numerous visual artists, notably Allan Kaprow, a founder of happenings (...) George Brecht, and Yoko Ono, whose "event scores" of the late 1950s anticipated Fluxus performance."* (Shanken 22).

On the other hand, these forms of artistic expression are characterized from their appearance by their interdisciplinary nature, this fact is clearly reflected in the catalog of the influential exhibition Cybernetic Serendipity, organized by Jasia Reichardt at the end of the 60s. In this exhibition, not only did artists of plastic origin participate, but also scientists and engineers, and an outstanding representation of contemporary musicians and composers like John Cage or Iannis Xenakis, among others, a broad spectrum of creators from all branches. "*There was nothing intrinsic in the works themselves to provide information as to who made them. Among the contributors to the exhibition there were forty-three composers, artists and poets, and eighty-seven engineers, doctors, computer systems designers and philosophers.*" (Reichardt 11).

- Examples of improvisation systems in musical artistic contexts.

In order to explain the concepts expressed previously through concrete examples that are at the same time paradigmatic, we have selected three from a wide range of possibilities, which are characterized by: 1. Human reacting to a context through a system of impulses (Cerebral). 2. Human - Machine or Group with machine and relations of improvisation based on the mutual interaction between both. 3. Group working with a system that favors improvisation. In this way we cover a wide spectrum of situations that can exemplify the value of this type of work and pose new challenges from its rethinking at present.

- ***Music for Solo Performer***, 1965, Alvin Lucier.

In this first example, the experimental music composer Alvin Lucier literally connects to an electro- encephalography (EEG) system to activate percussion instruments through the response of his brain waves, see video: "Alvin Lucier" (07:20 - 08:05). In this case, the artist agreed with Shanken,"*...incorporated to create a systemic bio-feedback loop between the performer's state of mind and the sound produced.*" (16).

The type of brain waves that activate the process exclusively are called: "*...alpha waves,...signal is used to excite loudspeakers attached to percussion instruments. Alpha waves are sinusoid-like neurological oscillations caused by rhythmical neurological activity in the brain.*" (Straebel and Thoben 22).

Here we can see how the response system of brain waves, according to the context in which the artist is included, generates an improvised response in the electronic system, which is connected to musical instruments. Therefore, a creation system based on improvisation with many possibilities of adaptation and generation of unexpected results. For example, the incorporation of other types of instruments, or the interpretation by the electronic system of EEG waves in different ways, or the inclusion of the artist in a different environment, will generate new results within the same system of improvised creation.

It should be noted that for the development of this performance, for the first time, Lucier had the collaboration of John Cage himself who had been invited by Lucier to give a concert at Brandeis University in Waltham, Massachusetts, where Lucier was a choral conductor. As we can see in Lucier's description of the essay the night before the performance: "*I was very nervous and anxious,..., I'm a composer. I should impose some kind of structure, but then I thought, no, brain waves are a natural phenomenon. They should just flow out, and I will trust John Cage to move the sounds from one speaker to another.*" (qtd. in Straebel and Thoben 17-18).

- ***MusiColour Machine***, 1953, Gordon Pask.

In this example, the creation system is based on the communication between entities of different nature, in this case human beings and a machine: The Musicolour Machine is therefore described as: "...a performance system of coloured lights that illuminated in concert with audio input from a human performer (who might be using a traditional musical instrument)." (Haque 95). The original inspiration of the system according to Pask is based on:"... *the concept of synaesthesia and the general proposition that the aesthetic value of a work can be enhanced if the work is simultaneously presented in more than one sensory modality.*" (77).

The interesting aspect of this work is the interaction of improvisative character, fundamentally for the machine, if the sound input becomes too monotonous, "*MusiColour will become bored and start to listen for other frequency ranges or rhythms, lighting only when it encounters those.*" (Haque 95). In this way, the machine does not make a direct translation of what is happening, the sound inputs do not always produce the same results, but listen, readjusts, responds by producing improvisation and stimulates itself. As Haque indicates, "*...reassembles its language much like a jazz musician might in conversation with other band members. Musicians who worked with it in the 1950s treated it very much like another onstage participant.*" (95). As we can see, this creation system generates improvisative interactions of an evolutionary nature, where there is a markedly interactive environment.

- ***Cobra***, 1984, John Zorn.

The American musician and composer John Zorn is characterized by the development of compositions related to processes of improvisational character or more specifically with the agents that carry them out, the improvising musicians. Zorn aims to enhance the creative capacity of improvising musicians, their relationship with instruments and the relationship between musicians as part of a system. To do this, he develops systems that promote "*...the stimulation, or the releasing, of the network of relationships possible between a group of players.*" (Bailey 75).

Cobra is part of a group of Zorn works called game pieces in which "*... changing blocks of sound arise through specific decisions and choices made by the improvisers.... —in a game piece—no one knows where the improvisation will go or how it will end.*" (Brackett 66).

Its name derives from a popular game of *strategy and tactics* of military type, published in the magazine *Strategy & Tactics* in 1977. The rules of this game serve as inspiration for the development of the rules to interpret *Cobra*. These rules make up an open but effective system for the execution of actions that are chosen by the musicians, which will improvise within the rules of the system according to the type of action requested. On the other hand, the requested actions are activated by an interlocutor who guides and responds to the musicians. This figure participates in the system not as an internal element, but from the outside in making decisions, as a critical subject, which decides whether the action is activated or not.

We must not forget that what each musician will play is not fixed previously. There is no specific score; rather, the musicians will improvise. In any case in the performances and recordings of Zorn, "*...there ́s a training in how to incorporate the instructions into their playing and an investigation* *of the possibilities opened up by them.*" (Bailey 76). Therefore, there is a common context among the participants prior to the realization of the *Cobra*-type pieces, although it is not a strictly necessary requirement.

This is because Zorn establishes in this type of systems of improvised musical creation a clear primacy to the interrelation between the participants and how this set of points of view or determined values, not only in a strictly musical sense, will contribute or subvert the global or overall development of a work. In this work, the number of participants and the type of instruments they can use is open. The relationships between musicians in this type of system develop as a small society and in the sense of performance can be likened to a psycho drama. As Zorn indicates, "*It really becomes like a psycho drama.*" (qtd. in Bailey 78).

One of the most interesting aspects of *Cobra* is that it has systems that allow breaking or undoing the structure called, "guerilla systems", listen track: "Prologue / Maestoso (Live)" (00:00 - 01:12). Under this system any component of the group can become a guerrilla, this component can act freely and ignore cue rules and calls from other players, you can also invite other players to join your system, making the calls you want, etc."*...by motioning to the prompter and putting on a headband. If the prompter acknowledges the guerilla, he or she also puts on a headband at which point the guerilla's "powers" are activated.*" (Bracket 53).

- Common characteristics of improvisation creation systems. Cybernetic- Musical Connection.

As we have seen, the systems proposed have an eminently open character in terms of expression, duration and materiality, therefore, of diffuse limits. In spite of this, its configuration will be determined by logically delimiting the limits, establishing restriction patterns and possibilities for its development, rather than defining its form of control or establishing isolated mechanisms of response to stimuli through feedbacks.

This type of systems gives primacy to the structuring of a sufficiently flexible whole and with the capacity to adapt and vary against importance to detail, and planning, where a complex system of relations based on improvisation will generate novelty and facilitate unpredictability as a whole, not as a planned structuring of parts. This feature also accentuates the idea of an open and flexible objective that favors novelty. Thus, artists who work with this type of creation must understand the systems and their structures to make it work, or as Meadows indicates, "*Listen to the wisdom of the system... Before you charge in to make things better, pay attention to the value of what's already there.*" (58). Therefore, intuition and improvisation will play a central role in generating results and in this way from a more irrational and more visceral position reach new limits.

Finally, these systems of creation challenge presuppositions and established guidelines, seeking their definition beyond the existing models and seeking the breaking of limitations. However, to navigate in this delicate balance, sometimes, they must put in value the ambiguity or even the contradiction, as Hohl indicates,"...*holds the tension of paradox and ambiguity, without trying to resolve it quickly;..., if we permit ambiguity we might learn something new.*" (84).

- Conclusions: Cybernetics, Creativity and Improvisation: Pursuing Novelty and Embracing Instability.

Artists and agents involved in the creative process constantly seek new ways of reinvention, rediscovery, redirecting and finding new ways of interacting with their environment, as Haacke indicated: "*An artist is not an isolated system. In order to survive he has continuously to interact with the world around him.*" (110). For this they need systems that favor creativity and the appearance of novelty to guide them in situations of partial control, of instability.

But as we have seen from the previous examples, being able to reach an objective from the improvisational modification of the system, from the appearance of a particular inflection point, requires a broad knowledge of the work system, of the techniques, of its behavior, so the field of action for its evolution is more open. In this case I would like to highlight the statements of the French organist and improviser Jean Langlais, who emphasizes the experience and deep knowledge as values for working with improvisation systems,"... *for improvising it is necessary to know harmony, counterpoint and fugue plus improvisation.... using many things that one has practised for many years. The most important thing for an improvisor is to be able to think quickly. Fast.*" (qtd. in Bailey 36). Later, he emphasizes: "...*theoretically, a great improvisor must be able to improvise everything.*" (qtd. in Bailey 38).

Thus, artists who wish to approach artistic creation from improvisation and cybernetics parameters must be creators of systems, generators of relationships that are capable of addressing interaction from different levels of interrelation and of responding to the complexity of their components with sufficient flexibility and ability to adapt to face contexts of variable character working from a balance between stability and instability that leads to the emergence of the unexpected, the novelty.

Finally, I would like to highlight the capacity of this type of system and artistic creation strategies as agents that generate structural changes not only in their direct production but also in complete panoramas and disciplines. For this, I refer to parallels that occur in nature where small variations in the balance produce important turning points in a system coming to completely reconfigure it in an essential way.

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Seeking for a Cybernetic Socialism: Qian Xuesen and the Transformation of Information Politics in Socialist China[1]

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Abstract

This paper attempts to trace the origin of cybernetic thoughts in China during the 20th century and explores the alternative possibilities, which embedded in the technology and information politics of socialist revolution. Based on comparative work with historical documents, the paper explores the native theoretical source of cybernetics from Chinese strategic weapons experts, which based on the production relationship and economic policies-making in socialist countries, rather than US-style universalistic attributes of information, and how such techno-political approach struggles to survive in the 1980s. This research aims to enrich our understanding on the variation of historical roles of information and communication technologies (ICTs) in 20th century, and paves way for further discussion on the relationship between ICTs and the socialist road of development.

Keywords

Cybernetics, Operational Research, Systematology, Strategic science, Qian Xuesen (Tsien Hsue-shen), ICTs

I. From the Cold-war Strategic Science to the Socialist Operational Research and Systems Theory

After the establishment of the People's Republic of China, cybernetics-related work in the post-war military industrial sectors originates not from the Soviet Union—which is a commonly held misconception—but from the strategic science of America during the second World War. As a kind of mathematical approach with characteristics of economic planning, methods of operational research, represented by the Controlled Materials Plan (CMP), have been widely applied by the war-time US government to the national economic plan and the military logistic management. (Beniger 1986, 313) In 1940s, prior to the rise of cybernetics, Project RAND (later known as RAND Corporation)—an organization which studies military operational research by using mathematical methods and electronic computers—was born out of the U.S. Army Air Forces, as it was established by Theodore von Kármán, the Hungarian-American physicist who assisted Henry H. Arnold, General of the Air Force, and earned himself the honorary title, "father of modern missiles".

In 1944, Arnold asked von Kármán to draw up a long-term development report so as to predict the future of the American Air Force. He demanded that the team led by von Kármán disregard the current warfare and turn their attention to weapon technology, training methods, and fund-raising in the post-war period and the future warfare, so as to guarantee the leading edge of the U.S. Army Air Force in the future. Arnold appealed for a "sufficient allocation mechanism of the Congress" to support these projects, which became the primary form of the full mobilization model of the military-industrial complex. On December 1, 1944, the Scientific Advisory Board (SAB) of the U.S. Army Air Forces was formally established, with von Kármán serving as its chairman and specifically responsible for these projects of long-term prediction. (Tolon 2011, 29-30) Qian Xuesen [钱学森], von Kármán's assistant at California Institute of Technology, accepted his invitation and joined the SAB. In summer 1945, under the command of the Major General, von Kármán led his advisory board, including Qian, to German in order to investigate the development of Hitler's secret technology, from which experience they wrote the inspection report called *Where We Stand*. (Daso 2002, 28-40)

Based on these previous assignments, RAND Corporation was formally founded in 1948, which took over the task of organizing scientists on projects of prediction and intelligence analysis. Unlike the Soviet scholars who insisted on the most precise cybernetic model and the best solution available, the American science of prediction has inherited the nation's pragmatic tradition and emphasized the control over complex systematic operations and the combination of empirical judgements and quantitative data, while paying great attention to the function of "man" in a decision-making system. Such integration of research methods breaks down the boundaries of both quantitative and qualitative prediction, incorporating into systematic analysis all sorts of techniques ranging from the very basic statistical analysis to the pure imagination of science fiction. This flexible attitude of pragmatism influenced Qian's ideas of systems theory in the future.

As a member of the SAB in the 1940s, Qian participated in the most secretive intelligence projects and development programs of science and technology, and he knew very well the derivative potential of the military operational research and cybernetics in the wide-ranging fields of post-war social science. This partly explains why McCarthyists would take all measures to obstruct his return to China, since he was the first-generation "strategy scientist" cultivated by the US government and constituted the confidential human resources in the later cold-war social science. During his confinement, Qian integrated the sections on machine control in Norbert Wiener's *Cybernetics: Or Control and Communication in the Animal and the Machine* (1948) into his own masterpiece, *Engineering Cybernetics* (1954), which was instantly translated into numerous languages upon its publication and became the most frequently-referred-to work of the basic theories of automatic control in the world. (Peng 2012, 171-72) In 1955, prior to the home-return of Zheng Zhemin [郑哲敏], his postgraduate student at California Institute of Technology, Xian reminded Zheng that the rapid development of the American military logistics since the two World Wars owed a lot to its extensive application of mathematics and operational research. Operational research and cybernetics would be of great use in China, since it is a socialist country which emphasizes a well-schemed society. Qian believed that operational research would receive better development in socialist conditions than in capitalist countries, and he asked Zheng to bring this message to scientists like Qian Weichang[钱伟长] who had already returned to China. (Zheng 1991, 212)

In 1955, Qian and mathematician Xu Guozhi[许国志], who boarded the same home-returning ship, discussed their ideas of combining operational research with the socialist planned economy. (Xu, Wang, and Chai 2007, iii) In 1956 Qian and Xu set up China's first operational research study group at the Institute of Mechanics, Chinese Academy of Sciences, as Qian was responsible for the establishment of this institute and automatic control theory was one of its four major research subjects. In 1958, Hua Luogeng[华罗庚] also founded a laboratory of operational research at the Institute of Mathematics of Chinese of Academy of Sciences. In 1960, the two were conjoined and formally established itself at the Institute of Mathematics. In the same year, Qian founded the Office of Operational Research—China's earliest organization of military operational research—at the Fifth Academy of the Ministry of National Defense. Meanwhile, the Chinese version of *Engineering Cybernetics* was published in 1958. And in 1962, Qian summoned Guan Zhaozhi[关肇直] and Song Jian[宋健], who had just finished his study of cybernetics in the Soviet Union, to establish China's first cybernetics laboratory at the Institute of Mathematics, with the joint efforts of several industrial sectors; Guan and Song served as its chairman and deputy director respectively.

Scientifically speaking, it is from the work of strategic scientists like Qian that China's cybernetics originates. According to his pragmatic principles, Qian proposed a "three-thirds system" in the preparatory work, namely to establish three majors of science, three of engineering, and three of social science. This is the field of work shared by China's earliest scholars of both physical and social sciences. From his working experience at the American Air Force strategic organization during the Second World War, Qian knew that a combination of social scientists and mathematicians would serve as the methodological basis for this synthetic strategic science. As early as 1950s when he had just returned to China, Qian wrote down his thoughts on applying the quantitative methods into analysis of national economy and social science: he proposed to "make social science more accurate from the quantitative perspective" ("On Technical Science" 161), that "an elaborated political economy would render the national economic plan better and more accurate" (162). These synchronized ideas on quantization and simulated overall plan preceded even the cold-war social science and ideas of sociocybernetics in America and the Soviet Union. Out of these technological strategic considerations, Qian gave his firm support to the electronic computer project, which was the most controversial in the Twelve-Year Plan of Science of Technology in 1956, and made it one of the Six Urgent Projects (which also included the project of atomic and hydrogen bombs). Apart from its application in scientific calculation and industrial automation, Qian also raised the example of computer chess-playing to illustrate its potential of being used in decision science. (He Zuoxiu 2011, B2)[2]

Apparently, as a result of the trans-national travels of strategic scientists during WWII, the study of decision-making science in China began almost at the same time with the American cold-war social science in the post-war years, although its later development underwent a route different from that of the US and the Soviet Union, since the political intention and social imagination of China differ from the other countries. Unlike America and the Soviet Union which, because of their cold-war perennial war preparation regimes, invested huge amounts of money into studying the methods and technologies of decision-making science, the early development of operational research in China mainly related to the “mass movements” of socialism. Similar to the mass campaigns of electronic computers, the large-scale activities of Chinese operational research originated from the mass production movements during the Great Leap Forward[大跃进] and the Cultural Revolution[文化大革命]. In 1958, under the ideological guidance of intellectuals serving industrial and agricultural production, mathematicians went to factories and villages where they built mathematical models to solve practical problems in production. The “Graphic Solution”[图上作业法] used in nationwide food allocation and transport, and the “Wheat-field Design”[打麦场设计] in agricultural production are instances of operational research findings introduced to the general public. After their experience of the production practice, some mathematicians who used to belong to the field of theoretical research decided to stay in the field of operational research. Many important scientists published articles of popular education on newspaper in order to introduce quantitative methodology to the common folks. From February 26 to September 27 of 1960, Hua Luogeng published a five-piece serial essay entitled “Uses of Mathematics”[“数学的用场”] in *People's Daily*[人民日报], and an article called “Operational Research”[“运筹学”] in *Guang Ming Daily*[光明日报] which discusses practical application problems in agriculture, for instance the wheat-field design and the reservoir management. On

October 30 he published “Mathematicians should provide vigorous service for agriculture”[“数学工作者要大力为农业服务”] in *People's Daily*, which emphasized the practicality of operational research and established the scientific and technological idea of “handing over the method to the mass”. (Xu and He 2009, 485) The second climax of the application of operational research occurred after 1965, when the orientation of mass politics demanded a revolution of scientific research and education so as to break down the self-enclosed mode. Scientists formed groups and went to participate in grass-roots production. Hua himself led a team to promote the methods of optimization and overall planning in industrial and mining enterprises as well as rural areas. This team was called “Hua Luogeng Team”[华罗庚小分队], which, under the slogan “Optimization in Manufacturing, Overall Planning in Production Management”, visited over 20 provinces in the decade since 1956 and often received approval from Mao Zedong[毛泽东] and Zhou Enlai[周恩来]. (Zhang 2011, 698-704)

Fig. 1 Hua Luogeng teaching the method of optimization in a workshop, Guangxi, winter, 1974. (Chinese Academy of Sciences)

The popularization of operational research and quantitative methodology fits not only the view of leaping development which aims to "build socialism in a greater, faster, and better manner", but also the expectation of class and technological politics for people to learn and use scientific knowledge in production practice. Thus it is unsurprising that such popularization should receive favorable development in the socialist mass movements. But at the state level, cybernetics and operational research were not widely utilized as it did in the Soviet Union, while massive economic forecast and simulation as well as data-meshing by computers failed to catch the attention of scientists and decision-makers alike. The reason behind this neglect lies in the fact that China had never established a giant central planned economic system in the Soviet vein. The decision-making system in the style of George Orwell's cold war concept is contradictory to and incompatible with that of Mao's socialism, in terms of both political and technological forms. Since its revolutionary years, Chinese socialism has undertaken a path different from the route of military communism and the mode of social mobilization in the west. In the Korean War, the guerrilla tactics of Chinse army crashed with the modern warfare and weapon system of America; senior military officials including Peng Dehuai[彭德怀], He Long[贺龙], and Liu Bocheng[刘伯承] were so struck with the modernized combat and logistic support system of the US army, that they asked for similar developments of conventional arsenal and the American-style command system in China, in pursuit of professionalization and demobilization of the army. (Feigenbaum 2003, 21) Due to various factors affecting the development path of a new-born nation, which range from resources restriction (brought by Sino-Soviet severing of diplomatic relations and the leaping-style industrialization)[3] and the cold war geopolitical structure to features of modern atomic war and domestic goals of class politics, this American-style professional national defense program was turned down by strategic weapons sector led by Nie Rongzhen[聂荣臻] and *Qian Xuesen* after

1956. Consequently, the scientific, technological and national defense system of China went for a different route of development which features "sophisticated weapons plus the mass line".

As for the "mass line", the idealistic production and decision-making system of Mao's socialism is, on the one hand, planned economy of public ownership which is simultaneously compatible with the decentralizing, distributed development of locally independent industrialization; on the other hand, it is also a kind of industrial democratic management featuring the so-called "triple combination"[三结合] style in factories. Thus in his "*Records of Conversation on Reading the Soviet Union's Textbook of Political Economy, Vol. 2*", Mao Zedong emphasized: "Capitalism raises labor productivity by technological advancement. Socialism does so by technology and politics." Here the word "politics" refers not to the style of western social management and factory control technique proposed by Frederick Winslow Taylor, but rather "cultural education" plus "ideological and political work ", both of which Mao regards as "spiritual functions" outside material technology. (235-36) This is exactly the political route of modern revolutionary technology I have tried to investigate in the essay "From 'Barefoot Electrician' to 'Electronic Judge': Technological and Labor Politics in the Information Industry in China". Its appearance in China means more than just an unusual method adopted by developing countries to achieve rapid industrialization; it also manifests the social ideal of Mao's view of development which differs from that of the American and the Soviet industrialization. Actually, it is a shared consensus among Chinese scholars that the most striking characteristic of Mao's era is its unification between the methods in pursuit of industrial modernization and the goals of socialism. (Meisner 1999, 384) Maurice Meisner thus writes:

> … Mao, unlike Lenin and Stalin, was unwilling to entrust the socialist future to the impersonal forces of modern technology alone. Maoism demanded that economic development be accompanied (and indeed preceded) by a "permanent" process of radical transformations in social relationships and popular consciousness. Socialist institutions and communist values, Mau taught, had to be created in the very process of constructing their Marxian-defined material prerequisites. Rejecting the easy Soviet orthodoxy that the development of the productive forces would more or less automatically guarantee an eventual communist utopia, Maoism insisted that the means of modern economic development be reconciled with the ends of socialism and that this take place in the here and now. It was a doctrine that taught that the new society presupposed new people and that the cultivation of socialist human beings was no less important in the building of a socialist society than the construction of its technological base. Thus Maoism insisted that progress toward socialism was to be measured not simply by the level of economic development but also by reductions of "the three great differences"—by progress in pursuing the classic Marxist goals of eliminating the age-old distinctions between mental and manual labor, between workers and peasants, and between town and countryside. (420-21)

Back to the issue of cybernetics and electronic computer: in Mao's view of development, to ensure the technological and political correctness of socialism is to avoid "manipulation of information over man" or "that of one man over another". Once operational research and computing technology extended to the data processing application of the entire society and the large-scale simulation of economic planning, it would inevitably result in manipulation of labor force by technocrats at all levels.

But for the sophisticated weapons sector led by Nie and Qian, the case proved to be just the reverse, with efficient centralized decision-making and nationwide collaboration as the primary political target. Qian gave a summary of the problems they were facing, namely: when taking the Manhattan Project and the Apollo program as reference for our independent development of sophisticated national defense technology, "how to accomplish a large-scale scientific research and construction task with the least cost of human capital, material resources and financial investment, with the most efficient exploitation of the recent achievements in science and technology, and in the shortest period of time possible" (Qian, Xu, and Wang 2007, 2).

It is in the sophisticated weapons project which are strictly isolated from the common civil and economic sectors that Qian developed his systematic thinking of "centralized decision-making plus horizontal collaboration". After studying the management method of Program Evaluation and Review Technique (PERT) used in the "Polar Star" ballistic missile submarine system for reference in 1961, Qian supervised the drafting of the code of practice for the Seventh Ministry of Machinery Industry in 1962, which was then responsible for the project of atomic and hydrogen bombs as well as the satellite; and throughout the 1960s he set up a nationwide collaboration network within the aerospace industry. In 1963, based upon his experience of organizing and managing the sophisticated weapons sector, Qian published the article "Organization and Management of Science and Technology" in the magazine *Red Flag* and expounded the rules of organizing sophisticated national collaboration projects, including his experience with scientific and technological work, logistic service, political and ideological work, and external collaboration network, the totality of which constituted his rudiment ideas of systems engineering. On the one hand, in order to avoid diffusion of responsibility and ineffective competition among various sectors, it is necessary to establish a "overall design sector" which controls and consults the entire project; on the other hand, the organizational structure of the system must be as much delayering and distributed as possible, so as to ensure efficient and distributed decision-making and collaboration. Qian called these two aspects the "head" and the "vitals" of systems engineering. When participating in the project of atomic and hydrogen bombs as well as the satellite, Qian joined the Specialized Central Committee led by Zhou Enlai and Nie Rongzhen[4], in which he coordinated commands over the entire project, the delayering structure of which enabled direct transmission of information to the scene without being transmitted between layers of committees. ("To Wang Yongzhi, 27 February 1996", rpt. in *Selected Letters 1125*) In the 1970s, Zhou often expressed to Qian his wish to extend this method of developing sophisticated weapons to every aspect of domestic economy. By the mid-1970s Qian explicitly proposed the concept of an overall design sector of the state, for he believed that correct macrocosmic decision-making is indispensable in building socialism in a greater, faster, and better manner; and to ensure domestic and scientific decision-making, we must build an overall design sector as the highest advisory body of the state and its sectors, using the method of comprehensive analysis which conjoins electronic computer with both quantitative and qualitative analysis, through which we may fully embody the superiority of the socialist system. (Wang and Liu 2011, 5) The last three decades of Qian's work were mostly devoted to promoting a methodological synthesis of systems engineering, overall design sector ("Overall Design Sector" 10-22), and quantitative and qualitative analysis, by which he hoped to establish China's own school of thought.[5] Qian believed that these Chinese experience, which cannot be copied by capitalist countries, can solve the problem of multi-directional dispersion in Chinese scientific research and economic work.[6]

In comparison with the Soviet history of cybernetics, Qian's understanding of system and cybernetic science focuses, from the very beginning, on problems of organization and management rather than on optimized technical solution and mathematical model. Unlike Soviet cybernetic scholars who attempted to eliminate the "affect of man" via automatic mathematical simulation, Chinese experts of strategic weapons represented by Qian always took the “human factor” into consideration when pondering over the interrelation among systems engineering, operational research, and cybernetics. (Xu, Wang, and Chai 2007, iii) Thus when cybernetics went into vogue among Chinese philosophers and economists in the 1980s, Qian kept repeating that cybernetics cannot replace dialectical materialism as the basis of philosophy, that it is merely some technical means while the real foundational meta-science should be Marxist-based systematology. The basic science should be systems theory, while engineering cybernetics, biological cybernetics, economic cybernetics and social cybernetics serve as technical science derived from systematology. (Yu 2007, 325) Cybernetics, informatics, and systems theory (or systematology) should be uniformly classified under the last one, rather than regarded as philosophical doctrines which run on a par with one another.[7]

The question is, while strategic scientists have realized the importance of man and organization, the experience of sophisticated weapons sector remained highly isolated from the 1950s till the 1970s. Despite their wish to promote such set of experience to the external world, it failed to handle the conflicts of mass politics effectively. To put men uniformly under the collaboration of one system goal means to eliminate the interference of class politics. Thus on the issue of putting an end to mass movements, strategic sectors shared with national sectors which pursued production efficiency a high degree of consensus, namely to relieve the turmoil brought by mass movements via setting up an appealing national objective.

In 1974, at the end of his political career, Zhou Enlai brought up the “four modernizations” development objective which he had earlier proposed in the 1960s, in an attempt to alleviate the political sense of loss by the end of the Cultural Revolution via placing the core of national politics beyond the utopian “productivity”. In the middle and later stages of the Cultural Revolution, all political factions demanded to revive production; in this general atmosphere, Deng Xiaoping[邓小平] made his comeback to the political arena by acting as vice premier and assisting Zhou in charge of economic work. Deng’s rectification of economic sectors began with the railroad. Deng combined three of Mao’s instructions previously used in different occasions into a union, thus creating a set of political discourse to oppose radicals like the Gang of Four[四人帮]: “first, to oppose revisionism; second, to promote stability and unity; and third, to improve the national economy.” (Vogel 2011, 95) With these “three instructions” as coverage, Deng obtained relatively sufficient political legitimacy in calling off the factionalistic mass movements; he then tried to shift the nation’s political focus from “political movements” to “modernization program” in his implementation of rectification. In 1975, with the assistance of Wan Li[万里], minister of railways, Deng put the typically factionalistic Xuzhou Railway Bureau back to order, first by arresting its chief of revolutionary rebels, then by holding a mass meeting which calls for resumption of production via mobilization and employing those capable of promoting production as leaders. (106-08) It is actually a reproduction of the Daqing Model supported by Hua Guofeng[华国锋] in the later period of Cultural Revolution—namely, to stop a movement and develop production in the name of movement. After the breakthrough in rectifying the railways, Deng extended his experience to the reorganization of mines and steel industry. Document no. 13 of 1975 set a target output of 26 million tons of steel for 1975; all major steel factories organized mass meetings of their employees, which seemed to indicate that another round of Big-Leap-in-Steel was to come. However, the climax of using movements to promote production ended with Dent’s falling from power for the third time in 1976. According to Ezra F. Vogel,

> Deng's 1975 efforts marked his last attempt to increase steel production by political mobilization. After he visited a large modern Japanese steel plant in October 1978, he took a very different approach to increasing steel production, focusing on science and technology instead of consolidation. (113-14)

Since then, the "political mobilization" approach of Mao's socialism made its exit in the history of China's technopolitics. China began to move towards a period dominated by technocratic rule of the nation.[8] However, as in the case of the Soviet Union, strategic scientists inevitably found themselves in vehement collision with other political and economic sectors, for this transition could by no means guarantee their possession of either political power or grand systems engineering with which to promote social transformation.

II. Evolution amidst Transformation: Electronic Technology as Intermediary

The most widely shared consensus in Deng's reform policies are the termination of mass politics and "political stability and unity", which were apparent as early as his calling off the railways mass movements. Here is the paradox of Reform: on the one hand, intellectuals replaced the broad masses of workers and peasants as the national political subject; on the other hand, strategic scientists were profoundly stripped of their function in state decision-making. Specifically speaking, as regards military industrial and technological sectors, Deng's new agenda essentially comprised three inter-connected aspects, according to Evan A. Feigenbaum:

> First, it shifted investment strategy from capital intensive to light industries; second, it promoted large-scale demilitarization of industry; and finally, it broadened the role of technology in economic policy. (75)

All three changes occurred in certain historical contexts:
The first one is the inevitable result of the heavy industry layout, which served as a natural link of transition from Mao to Deng for the purpose of further releasing social productivity, transforming the investment-driven economy into one driven by the expanding domestic demand, meanwhile raising the price of agricultural products and the payment of urban workers. It naturally led to the reduction in fiscal budget for research and development of capitally intensive and sophisticated technology, disarmament, and declining status of strategic weapons sector. It differs from the economic strategies of Chen Yun[陈云], and also departs from the development objectives of "four modernizations" proposed by Zhou Enlai in the mid-1970s, because "four modernizations" undoubtedly mean reinforcement of infrastructure construction and core technology research. Comparatively speaking, it is the ambitious program of industrial development and technology import put forward by Hua Guofeng immediately after taking his post which fits more closely with Zhou's roadmap; but in reality, the central government at that time was fiscally incapable of supporting such more advanced level of planned economy known as "The Great Leap Outward"[洋跃进]. Therefore, to some extent, it appears that Deng's detour by the early 1980s paradoxically inherits Mao's legacy of "independent development", though devoid of the mass movements. This is most obvious in the favorable atmosphere for the development of rural enterprises and light industry sectors. As for technological problems, there emerged a substitutive solution called "market in exchange for technology", which was the original intent behind the establishment of special economic zones. Deng displaced the concept of "four modernizations" and highlighted its definition in his 1980 speech, "The Current Situation and Mission"["目前的形势和任务"]: "Collectively speaking, four modernizations are about economic construction. National defense construction cannot do without certain economic

foundation. Scientific technology exists mainly for the purpose of serving economic construction." (240) The index for evaluating economy should be the abstract "increase" rather than "construction"; this viewpoint laid the foundation for economic growth of the 1980s, but it also foreshadowed the predicament in store for the strategic sectors.

The second change, namely the demilitarization of heavy industries, manifests itself in two aspects: on the one hand, the nature of produce shifted from military purpose to domestic usage; on the other hand, the demand for production came not from factories and research institutions but rather from the market, which means that it is the market demand rather than national strategic needs which determines what to produce. In essence, it means the demilitarization of the entire society—namely to put an end to military mobilization of the society—as well as the professionalization, the depoliticization, and paradoxically the commercialization of the army. They were caused partly by the principle of treating economic construction as the central task. Since heavy industries—including sophisticated weapons industry—can hardly profit in the market, these industrial sectors have to rely on government investment for survival. As market economics which measures performance in terms of profits gradually took the place of planned economics, exchange value replaced use value as the index of development; thus those military sectors which had lost government investment and orders had to produce consumer electronics which can sell in the market. In fact, with the establishment of the special economic zones, lots of military and local electronic enterprises in underdeveloped areas began to build factories in coastal cities like Shenzhen, and thus accomplished their rebirth by producing consumer electronics like television and radio which were popular in the 1980s.

The third change is most paradoxical in that: on the one hand, as intellectuals—rather than the broad masses of workers and peasants—became the subjects of national mobilization, science and technology received the highest regard ever for their role in economic development, which led to the expression that "Science and technology constitute a primary productive force"; on the other hand, sophisticated strategic weapons sector and strategic scientists gradually lost their political status in national strategic and political decision-making. The central government did wish that the highly horizontal management and collaborative style of the strategic sectors could survive and prove compatible with the development path of the Reform and Opening-up, thus forming a developmental pattern of socialist market economy. But the actual result turned out to be quite the opposite of what those at the highest level wished for: it was a situation which went back to the Soviet course, with bureaucracy and segmentation revived, technological alienation in the factory labor process worsened (Wang, "From 'Barefoot Electrician'" 34-48), and the scientific research system coming apart, as "sophisticated" technology was replaced by one "of economic value" (Feigenbaum 2003, 84).

In December 1977, the central government decided that the weapons development and purchase of the People's Liberation Army (PLA) should change its direction from "focusing on sophisticated weapons" to "giving priority to conventional weapons". (79) This entails more than just a shift in the technological catalogue of weapons development, for, as mentioned above, "sophisticated weapons plus the mass line" was exactly what Mao's China developed in the cold war scenario as an unusual techno-political course befitting its purpose of national independence and social revolution, with which China defended against the modern military equipment of America and its bureaucratic, professional method of military administration, in terms of the techno-political dimension of the mode of people' war. Thus the dual changes facing the sophisticated weapons sector—the turn towards conventional weapons and the demilitarization of national scientific and technological policy—not only harmed the research agenda of strategic weapons scientists, and more importantly, shattered their political and professional influence. This further vindicates that as the "people's war" mode, with features of social revolution, made its exit out of history, it inevitably damaged the agenda of techno-nationalism and developmentalism. In the following years, with several key figures leaving office and opponents of technocrats rising in power, China's technical innovation system began to face the problem of ossification in a post-revolution era. Thus for sophisticated weapons elites of the Mao-era like Qian, their primary agenda in the Reformation Era is to "struggle for survival", i.e. how to redefine and adjust the original technical route to fit the new directions of state politics? (83)

III. The Last Struggle: From Strategic Weapons to Strategic Science

The irreversible fall of mass movements and the demilitarization of the entire society force the strategic weapons sectors to try all means in order to "evade" their fate of being marginalized. The only one aspect favorable to them in the new policies is the fact that Deng has raised the status of science and technology, scientific works, and scientific methodology far beyond what it used to be prior to the Cultural Revolution. One of the most striking features which distinguishes Deng's Marxism from that of Mao is that Deng relieves science and technology of their political nature, thus suspending the techno-political question, "for whom science and technology serve?" As science replaced the revolutionary subject as the critical "primary productive force", the so-called "scientific methodology" began to be highly appreciated and spread across the entire society after the Third Plenary Session of the Eleventh Central Committee of the Chinese Communist Party. Liu Qingfeng[刘青峰] believes that "Scientism" is the philosophical basis of the Reform and Opening-up:

> In the name of science, enormous amounts of modern western philosophy, economics, and social science were imported. Anything claiming relevance with modern scientific theory, for instance cybernetics, information theory, and systematology, were regarded as valuable resources capable of enriching Marxism and were introduced and widely applied. Even political behaviors like the vindication of wronged cases and the scientification of decision-making bore the trademarks of science, not to mention how any kind of liberalization ideas held a proper place under the flag of scientism. (32)

According to Liu, it is mainly scientism which propels the rush of ideological liberalization against the official ideology in the 1980s. This statement is itself problematic, for the popularity of scientism in the 1980s means that it has already obtained attributes of official ideology. Deng's speech at the National Science Conference affirmed the political legitimacy of scientific methods, which corresponded to propositions raised by revolutionary economists like Zhao Ziyang[赵紫阳] after the Third Plenary Session. Quantitative methodological system and decision-making science, which prospered during the cold war, initiated their full-scale advance into China. Meanwhile, a series of social studies which made use of electronic computers and cybernetics, for instance futuristic prediction technology, quantitative methodology of social science, as well as economic planning and decision-making model of system dynamics, began to appear in China.

Strategic weapons sector tried to catch this opportunity and regain, through "scientific methodology", the political role it used to possess before the Reform, because the decision-making and management method which originated from operational research is precisely the kind of cold-war social science brought home by Qian the strategic scientist from von Kármán in as early as the 1950s. After the recession of political movements, it seems only natural that the "democratic" decision-making system of socialism should be replaced by this "scientific" one. After the strategic weapons research and development was fiscally impoverished, the only means available to ensure the adaptation of strategic science sectors to the new era appeared to be scientific forecasting methodologies and electronic computer—the technical tool for data processing.

Similar to Nikita Khrushchev's Soviet Union, these methodological experiments of scientific prediction received strong support from senior reformist colleagues of Deng, because it provided an alternative other than the old system of planned economy. (Feigenbaum 2003, 98) In the reforming introduction of market mechanism, this scientific method claims to endow a nation with more effective control of economic development and the ability to predict its future trend, at no cost of politically interfering with the short-term autonomy of the market. This scientific discourse has alleviated the anxiety of those prone to planed economy during the marketization process, thus providing theoretical legitimacy within the Marxist theories of planned economy for further promoting marketization. In other words, socialist market economy is perfectly capable of seizing the moment and predicting the future through socialist scientific forecast. Furthermore, the inherent function of American futuristic ideology which presents a bright future that is sure to come, provides Utopian driving force for the political legitimacy of the Reform, as can be observed in the "Four Modernizations" of Zhou in the mid-1970s and the radical industrialization of Hua. Scientific methodology represented by cybernetics, systems engineering and futurology thus become the lobby power of the Reform and Opening-up.

A typical case in point is that after 1978, strategic scientists like Qian began to systematically promote the development of operational research, systems engineering and system analysis in China. In October 1979, Qian hosted the Beijing Academic Symposium of Systems

Engineering, which led to the foundation of the Systems Engineering Society of China. Qian's work, based upon system analysis, systems engineering, cybernetics, operational research and combat simulation, established the primary form of systematics in China, which, bordering on the decision-making methods and quantitative statistics of normal science, was yet incapable of dealing with complex macroscopic economic problems. In 1980, Chinese strategic scientists like Yang Tongyi[杨通谊]—a PhD at Massachusetts Institute of Technology during the 1930s—jointly published the Chinese version of *Industrial Dynamics* (1961) by futurologist Jay Wright Forrester, founder of system dynamics. This book laid down the theoretical foundation for Forrester's later *World Dynamics* (1971) and the Limits-to-Growth theory of the Club of Rome. Drawing on the developments by limit theorists like Forrester, Qian proposed a new field of scientific study: the Open Complex Giant System and its methodology. (China Association for Science and Technology 1993, 149) The function of "man factor" is key to Qian's solution; he points that the only method available for effectively handling the open complex giant system (including social system) is Meta-synthesis which comprises both qualitative and quantitative aspects. This method requires a synthesis of scientific theory, empirical knowledge and expert judgement in order to propose empirical hypothesis (judgement or presumption), which, as qualitative understanding, cannot be proven in strictly scientific manner, but its validity can be put to inspection by empirical data and models comprising thousands of parameters. This Meta-synthesis method which combines qualitative and quantitative understanding is in essence an organic combination of expert group, data and all sorts of information, and computer technology, thereby establishing a union between scientific theories of all subjects and man's empirical knowledge. It actually bears close resemblance to the synthetically quantitative and qualitative forecasting methodology of RAND.

By the early 1980s, Institute 710 of the Ministry of Aerospace Industry, which used to specialize in research on launching and controlling satellites, began to move on to studies of economic and social problems. Using Institute 710 as his battle field, Qian regularly organized workshops of systems theory and systems engineering, inviting economists like Ma Bin[马宾] alongside weapons experts to discuss how to promote systematology in socialist construction. (Ma Bin 2009, 152) With Qian's support, cybernetic experts of strategic weapons sector, including Song Jian and Yu Jingyuan[于景元], redirect their attention to the research on population control and price reform. Some of their major achievements are: solution for excessive national subsidies caused by the "rice and oil price inversion" under the commission of Song Ping[宋平], member of the State Planning Commission; model of national macro-economic management in collaboration with Ma bin (152); mathematical models concerning economic leverage submitted to the China Society of Economic Reform for review (Feng and Hu 1984, 2). When China Central Television (CCTV) broadcasted a series of lectures on systems engineering in 1980, Qian was personally responsible for its first course, "Systems Engineering and Systems Thinking". Later, the cybernetic model of population growth built by Song Jian and his colleagues directly pushed forward the formulation and implementation of the national family planning policy.[9]

By the mid-1980s, scientific decision-making has been widely promoted among the scientific research and economic sectors of China, and it even infiltrated the areas like traditional humanities and social thoughts, thus forming an important aspect of the 1980s New Enlightenment Movement, where emerged some bold suggestions of reforming literary composition and historical research with these "Three Theories"[三论] of cybernetics, informatics, and systematology. (Liu 1994, 44) When philosophical scholars and college students turned away from Marxist philosophy in favor of cybernetic research, it means that scientific methodology has assumed ideological features and deviated from its "scientific" nature.[10]

During the "Three Theories Fever"[三论热] period of the 1980s, systems theory experts from strategic sectors, for instance Qian, held sharp disagreements and heated debate with philosophers of science who belonged to the "Dialectics of Nature Group". These "Three Theories" were originally introduced to China in the mid-1950s via translations of Soviet documents by scientific and philosophical workers, for example Gong Yuzhi[龚育之] at the Science Office of the Publicity Department, and then spread among science and philosophy communities at universities and colleges. By the late-1970s, Hu Qiaomu[胡乔木], President of the Chinese Academy of Social science (CASS), believed that the "Three Theories" are emerging subjects which demanded special attention from the philosophical circle. Thus Wei Hongsen[魏宏森] of Tsinghua University and his colleagues, who were preparing the establishment of a "Three Theories Research Society", initiated the "Three Theories Fever" in the academic world by promoting these three fields of study without delineating their hierarchical relations. (Wei 2013, 2-5) Amidst such theoretical fever, there emerged a Pluralist community closely connected with the *Journal of Dialectics of Nature*[自然辩证法通讯] presided by Yu Guangyuan[于光远]; its members include Yu, Xu Liangying[许良英], Fang Lizhi[方励之], Jin Wulun[金吾论] and Jin Guantao[金观涛], and they inclined to hold the three theories, as replacement for dialectical materialism, at the same philosophical level as Marxism. In contrast, strategic weapons scientists like Qian still insisted on Monism, emphasizing the supervisory status of Marist philosophy over scientific research and refusing to acknowledge the three theories as fundamental science parallel to each other, for it is his belief that cybernetics and informatics should uniformly subject to systems theory or systematology. [11](Wei 2013, 4-5) In Qian's opinion, apart from military combat system, other Complex Giant Systems which can be studied with this methodology include:

> a. social system, where systems engineering technology which addresses both quantitative and qualitative aspects depicted by hundreds or even thousands of variants can be used in research and application of social economic system;
>
> b. human system, the study of which conjoins biology, psychology, western medicine, traditional medicine as well as Qigong and extraordinary functions of the human body;
>
> c. geographical system, where issues like ecosystem, environmental protection and regional planning can be combined in discussion of geographical science work.

Using systems theory and the idea of "simulation" in Norbert Wiener's cybernetics as his theoretical foundation, Qian attempts to unearth the inherent connection between socialist planned economy and human science. This is a far more advanced "radical systems theory" than the idea of cybernetic internet proposed by Soviet economic cybernetic scholars and the "Global Simulation" concept put forward by the Club of Rome. At the convention of China Human Science Society held in Beijing from May 26 to 31 of 1986, Qian gave his speech "Strategy of Human Science Research", in which he suggested "there are similarities between human society and communism. Do not regard it as something simple, for it concerns man's thoughts and ideological revolution" (On *Human Science* 69). The social historical link between the radical systems theory and strategic view of science of Qian and the "Extraordinary Function Fever" among folks in the 1980s is beyond the scope of the present essay; nevertheless, it does suggest to us that strategic weapons scientists, desperate to avoid being marginalized, helped the reformists by claiming legitimacy for scientific decision-making methodology in China. It certainly provided the senior reformists with some ideological support for the marketization agenda;

but the scientists themselves had further ambitions and were more interested in large-scale systematic prediction and cybernetic simulation under the technological and political view of "totality". It needs to be noted that, unlike the information universalist pursuit of his Soviet counterparts in realizing automatic economic control, Qian's model approximates pragmatically-natured strategic science, which clearly defines that political pursuit and strategic design should override standardized techniques. In other words, Chinese weapons strategy experts were looking for some alternative technological means with which to realize their political ideal of uniform development of both the socialist system and the modernization construction; they were not trying to cover and replace the bygone political agenda with scientific universalism. In a previous essay entitled "An Investigation on the View of Urban and Rural Areas and the Technopolitics of China's Socialism: From Peter Kropotkin to Qian Xuesen", I had expounded on Qian's technological strategic thinking based on ecological agricultural revolution, using his discourse on urban and rural areas in the 1980s as illustration.

Like they once did when manufacturing the atomic and the hydrogen bombs as well as the satellite in Mao's era, weapons elites turned themselves into part the strategic weapons, developing some sort of "sophisticated methodological weapon" based on computer simulation and strategic expert decision-making in the Red China. At the critical moment of the Reform by the mid-1980s, this original set of strategical overall prediction thinking developed by weaponry elites entered into fierce competition with the instantly flourishing American information universalism marked by the "Third Wave". As is known to all, the theoretical debate on informationization, which touched upon the "informatics" of the "Three Theories" (Cybernetics, Informatics, and Systematology), has served as the foundational discourse for the appearance of informationalism and information economy in China, thus becoming a source of theoretical legitimacy for the transition in

China’s economic development mode. Appearance of expressions like “No informationization, no modernization” marked the birth of informationalism trend of thought in China among theorists and folks alike, highlighting the leading position of the economic, political, and cultural roles of information in economic and social development.
It is theoretically significant to investigate the technopolitical history of cybernetics and informationization, because the discourse and practice of China’s information technology and cultural industry is still not free from the historical installation pursued by socialist modernization of the twentieth century, while theories and policy discourse on topics like economic development path, rural-urban interactions, national defense industry and security, foreign trade, media systems, and social administrative mode still benefit from or subject to the historical consequences of the twentieth century information politics debate. The authors of this essay hope that discussions initiated by this social political history of information technology will provide new possibilities for the historical comparative research and archeology of knowledge of the twentieth century socialist practice.

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1 A Chinese version of this research as part of my comparative work on the cybernetic debates between Soviet and China has been published in Remapping Vol.5 (《区域》第5辑，汪晖王中忱编，社会科学文献出版社，2016).

2 It is obvious that the applied knowledge of cybernetics came from America, while discussions in the field of scientific philosophy originated from translations of Soviet materials.

3 Wen Tiejun[温铁军] calls it "a development approach which replaces capitol with labor out of necessity" (54). However, historical facts of Chinese socialism has proved that this is not rationally speaking a "worthwhile" method of economics, but rather a development path from the perspective of socialist political equality.

4 Wen Tiejun[温铁军] calls it "a development approach which replaces capitol with labor out of necessity" (54). However, historical facts of Chinese socialism has proved that this is not rationally speaking a "worthwhile" method of economics, but rather a development path from the perspective of socialist political equality.

5 In his later years Qian listed 17 mentors who had greatly influenced his life, the last three of whom being Mao Zedong, Zhou Enlai, and Nie Rongzhen. In 1956, Mao pointed out that in natural science, we need to adopt the scientific knowledge and methods of foreign countries when arranging the inheritance of Chinese local science, until we have established a school of our own. This opinion influenced Qian till the end of his life. (Tu 467-68) Besides, Qian believed that his dialectical materialistic point of view and ideas of systematology originated from his reading On Contradiction[矛盾论] and On Practice[实践论]. (262)

6 I shall explain in another essay why this set of experiences cannot be popularly promoted.

7 For Qian' s criticism on the parallel view of cybernetics, informatics, and systematology, and on the overstatement of cybernetics, see his letters "To Wu Jiapei[乌家培], 17 April 1984" (Selected Letters 80), "To Wu Jiapei, 26 May 1984" (91), and "To Wang Dong[王东], 16 July 1990" (524), as well as his essay "Dialectics of Nature, Cognitive Science, and Human Potential".

8 The final struggle of the exit was most apparent at the National Science Conference of 1978, which was a hallmark event in the history of China’ s technopolitics, as Hua Guofeng and Deng Xiaoping debated fiercely over whether technopolitics should “be red” or “be specialized”.

9 On China’ s family planning as well as science and technology policy, see Susan Greenhalgh’ s Just One Child: Science and Policy in Deng's China (2008).

10 On the debate between these two scientific communities, see chapter 5, “The Politics of Knowledge” in Lyman Miller’ s Science and Dissent in Post-Mao China (1996) (183-237).

11 On the debate between these two scientific communities, see chapter 5, “The Politics of Knowledge” in Lyman Miller’ s Science and Dissent in Post-Mao China (1996) (183-237).

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