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Building "The Plotter" – an Aesthetic Exploration with Drawing Robots

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Abstract

This paper presents the drawing robot "The Plotter" and an exploratory preliminary study with other drawing robots. Around notions of authorship, control and "Eigensinn", the paper describes these artworks and situates them in a context of generative art and abstract expressionism. Relating to Brooks' subsumption architecture for Artificial Intelligence, this paper addresses the question, if the chosen setup is capable of evoking particular aesthetics that lie beyond the control of the programmer. The paper concludes with describing potential visual attributes of such aesthetics.

Categories and Subject Descriptors (according to ACM CCS): I.2.9 [Artificial Intelligence]: Robotics—Lego

1. Introduction

"The Plotter" is a robotic drawing installation artwork built by the author. The Plotter produces a generative drawing on a looped strip of paper over the course of several hours. The installation is conceived to run self-sufficiently in a gallery situation; it was on display for two days in a public exhibition space where the audience could witness the entire process of a drawing.

The Plotter was preceded by a preliminary study, in which the author created a series of drawing robots operating with different algorithms. The study served as a first exploration, with the goal of producing the Plotter as a self-contained artwork. Through exploring aesthetics of software-controlled, autonomous robots, both the study and the Plotter address questions on the relation between humans and machines in general:

Will images produced by a machine become predictable over time? Or will it be possible to evoke visual aesthetics that lie beyond the control exercised by the programmer? If so, with which visual attributes can these aesthetics be described? And will some of these visual attributes be consistent over different drawing processes and setups, so they can be generalized as constituents of typical machine aesthetics?

The artist wants to draw the attention to those specific properties belonging to a machine, in contrast to human expression. He aims at evoking an aesthetics of imprecision that challenges common notions of human control over machines.

2. Context

In this paper, the term machine is used when referring in a general sense to a technological setup operating in physical space. More specifically, the term robot is used for machines that are controlled by a software program, and operate autonomously in physical space, i.e. free from direct human interaction.

Making Art with machines in general, and robots in particular means working with inherent aesthetics of technology. Any such artwork offers aesthetic insights into the technology with which it is produced. Drawing robots produce images that are a result of processes defined by the artist/programmer on one side, and of the properties of the robots and technical setup on the other side. The images thus speak to the degree of control the programmer exercises over the machine.

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2.1 Generative art, the role of the author, and the Eigensinn of machines

In this paper, the term generative art is used for a system – a machine, a robot or a computer – that creates aesthetic output based on a rule or algorithm specified by the artist. generative art challenges established notions of authorship: the form of the aesthetic output is not solely determined by the artist through the algorithm, but also by specific properties of the system.

Frieder Nake was one of the German pioneers to explore computer-based generative art. Nake reflected on the question of what role is left to the artist, if an algorithm produces aesthetic output. He drew comparisons to the abstract expressionist work of Jackson Pollock, who produced images by repetitive “dripping” gestures. Nake claimed the role of the artist lies “in controlling the process of the image, but not the production of the image itself” [Nak95] “Kontrollieren des Prozesses des Bildes, nicht im Herstellen des Bildes selbst” (quote translated by the author of this paper).

Giacco Schiesser has written about how specific properties of media shape the content they convey. He has coined the German term “Eigensinn” (own sense), to denote the obstinacy that media have against the expressive intention of the artist. According to him, the artist is in a dialog or constructive argument with the media he or she is using. Schiesser states: *“I propose to consider the Eigensinn / Eigensinnigkeit of a media as a productive force of its own. It is this collision of the Eigensinn of the media with the Eigensinnigkeit of creators that initiates and perpetuates a significant and paradoxical process.”* [Sch04]

Similarly, Vito Campanelli talks about the *“creative potential of the error”* and postulates a *“machinic subjectivity”* that he describes with the words *“every computer, every software, every input device has its own personality that cannot* not *influence the creative process.”* While Schiesser’s Eigensinn still reads like the disobedience of a subordinate tool, Campanelli puts the machinic contributions to aesthetics on the same level as the human ones and brings up the notion of a *“human-machinical consciousness”*. He adds later on: *“there is a clear urgency for aesthetic research that allows machinical subjectivity … more generally to surface. By shifting our awareness towards such practices, a closer dialogue with machines becomes possible.”* [Cam10]

A conversation between Andreas Broeckmann and Ken Wark also revolves around this dialogue “ *… when are human-machine assemblages organised as repetitions and when are they self-differentiating? When do they record and rerecord territories and when do they escape from territories?*” Similar to Schiesser’s Eigensinn notion and Campanelli’s machinic subjectivity, this demonstrates an interest in things that machines do, deviating from instructions by humans or producing unpredicted outcomes of such *(“they escape from territories”)* [BW97].

When making art with machines, the physical properties and constraints of the technical setup will exercise Eigensinn, and give rise to specific aesthetics of the produced result. This paper relies more on the notion of Eigensinn than machinic subjectivity, as it emphasizes the specifics of the machine more than the nature of the human-machine dialogue.

2.2 Robots and Brooks’ subsumption architecture

The collision of the Eigensinn of a machine with the intention of a human creator has a parallel in Artificial Intelligence (AI) research. Rodney Brooks has introduced the subsumption architecture [Bro91], in which the behavior of a system results from its interaction with the physical environment, and is not explicitely programmed as an algorithm. Thus the physical properties of the system collide with human intentions expressed through programmed behaviors.

Subsumption architectures rely on sets of behaviors, which are hierarchically organized in layers of different priorities. Taking the example of a mobile robot, the behavior “avoid obstacles” will have high priority, and temporarily overwrite a behavior like “move towards the light”. If behaviors of different layers overwrite or eliminate each other, the emerging actions will take both layers into account. The resulting action is not explicitly programmed, thus it is unpredicted.

The robotic systems described in this paper do not claim to be reproducing a subsumption architecture in the exact sense of Brooks. However the specific architectures will be described in terms of the factors *instructions* and *mechanical friction* that both determine the behavior of the different robots. Based on this distinction, the paper will look for aesthetic attributes that result from interactions between the robots and their environment (and not from programmed instructions alone). Such attributes are likely to result in unpredictable images beyond human control, and would be constituents of a typical machine Eigensinn.

2.3 Art historic situation

The work with robot drawings presented here has roots in generative practices that evolved out of abstract expressionism. Its inspirations go back to the drawing machines of Jean Tinguely, who imitated the painting gestures of abstract expressionism in an ironic way with his “Métamatics” series of drawing machines in 1959 [Tin59]. While Tinguely’s earlier machines aimed at mimicking other artists (e.g. Meta-Kandinsky [Tin56]), the Métamatics were meta-artworks with unique and idiosyncratic drawing styles.

The painting robot “Aaron” by Harold Cohen emulates a human artist, arranging and recombining recurring motifs, e.g. humans, flowers, or room interiors [Coh95]. Every painting is different from all others, due to a combinatorial algorithmic process. Though Aaron’s paintings are “*self-differentiating*”, they do not “*escape from territories*” of algorithmic control.

Contrastingly, in the explorations that are discussed in this paper, the process is generative, but the resulting images are not only a result of an algorithm. Their aesthetics are intrinsic and typical for the architecture of a robot.

The swarm painting robots *ArtSbot* by Leonel Moura and Henrique Garcia Pereira are a very close reference for the “preliminary study” that will be discussed below. Autonomous robots are programmed with simple instructions. They move over a canvas, leaving marker traces, while reacting to the environment and to traces of the other robots. The artists speak *of "a symbiotic relationship with human partners*" – the programmer and the viewer – and conclude, "*what we can consider 'art' here, is the result of multiple agents, some human, some artificial, immerged in a chaotic process where no one is in control and whose output is impossible to determine."* [MP03]

The plotter challenges this view: while details of the drawings are indeed unpredictable, this paper discusses consistent attributes of the Eigensinn of the robot and thus looks for predictable patterns.

3. Explorations with drawing robots

3.1 A preliminary study with drawing robots

This section presents a preliminary study, conducted with drawing robots that the author built with Lego-mindstorms. For the study, a number of different robotic vehicles were built and iteratively modified and reprogrammed with different instructions. The study explored robotic aesthetics with the goal of producing the Plotter as a self-contained artwork.

Lego-mindstorms is an extension of the Lego system that contains programmable elements, robotic sensors and motors. It was designed at the Massachusetts Institute of Technology as a didactic system to introduce students from age 10 up to adults into robotics and computer technology. As it is easy to handle and relatively error-proof, it is not only a good didactic tool, but offers potential to be used for low-fidelity prototyping as well.

The robot vehicles were running on two caterpillars, and thus were able to move in all directions over a flat canvas consisting of a DIN A2 sized paper (59x42cm), unless otherwise mentioned in the results section. During the study, the artist explored different combinations of attaching one or several pens of different thickness and colour to the vehicle. The pens were firmly attached to the vehicle, and tracked the motions of the vehicle, so the resulting pattern was a trace of its path over the canvas. The drawing process lasted between 10 and 45 minutes. The ending moment was determined by the artist, based on a spontaneous aesthetic judgment.

The architecture that determined the behavior of the different robots consisted of *instructions* and *mechanical friction*. The instructions were kept very simple, as the focus of the exploration lied on the deviations, rather than on the complexity of the shapes themselves. An instruction-set typically prescribed a repetition of a few elementary movements, e.g. "(repeat forever:) forward, right turn, backward, right turn".

Mechanical friction describes the paradigm, under which robots interacted with the real world. This allowed deviations from the elementary shapes given by the instructions. The low-fidelity nature of the Lego setup was welcome, as it was imprecise enough to allow deviations, but reliable enough to run for the duration of a drawing.

3.2 Results of the preliminary study

Some of the drawings that allowed significant conclusions for the further work are described here.

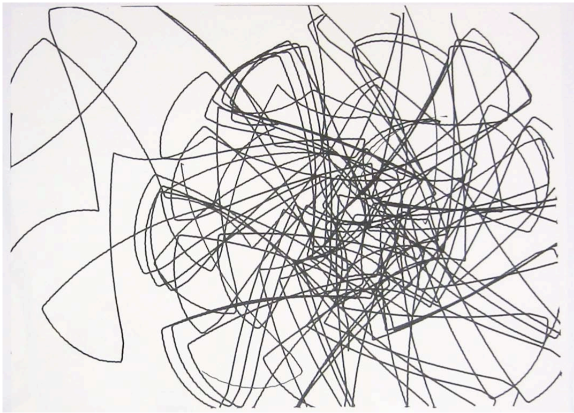

Figure 1: *Robot drawing from the preliminary study.*

Figure 1 shows a drawing that was produced with simple instruction of straight and turning movements. The drawing was produced on white paper with a heavy black marker. The robot ran without human intervention for 10 minutes, and then it shifted off the canvas and was stopped by the artist.

One of the visual characteristics of this drawing are nearly congruent forms, indicated by several lines running alongside each other. Partial rotational symmetry is another characteristic, but some forms deviate from this regular pattern. The drawing features a zone of higher density, right of the centre. An analysis of the negative space yields a variety of different sizes and forms that are defined and separated by the lines.

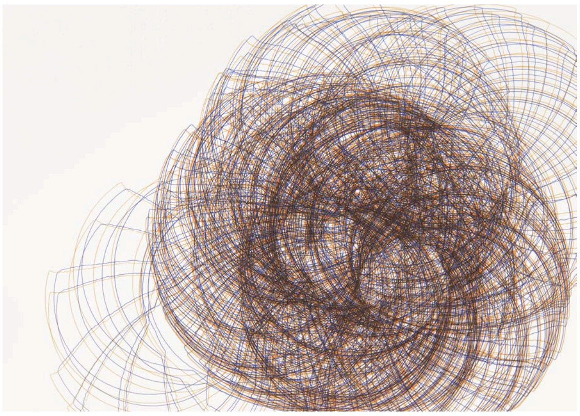

Figure 2: *Robot drawing from the preliminary study, two pens were mounted in parallel.*

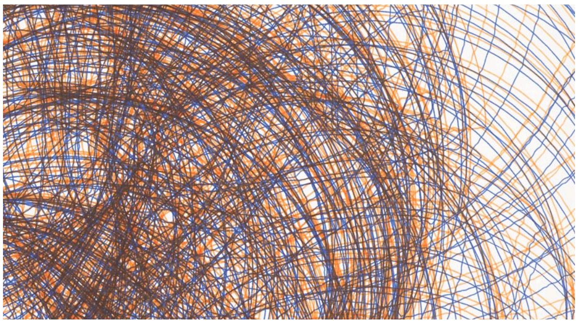

Figure 3: *Detail of Figure 2.*

Figures 2 and 3 show another drawing that was produced with simple instructions. In this drawing, two fine pens were mounted on the vehicle, so they were drawing in parallel on the canvas. The vehicle ran for 30 minutes. During this time, it moved off the canvas several times, without losing its regular and predictable path. Independently from this, it was reset to new starting positions chosen by the artist.

Like the previous example, this drawing features near-congruent forms, indicated by lines running alongside each other. Several forms with some degree of rotational symmetry are overlapping. No lines deviate from or disturb the rotation symmetric patterns, in the way this happens in the previous example. The negative space is divided into small areas that are uniform in their sizes.

Figure 4: *Robot drawing from the preliminary study.*

Figure 4 and 5 show a drawing produced with a slightly more complex set of instructions that had shorter segment movements than earlier drawings. Canvas edges were covered with masking tape, to achieve a cleaner look. The vehicle ran for 45 minutes, with a grey pen attached to it on a canvas of A3 size (42 x 30cm). During this time, it shifted off the canvas several times, and was reset to new starting positions chosen by the artist.

While this drawing seems to have more irregularities than the earlier drawings, we can still identify near-congruent forms, and curved segments of the basic shape give rise to some degree of overall circular geometry as well. The shorter segment movements seem to make the drawing more prone to deviations from near-congruent forms and rotation symmetric patterns.

The negative space is divided into forms of different sizes and proportions. Over the whole drawing, there is a variety of dense zones with smaller forms, contrasted with more open zones that have bigger forms.

Figure 5: *Detail of Figure 4.*

Due to the longer duration, some densely painted areas of the canvas were roughened, and ink spots are visible here and there, testifying from moments when the robot got stuck at one location. The ink spots are a result of mechanical friction and of the interaction of the robot vehicle with its environment; they are thus part of the robot's Eigensinn. When such a situation occurred, the artist reset the vehicle to a new starting position, allowing continuation of the drawing.

Summary of the results. The preliminary study consistently shows some regular patterns in the robot drawings: rotational symmetry and near-congruent forms with lines running alongside each other. Less consistently, some irregular patterns are observed that manifest in violations of the symmetry and of the near-congruence. Other less consistent patterns are roughened areas of the canvas and ink spots.

The emergence of the patterns is caused by the interplay of instructions with mechanical friction. The same instructions were repeated again and again (e.g. "forward, right turn, backward, right turn"). In each iteration, mechanical friction caused small deviations in position and angle of the vehicle. The angular deviations resulted in rotational symmetry; the deviations in position resulted in near-congruent forms. As these patterns are clearly an emerging result of the interaction between the robot and the environment, they are part of the Eigensinn of the system.

The study also revealed some methodological constraints that were taken into consideration for building the Plotter:

The robot with time often shifted over the edge of the canvas. This was because robots did not have an internal spatial model that would have indicated the boundaries of the canvas. The shifting was an undesired effect, as human interference was necessary to continue the drawings, which obscured the view on entirely robotic aesthetics.

The process of the preliminary studies was open ended. It was usually terminated by the artist, based on spontaneous aesthetic judgment. Again, this conflicted with the goal of exploring aesthetics that are independent from the human programmer.

The preliminary study was not publicly displayed, as its goal consisted primarily in producing insights for the production of an artwork.

3.3 The Plotter – a robotic drawing installation

The preliminary study had revealed the recurring aesthetic attributes of rotational symmetry and near-congruent forms. It demonstrated that shifts of the drawing vehicles off the canvas were problematic, and that human interruptions of the drawing process blurred the view on intrinsic robotic aesthetics.

Based on these insights, the robotic drawing installation the Plotter was built, with the aim of creating a more self-contained system and shifting the exploration even more towards an exploration of autonomous robot aesthetics for the given setup.

Setup. The Plotter is a mechanical drawing installation built with components of Lego-mindstorms. A pen is freely moveable on one axis and controlled by a motor. An endlessly looped paper is moved into the orthogonal direction by a separate independent motor. Both motors are steered by a microcontroller in the Lego-mindstorms main unit. Thus there are two independent degrees of freedom, allowing drawings in two dimensions on the canvas-loop.

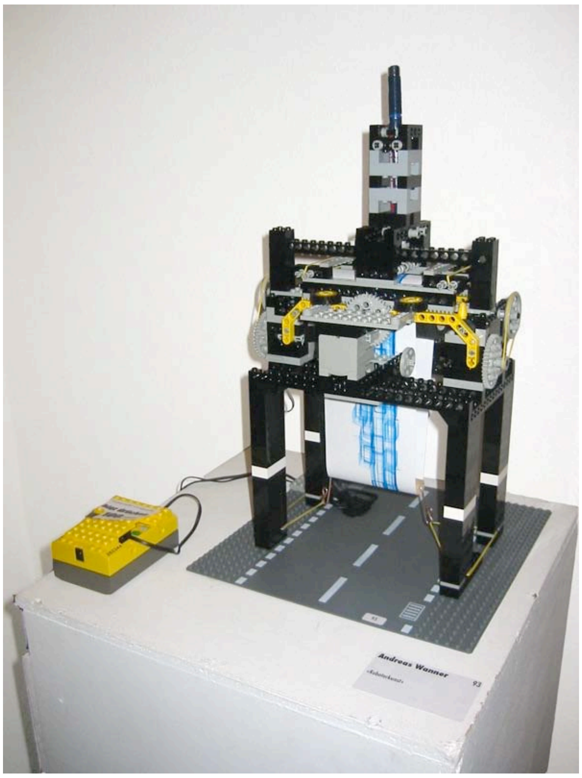

Figure 6: *The Plotter, as it was on display at Station21. The pen moves from left to right, whereas the canvas moves vertically in a loop.*

The Plotter integrates the canvas as a moveable part of the drawing robot. As in the preliminary study, there is still no calibration or internal spatial model, but the moveable range of the pen and the canvas are constrained in a way that the pen will always stay within the surface of the canvas. Consequently, the pen cannot shift off the canvas, as it did in the preliminary study.

The drawing procedure still has no natural completion point – a fact that is underlined by using a looped canvas that has no ending either. It is capable of running several hours without having to be interrupted by a human. The canvas eventually gets covered very densely with lines, and a human can safely stop the process at this point, without drastically interfering with the aesthetics.

As in the preliminary study, the behavioral architecture of the Plotter consists of instructions and mechanical friction. Again, the instructions were simple, and consisted in repeatedly drawing a rectangle.

3.4 Display and Results of the Plotter

The Plotter was exhibited for two days in February 2006, at the "Kunstbazar", a group exhibition at the gallery "Platform Station21" in Zurich, Switzerland. Station21 is an independent artist run space with regular, monthly programming. Around one hundred visitors visited the exhibition and saw the Plotter. The Plotter produced two drawings; both ran for several hours, during the whole duration of the exhibition. Other drawings were produced later on, to further investigate the aesthetic questions of this paper.

The resulting drawings displayed consistent aesthetic attributes, in a similar way as the drawings from the preliminary study, however the attributes were different ones.

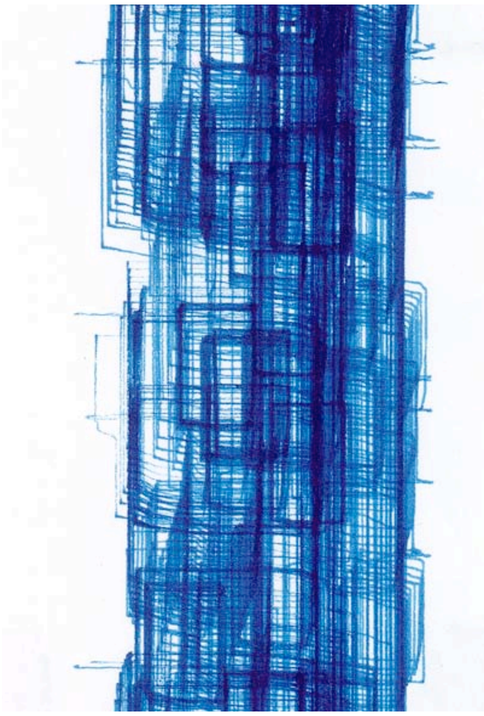

Figure 7: *Drawing by the Plotter (day 1, detail)*

The drawings produced during the exhibition display near-congruent forms, similar to the ones observed in the drawings of the preliminary study. In contrast, there is no rotational symmetry. The drawing lines remain entirely within the canvas, as caused by the constraints of the setup. As in some examples of the preliminary study, there is roughened paper in zones of high density. The drawing of day 2 (Figure 8) features big ink spots, evidencing the fact that it was executed without human intervention: when the pen got stuck at a specific location, it left a big spot. Again, the ink spots result from the mechanical friction layer and are evidence of the robotic Eigensinn.

In both drawings (Figure 7 and 8) shown here, the lines cover a significant part of the available drawing area, due to the long time of execution. As a consequence, the areas of negative space are vanishingly small, and there is little contrast in size between different shapes of negative space: the drawings become uniform.

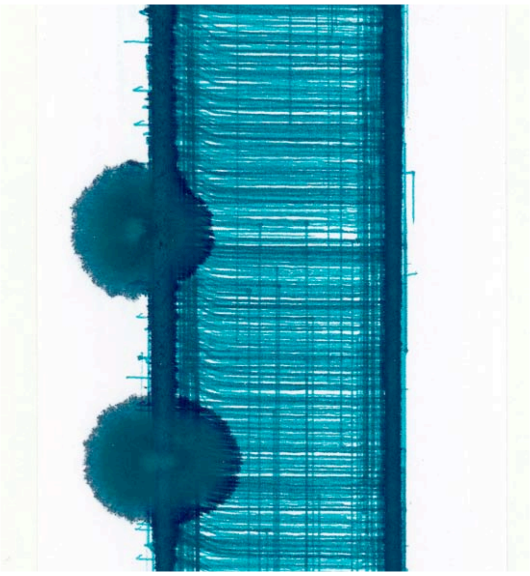

Figure 8: *Drawing by the Plotter (day 2, detail)*

Two drawings (Figure 9 and 10) produced with the same setup, but terminated at a freely chosen moment by the artist, display a structure of near-congruent forms. Conglomerations of several thin lines into a thicker line result in high-density zones, in which the paper gets rougher. In the corners of these thicker lines there are small circular spots that are about to turn into “ink spots”, similar to the ones observed in drawings of longer duration. Gradual mechanical friction-shifts in the position of the canvas and the pen cause uneven distribution of these rectangles and give rise to a composition of shapes of negative forms. These negative forms have different sizes and proportions. The resulting composition emerges from the physical interaction of the Plotter with the canvas; they are caused by the Eigensinn of the setup.

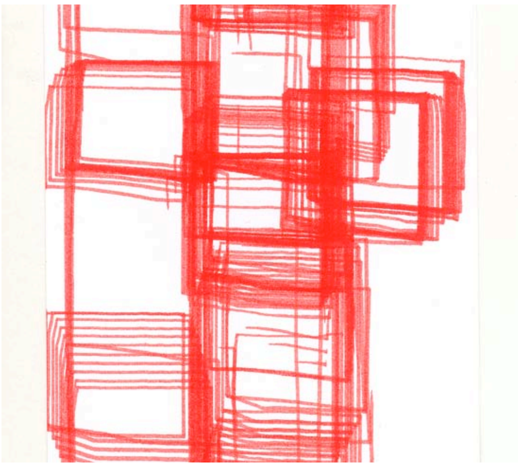

Figure 9: *Drawing by the Plotter (detail), stopped before completion.*

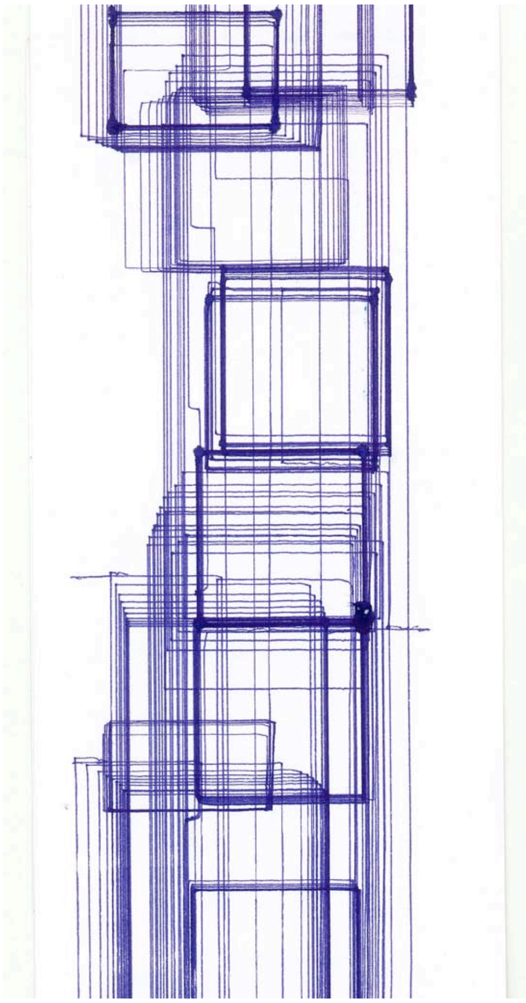

Figure 10: *Drawing by the Plotter (detail), stopped before completion.*

4. Conclusion

The preliminary study and the installation the Plotter, are both explorations of the aesthetics of a mechanical Lego-mindstorms construction as a generative system. The drawing-processes of both explorations were capable of producing images that were not predictable in detail. The interplay between instructions and mechanical friction gave rise to aesthetics beyond human control.

The preliminary study consistently displays regular patterns of rotational symmetry and near-congruent forms. The attributes of negative-space compositions and ink spots appear less consistently.

The Plotter consistently displays near congruent forms, but not rotational symmetry. It also displays negative-space compositions, which vary for each run of the Plotter, but appear consistently.

All these attributes support Brooks' paradigm of behaviors that emerge through interaction with the physical environment. Consequently, they are aesthetic Eigensinn-attributes of the specific setup, in which they appear. The attribute of near congruent forms appears consistently over different drawing processes and setups, and may be a constituent of a generalized machine aesthetics.

Future research has to explore the line between machine obstinacy and an autonomous machinic subjectivity. More theory is needed here, to explain in what ways machinic subjectivity is more than obstinate technology that passively resists the artistic intention of the human creator.

While the plotter emphasizes the difference between human and machine contributions to aesthetics, further explorations should also explore aesthetics of human-machine assemblages more synergistically: how does the interplay between humans and machines lead to new images whose aesthetics are more than a sum of human intentions and machine specifics?

As a future next step, it will be interesting to explore, *how* the construction of the robot shapes symmetries, near-congruent forms, or emerging compositions between different areas of negative space. Generative artists grounded in control based AI have been exploring the "rules for art". In contrast, the focus of the explorations discussed here is more the aesthetics of human-machine assemblages.

The author also plans to extend the exploration from Lego robots to machines that are closer to human everyday experience, e.g. household devices. Appropriation of such as drawing machines promises to allow a closer link for a potential audience to their own lives, speak to machine aesthetics in a more general way, and shed a new light on the technology that surrounds us every day.

References

[Bro91] BROOKS, R.A.: Intelligence Without Representation. In *Artificial Intelligence Journal* (1991), vol. 47, pp. 139-159.

[BW97] BROECKMANN A. & WARK K.: Machine Aesthetics – The beginning of a conversation between Ken Wark and Andreas Broeckmann (1997). Retrieved April 19, 2011 from http://www.nettime.org/Lists-Archives/nettime-l-9701/msg00069.html

[Cam10] CAMPANELLI, V.: Web Aesthetics – How Digital Media Affect Culture and Society. NAi Publishers, Rotterdam (2010).

[Coh95] COHEN H.: The further exploits of Aaron, painter. *Stanford Humanities Review* (1995), vol. 42, issue 2, pp. 141-158

[MP03] MOURA, L. & PEREIRA, H.G.: Artsbot (2003). Retrieved June 7 2011 from http://www.leonelmoura.com/artsbot.html

[Nak95] NAKE F.: Einmaliges und Beliebiges. Künstliche Kunst im Strom der Zeit. Aufsatz anläßlich der Berliner Sommer-Uni '95, Berlin (1995). Retrieved April 7 2011 from http://radicalart.info/AlgorithmicArt/Nake95.html.

[Sch04] SCHIESSER G.: Working On and With Eigensinn. Media | Art | Education [1]. In Schade S., Sieber T., Tholen G.C. eds., Morrison T. trans. *Schnittstellen, Basler Beiträge zur Medienwissenschaft.* vol. 1 (2004).

[Tin56] TINGUELY J.: Wundermaschine, Meta-Kandinsky I. Museum Tinguely, Basel (1956). Retrieved April 19, 2011 from http://arttattler.com/archivelandyandtinguely.html

[Tin59] TINGUELY J.: Métamatic No. 17. Moderna Museet, Stockholm (1959). Retrieved April 19, 2011 from http://arttattler.com/archivelandyandtinguely.html