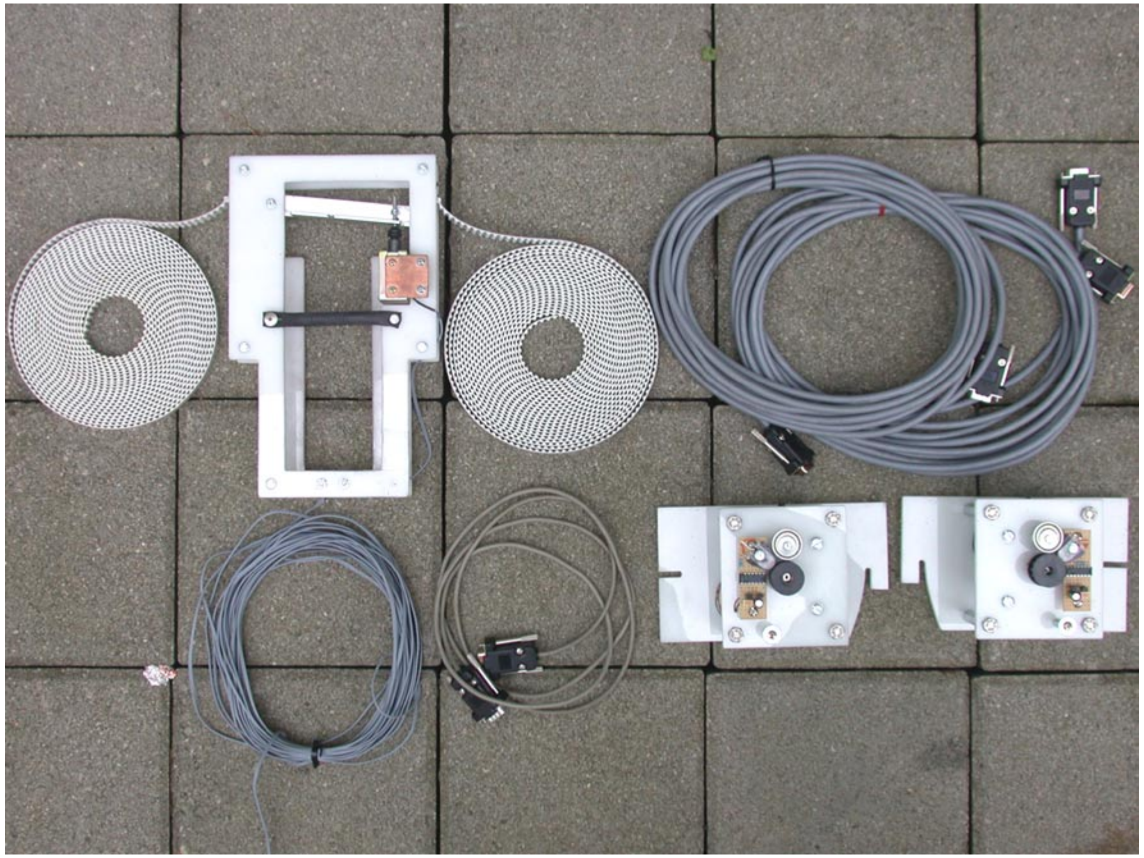
HEKTOR: Project of Jürg Lehni and Uli Franke, 2002, Écal
MANY THANKS TO: Urs Lehni, Melanie Hofmann, Cornel Windlin,
Jonas Meier, Jonas Biveroni, Ivan Engler, Yves Winistoerfer



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INTRO-DUCT-ION

The output of designers has always been strongly influenced by the tools they were using. Each tool offers special possibilities, optimizations and simplifications for certain uses but also has its limitations. You can hardly drive a nail with a screw driver, for instance. Tools were invented as an extension and abstraction of the human body, especially the hand, through which humans influence their surroundings. The implied abstraction in tools represents a very important step in the development of human technology.

With the invention of the computer, another step towards abstraction was taken: A computer is a tool that simulates other tools through programmation and therefore abstracts tools in general. A computer pretends to be – among many other things – a typewriter, a musical instrument or a movie cutting room. These simulated tools are called software and are never tangible. They are operated by the use of the common computer input devices and the treated object is looked at through the computer screen like a cell through the lens of a microscope. Therefore this object is never as real as the cell, it only becomes real when it leaves the computer through output device like the screen, the printer or the speakers. Inside it is represented through abstract information.

These facts lead to some fundamental changes in the way we create and work with things. One thing is – but this may just be personal – the distance to the treated object. Whenever I work with computers and especially when writing my own software, I never get completely rid of the feeling that what I create is not real. It is maybe the simple fact that I never can touch what I am creating. Another thing is the software itself: Developing software is hard and not so many people know how to write it. It is a long and intensive process to a completely functional product and therefore only a few big companies create software for the creative sector. *Adobe™* nowadays controls nearly the whole graphic design and publishing sector with *Adobe Illustrator™*, *Adobe Photoshop™* and *Adobe InDesign™*, while *Macromedia™* is responsible for the so called new media and interaction design sector with software like *Macromedia Flash™* and *Macromedia Director™*. These few applications are used by creatives all over the world and therefore they are responsible for a globalisation of and growing monoculture in the design. Vector-graphic aesthetics are omnipresent, a lot of graphic designers use the same few trend-fonts over and over again, and their creations are printed on the same output devices: laser printer, ink jet printers, black and white or color, A4, A3, A2, A1. Not to mention that since *Macromedia Flash™*, there are maybe too many animated and antialiased webpages.

This view of things combined with a fascination for computers, programming, mathematics, abstract forms and design motivated me to try to create a new output device for the computer, a tool that would offer new aesthetics and a different way to turn the abstract representations of things within the computer into real ones.

Another motivation for this was to relearn how to construct real objects by hand after having worked almost only with software for now more than 4 years. In an intuitive way it was clear for me from the beginning that it should be a machine that follows vector graphic paths and draws them, like the human hand follows a line when it draws it. Vector graphics and the bezier curves out of which they are made are simple but nevertheless very flexible mathematical representations of forms. The handling of a bezier curve is quite intuitive and still directly derived from its formulas. Therefore it is in my eyes a beautiful construct that always fascinated me.

But a normal printer does not translate these characteristics in an adequate way when printing such a shape, because it is simply rasterized and then printed scanline by scanline. The old plotters that moved a pen on the vector path or the computer controlled milling machines are much closer to what I had in mind, but I was looking for something different, something less perfect and more poetic. I wanted to create a machine that follows the lines in a loose way, that adds certain characteristics to it and therefore has its own expression and style, which would directly be derived from how it was constructed. It should not draw onto something like paper but instead directly on to the floor or the walls and the line it draws should also be a bit imprecise, I thought. Therefore I soon decided to use spray cans and to search for a way of moving the can while pushing and releasing its nozzle automatically, all remotely controlled by a computer. It was also important for me that the machine is not a huge installation but a transportable device that can be put up somewhere within a reasonable time.

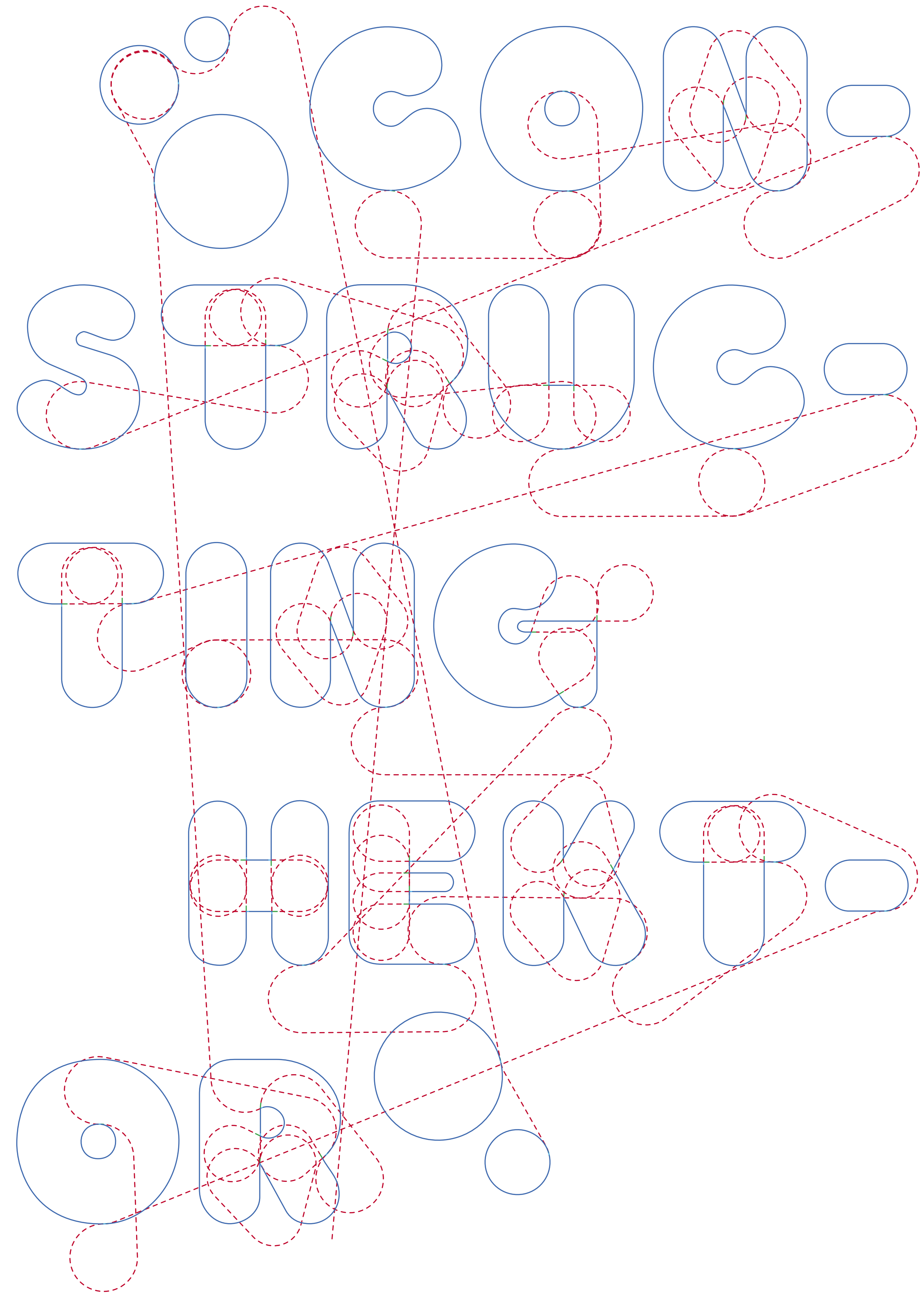
What I hoped for was that the machine in action and its result had an astonishing and irritating effect on the observer, caused by the contradictions that the machine would unify in itself: The precision and the high-tech feeling of the machine combined with the imprecise spray can, made for humans to spray by hand, which is not moved by a hand but seems to move autonomously on the wall.

First I thought about a huge plotter that consists of two parallely driving carts, connected by a looped belt on which the spray can would be mounted. The carts would drive in one dimension (X) while the looped belt would move into the other dimension (Y). But that seemed very hard to realize. Then I found a much simpler way of moving the can: I planed to mount it directly on a Radio Control (RC) Car, on a children's toy.

I did some research and contacted Uli Franke, a friend of mine who is studying Electro Engineering at the *ETH Zurich* in order to ask him about the technical feasibility and soon we were brainstorming about different ways of doing it. But then someone showed us the *GraffitiWriter* from the Institute for Applied Autonomy (www.appliedautonomy.com) a project very similar to what we wanted to create. Although the *GraffitiWriter* was constructed with activism in mind and uses five cans on one line to spray text messages at high speed with a mechanism similar to the system found in LED displays, it was too close to my idea to not immediately be connected with it by someone who knows both projects.

I had to rethink. Uli offered me to visit him in Sardinia where he did an exchange semester, I went there and the brainstorming continued on a very productive level. We abandoned the idea of a painting machine for floors and thought about a real Graffiti machine, one that sprays on walls. And on one morning in July, during a car ride the idea struck my mind: We only need to take an element from an idea we had the day before, move it higher on the wall and make the other element much smaller, and a completely new way of moving the can was found. One that is simple, hopefully feasible and more elegant than the other ideas we had in mind. The discussion about this project went on during my whole stay in Sardinia, and when we both went back to Switzerland, we immediately started to construct *Hektor*.

SARDINIA: *The two of us on the road.*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Of course we did not call it *Hektor* from the beginning, it did not even have a shape, it was just an idea. There were dozens of decisions to take and problems to solve, but the basic idea was clear: Four step motors, mounted onto the wall in the four edges of a rectangle would move the can, which would be connected to the motors by something like robes, the motors functioning like winches. The can in the middle and the four robes connected to the motors would form an X, and when the can is moved by pulling or releasing each of the winches, this X is distorted.

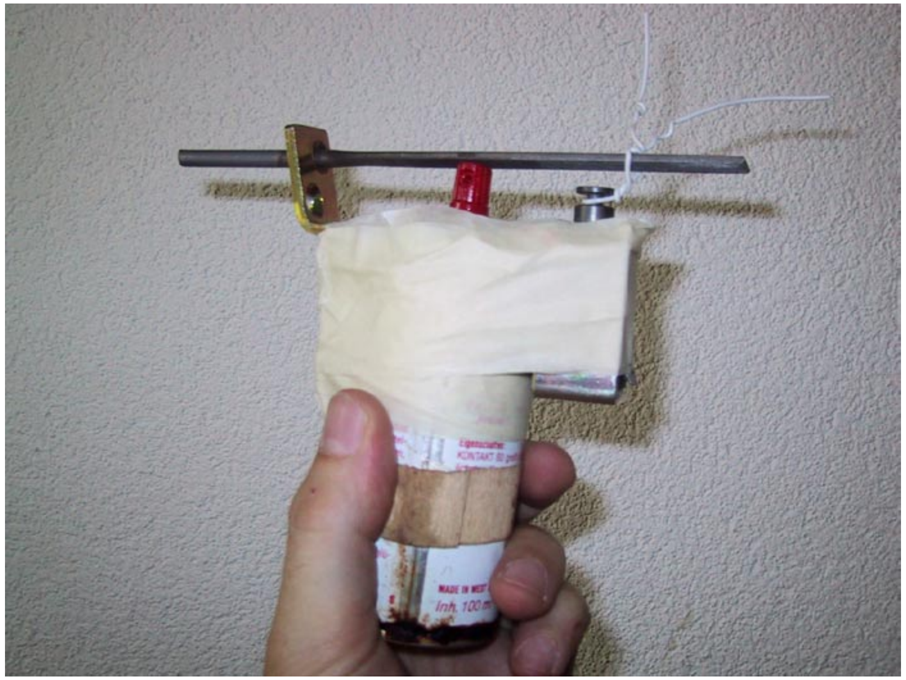
There would be so many advantages: The machine would be scalable, it would not spray within a predefined size only. One could mount the motors wherever possible and required, the only limitations would be the length of the robes, the accessibility of the locations for the motors and some other mechanical constraints. All the parts would fit into something portable, for example a suitcase.

Now this was the starting point. Uli suggested to use only the two upper motors, but I thought this would be to unstable, because the lower motors were planed to keep the can stable and near the wall, so we started to develop the machine with four motors.

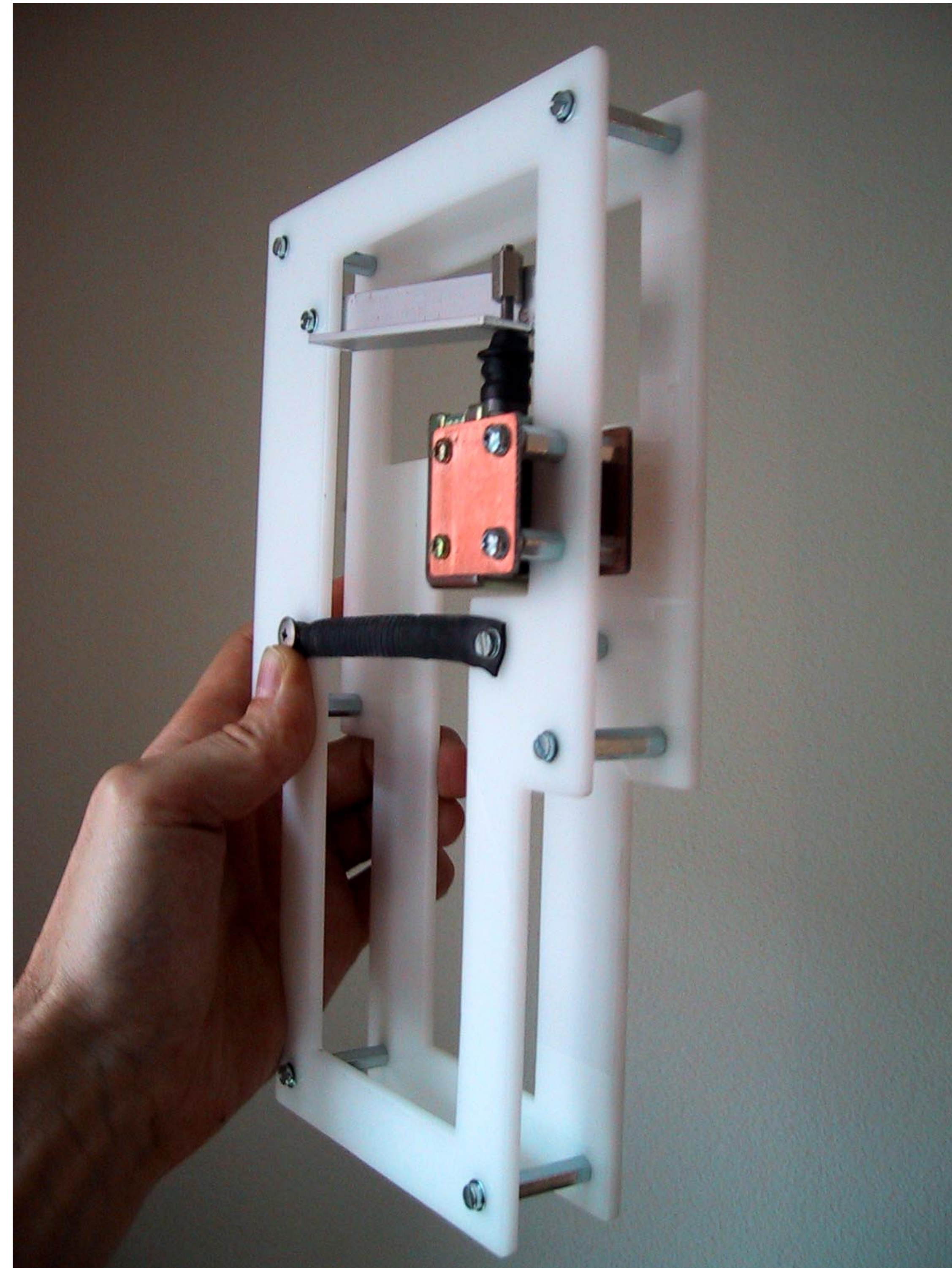
The whole project was a risky and somehow quite crazy experiment, because we only had about five weeks to finish the first prototype and we started with nothing. During these five weeks, which was a very intensive time indeed, we found solutions for the case of the machine, the robes (we took toothed belts instead), the circuit board, the controlling software, the sensors and the wrapping of the whole machine. As usual, quite a few things went wrong, the circuit board had to be etched three times, the lower motors caused instabilities and resonant frequencies and therefore had to be removed. This made the software much more complicated because it had to assure that the can only moves very smoothly, even for edgy paths. Problems with courier services caused delays in the delivery of the components, and all the time we were never sure wether it is going to work at all.

At some points we had indications that it will turn out to have been worth the work, for example after the first connection between the circuit board and the software on the controlling computer was established. Or after we saw the speed, the force and the precision the motors are capable of, but until we really sprayed the first vector path, we were never sure.

Uli and I had a real division of work during this time: He was responsible for the electronic parts, I developed the software and we both were involved in the mechanical construction of the machine.

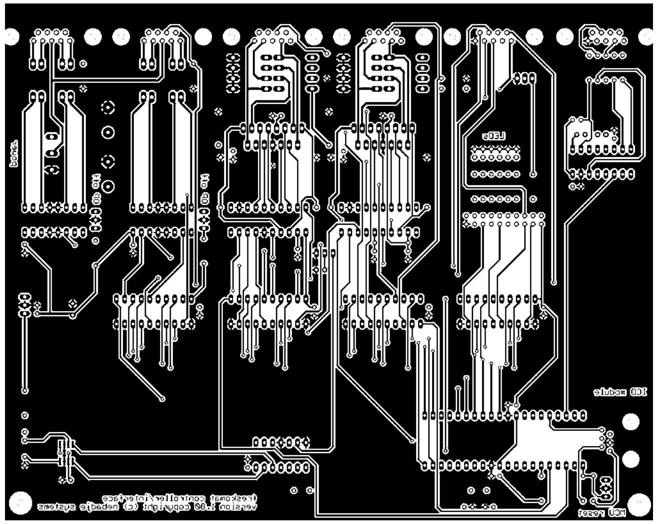


CAN-HOLDER: *A first prototype for the spray-activation mechanism. An electromagnet with a movable iron core is used to pull the lever that pushes on the nozzle.*

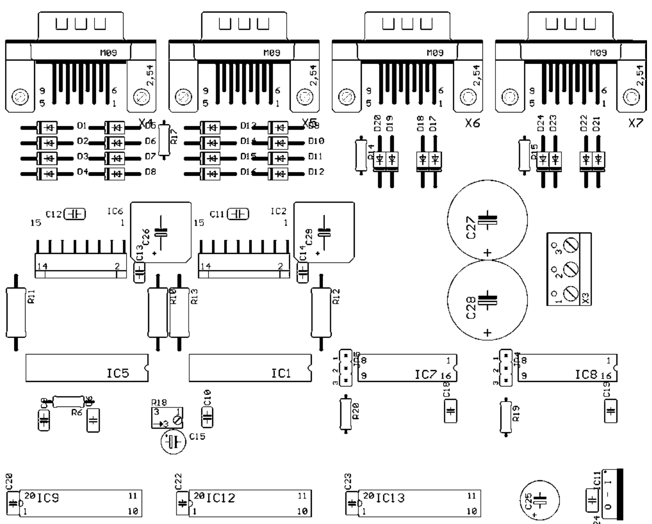


CAN-HOLDER: *The same mechanism in its final form, mounted on the can-holder.*

CONSTRUCTING HEKTOR: CIRCUIT-BOARD
DATE: 29.07.02 – 12.08.02

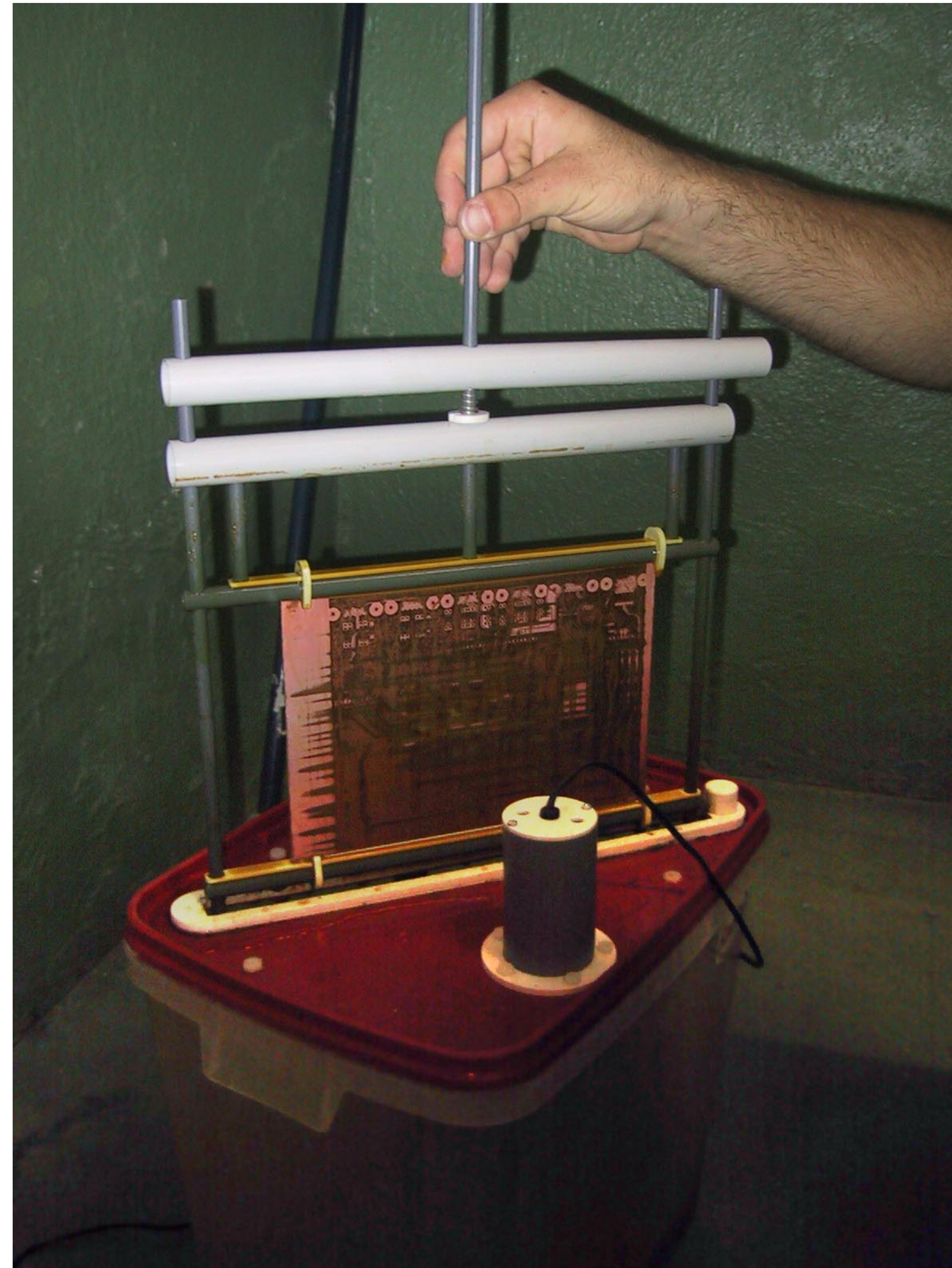


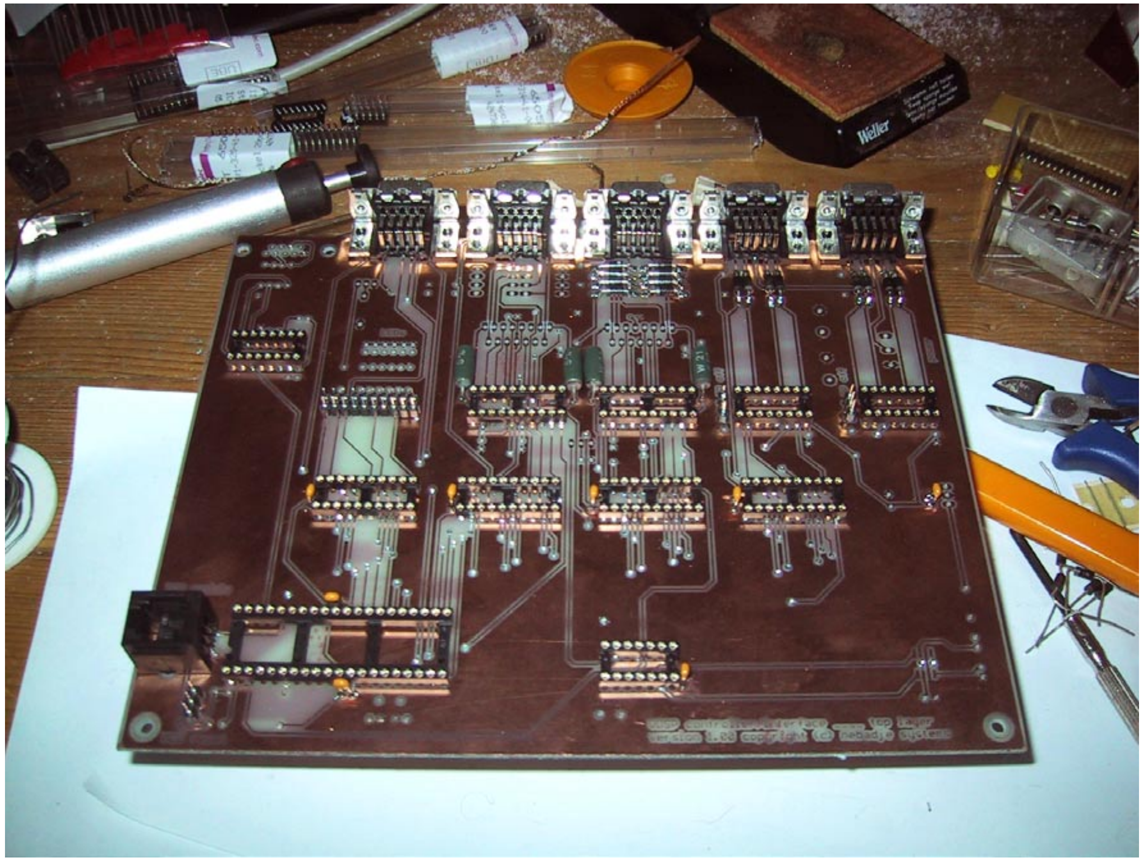
CIRCUIT-BOARD: *The photo-negative of the board's upper side.*



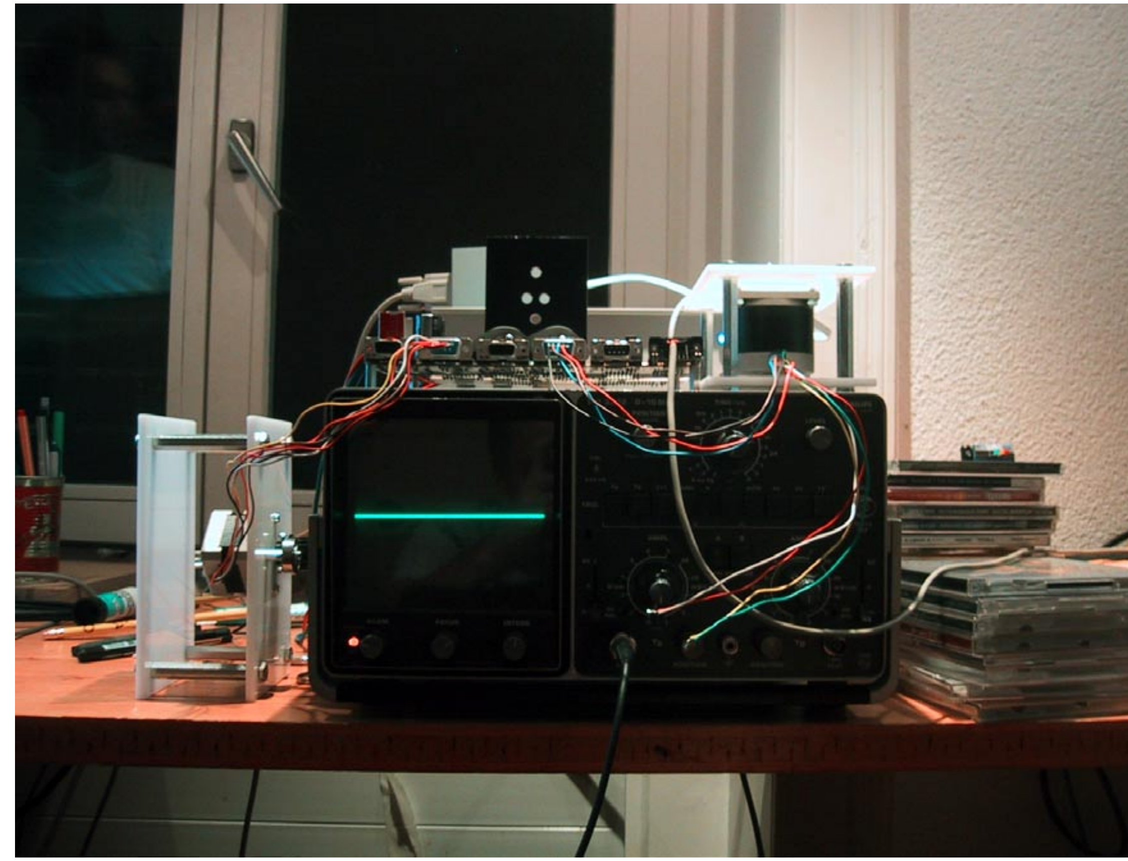
CIRCUIT-BOARD: *Detail of the board layout diagram.*

CIRCUIT-BOARD: *The first try of etching the board. Two further tries were necessary until we were successful.*



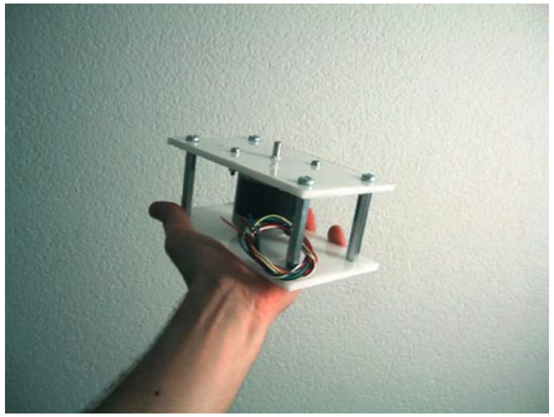


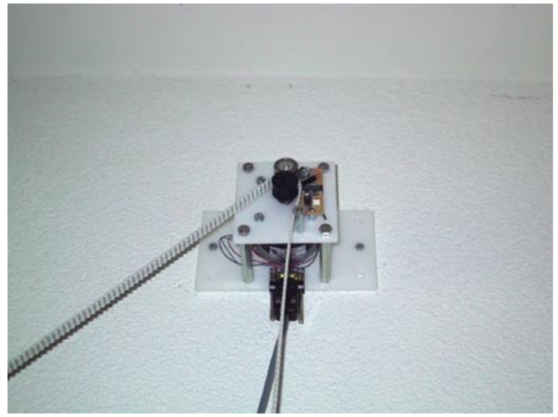
CIRCUIT-BOARD: *The board with some of the components already soldered onto it.*

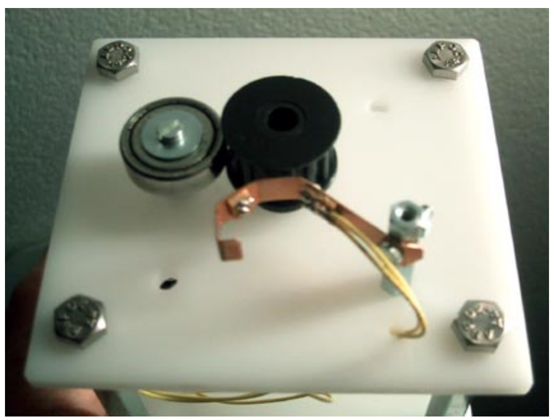


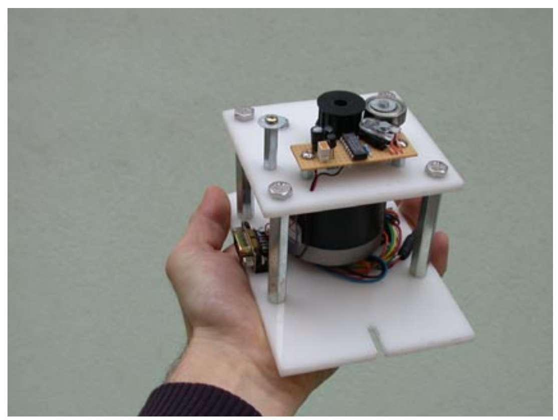
CIRCUIT-BOARD: *Testing the board with two engines connected to it.*

CONSTRUCTING HEKTOR: ENGINES
DATE: 01.08.02 – 15.08.02









ENGINES: *The first version of engine case.*

ENGINES: *The mechanical sensor that detects the minial distance to the can holder. It was later replaced by the optical sensor.*

ENGINES: *A later version of the upper right engine with the optical sensor, mounted to the wall.*

ENGINES: *The final version of the engine, with the rapid mounting mechanism.*

ENGINES: *Uli's kitchen converted into a working space.*

An important part of the machine is the software that controls it. First it was planed to create a little application that does nothing else than taking *Illustrator™* vector files, translating them to commands for the step motors and sending these commands to *Hektor*. Then someone came up with the idea of a real printer driver, which one could use in all the other applications, but that seemed far to complex for the short time. The solution was a compromise:

Some months before *Hektor* I started to work on *Scriptographer*, a scripting plugin for *Illustrator™*. *Scriptographer* opens up this rather closed and monolithic application by adding the possibility to write new tools with a simple scripting language within the application. The motivation for writing *Scriptographer* was the same I mentioned already in the introduction to this book: I hoped that the creation of new tools would lead to different aesthetics, and I wanted to offer everyone with a little programming knowledge this possibility. For *Hektor* I just had to add the functions that allow to communicate with *Hektor's* hardware through the serial port interface and then I was able to write the whole controlling software in *Scriptographer*. This saved a lot of time, because rapid prototyping was possible, and it means that *Hektor* now is directly controlled from *Illustrator™*.

Due to the unconventional way of how we planed to move the can holder and because the can needed always to be moved on smooth paths, this software got quite complicated and a lot of mathematics was necessary.


```
STUDENT > restart:assume(c, real): assume(d, real), assume(x0, real): assume(y0, real):
          assume(r, real):
STUDENT > e1 := (x - c)^2 + (y - d)^2 = r^2;
```

$$e1 := (x - c\sim)^2 + (y - d\sim)^2 = r\sim^2$$

```
STUDENT > e2 := (x0 - c)*(x - c) + (y0 - d) * (y - d) = r^2;
```

$$e2 := (x0\sim - c\sim)\,(x - c\sim) + (y0\sim - d\sim)\,(y - d\sim) = r\sim^2$$

```
STUDENT > y := solve(e1, y)[1];
```

$$y := d\sim + \sqrt{2\,x\,c\sim - c\sim^2 - x^2 + r\sim^2}$$

```
STUDENT > e3 := factor(solve(e2, {x})[1]);
```

$$e3 := \{x = (c\sim\,y0\sim^2 - 2\,c\sim\,y0\sim\,d\sim + c\sim^3 + x0\sim^2\,c\sim + c\sim\,d\sim^2 + r\sim^2\,x0\sim - 2\,x0\sim\,c\sim^2 - c\sim\,r\sim^2 + \sqrt{r\sim^2\,(-y0\sim + d\sim)^2\,(d\sim^2 - 2\,y0\sim\,d\sim + c\sim^2 - r\sim^2 - 2\,x0\sim\,c\sim + x0\sim^2 + y0\sim^2)}) \,/\, (c\sim^2 + d\sim^2 - 2\,x0\sim\,c\sim - 2\,y0\sim\,d\sim + y0\sim^2 + x0\sim^2)\}$$

```
STUDENT > readlib(C):C(rhs(e3[1]), optimized);
      t1 = y0*y0;
      t6 = c*c;
      t8 = x0*x0;
      t10 = d*d;
      t12 = r*r;
      t18 = pow(-y0+d,2.0);
      t21 = 2.0*y0*d;
      t23 = 2.0*x0*c;
      t26 = sqrt(t12*t18*(t10-t21+t6-t12-t23+t8+t1));
      t30 = (c*t1-2.0*c*y0*d+t6*c+t8*c+c*t10+t12*x0-2.0*x0*t6-c*t12+t26)/(t6+t10-t23-t21+t1+t8);
STUDENT > x := solve(e1, x)[1];
```

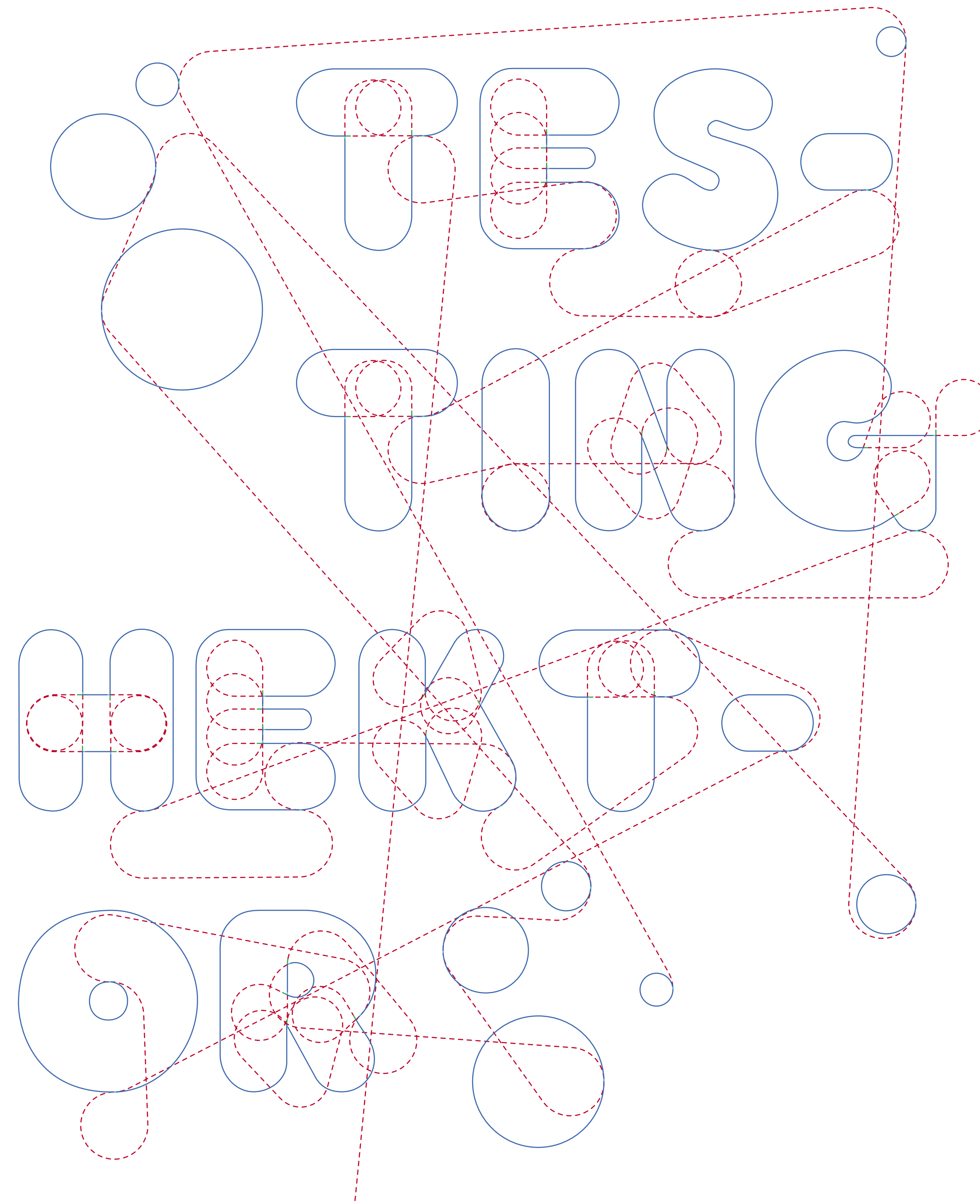
$$x := c\sim + \sqrt{2\,y\,d\sim - y^2 - d\sim^2 + r\sim^2}$$

```
STUDENT > e3 := factor(solve(e2, {y})[1]);
```

$$e3 := \{y = (r\sim^2\,y0\sim + d\sim^3 - 2\,d\sim\,x0\sim\,c\sim - 2\,y0\sim\,d\sim^2 - d\sim\,r\sim^2 + d\sim\,c\sim^2 + d\sim\,x0\sim^2 + y0\sim^2\,d\sim + \sqrt{r\sim^2\,(-x0\sim + c\sim)^2\,(c\sim^2 - 2\,x0\sim\,c\sim - 2\,y0\sim\,d\sim + y0\sim^2 - r\sim^2 + x0\sim^2 + d\sim^2)}) \,/\, (c\sim^2 + d\sim^2 + x0\sim^2 + y0\sim^2 - 2\,y0\sim\,d\sim - 2\,x0\sim\,c\sim)\}$$

```
STUDENT > readlib(C):C(rhs(e3[1]), optimized);
      t1 = r*r;
      t3 = d*d;
      t11 = c*c;
      t13 = x0*x0;
      t15 = y0*y0;
      t18 = pow(-x0+c,2.0);
      t21 = 2.0*x0*c;
      t23 = 2.0*y0*d;
      t26 = sqrt(t1*t18*(t11-t21-t23+t15-t1+t13+t3));
      t30 = (t1*y0+t3*d-2.0*d*x0*c-2.0*y0*t3-d*t1+d*t11+d*t13+t15*d+t26)/(t11+t3+t13+t15-t23-t21);
```

SOFTWARE: *Calculations for the path finding algorithm that smooths the movements of the can-holder..*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TESTING HEKTOR
DATE: 28.08.02 – 13.09.02

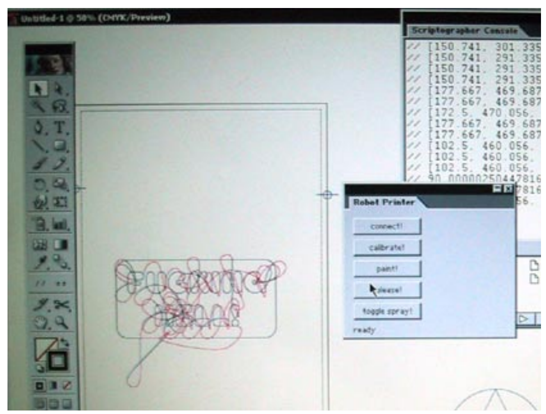
After first versions of all of *Hektor's* parts were finished, we mounted it on a wall in order to see whether it moves at all and whether the controlling software works.

We started with the four engines as described earlier and developed the calibrating algorithms, with which *Hektor* measures the wall it is mounted on. It all seemed to work very well, but then, when we wanted to let it follow some paths, we encountered serious problems with the lower engines: They caused strong vibrations and the whole installation shivered badly. Several changes to the software did not solve the problem, so we decided to remove the lower engines completely and changed the software to work with only two engines.

We proceeded without any other unsolvable problems, and within days, *Hektor* did more or less what we wanted it to, so we started to test it. After the first pre-tests, we decided that the next step in the project should be a serious test phase in order to find out as much as possible about *Hektor's* characteristics and capabilities. It was an interesting time, because although we constructed *Hektor*, we did not know what it is really capable of. So a series of tests was done, each test starts with an aim and ends with observations and thoughts about the result.

During the test-phase, several changes to the software were made: The algorithm that chooses the paths on which *Hektor* navigates was refined several times and other algorithms had to be added to compensate *Hektor's* inaccuracies.

TESTING HEKTOR: PRE-TESTS
DATE: 28.08.02 – 30.08.02

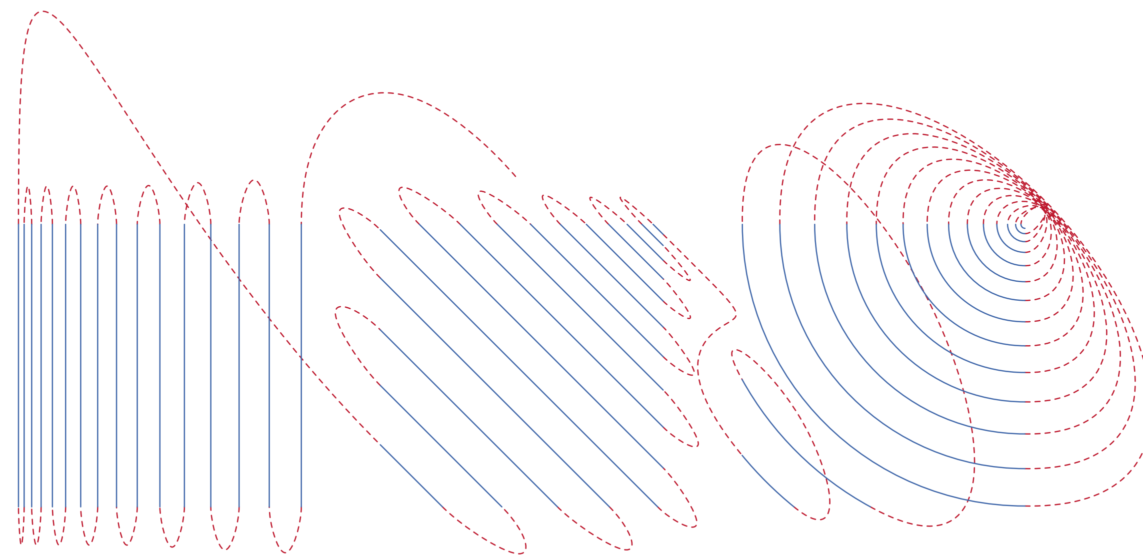


For the first tests, we just scotched newspaper onto the wall. First, we sprayed a star in a circle to see how well it can handly basic geometrical forms. The fact that it really worked and especially the perfection of the circle turned us completely euphoric, so we had to express that feeling with the second piece. Of course there still were problems and bugs, but on that day it was clear for the first time that the harder part of the project was over.

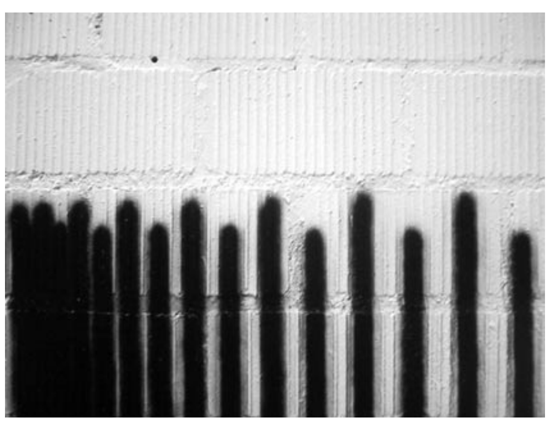
For weeks we were looking for walls where we could legally test *Hektor*, and finally, we found three nice walls in an industrial hall in Winterthur. Before we painted them white, we tried out a few other things in order to see how the project could continue. While the huge *Hektor* logo worked surprisingly well, the TV test screen was a disaster: The software crashed three times and left the can spraying onto the same spots without stopping it. After the third try, we had to abort this test.

TESTING HEKTOR: TEST#1 (LINES)
DATE: 05.09.02

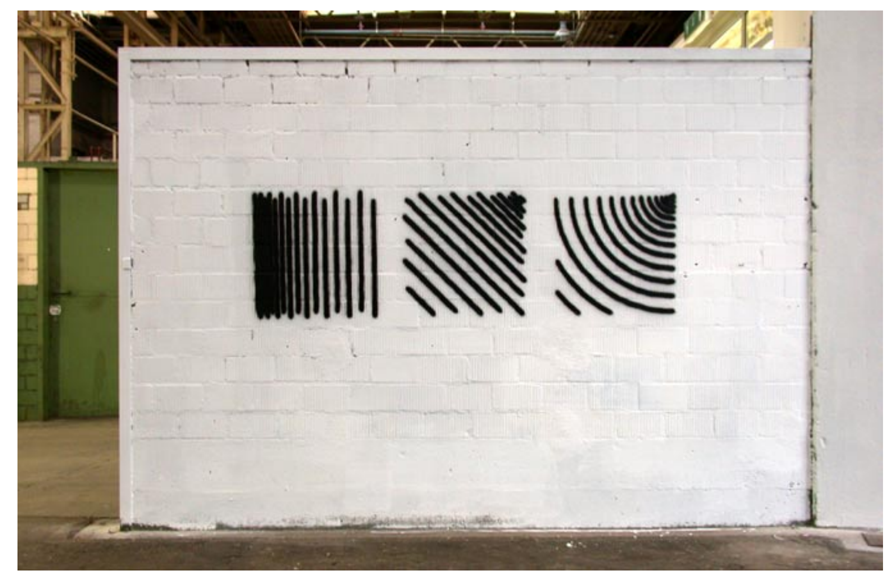
AIM: See how different lines in different parts of the sprayable area are sprayed.
CAN: Belton Special, RAL 9005, deep black
CAP: Standard cap
OBSERVATIONS:
- The spray activation mechanism is a bit slow and the speed of the can varies depending on the area and the direction of its movement due to *Hektor's* unconventional geometry. These two effects together lead to varying offsets in the starting and ending points of the lines.
- All lines seem to be very straight, even the concentric circle lines.



TEST#1: *The can's paths, chosen by Hektor's path finding algorithm.*



TEST#1: *The offsets, growing from left to the right, where vertical lines are sprayed faster.*

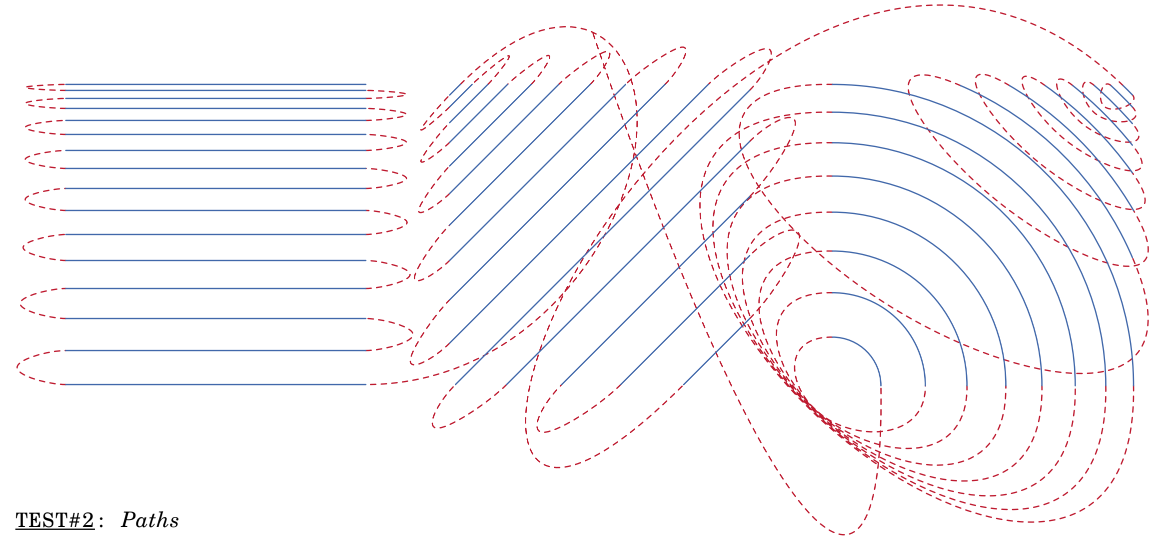


TEST#1: *The result. Notice the visible offsets, sized between 1 and 2 cm.*

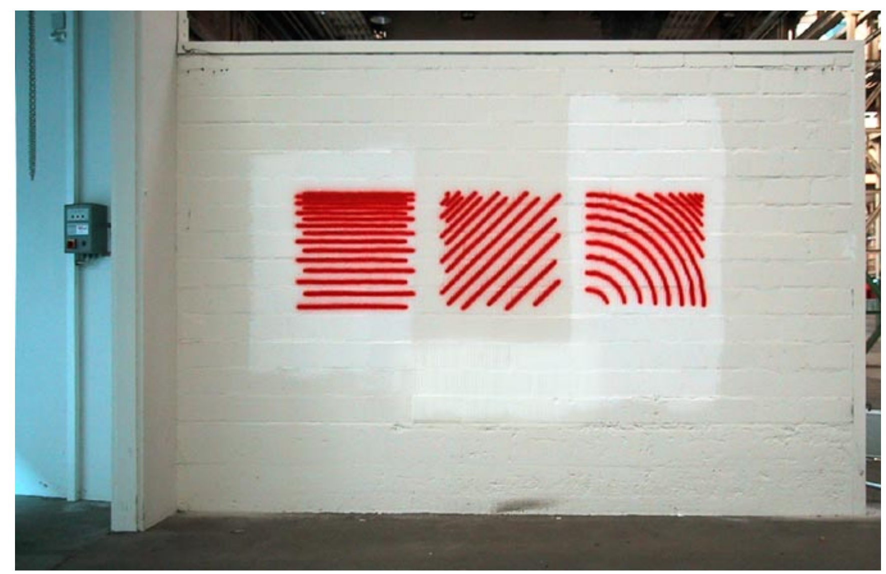
TESTING HEKTOR: TEST#2 (LINES)
DATE: 05.09.02

AIM: See how different lines in different parts of the sprayable area are sprayed.
CAN: Dupli Color, RAL 3000, signal red matt
CAP: Standard cap
OBSERVATIONS:

- The more expensive Dupli Color can leads to much better results than the Belton can, used by a lot of sprayers, because it has less pressure. With the same cap, the line is thinner, and the can could move slower.
- Line offsets are as bad as with the Belton can.
- The circle are worse than in Test#1, because they don not run around the upper right motor, therefore both motors have to move more and the can starts to shiver slightly.
- The path finding algorithm does not always find nice paths (see the diagram to the right).



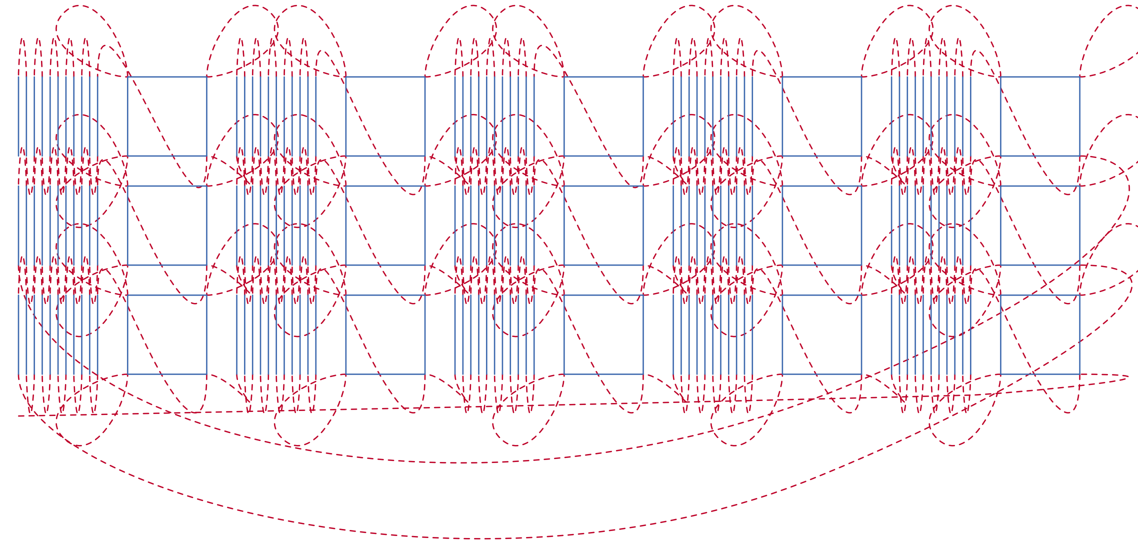
TEST#2: *Paths*



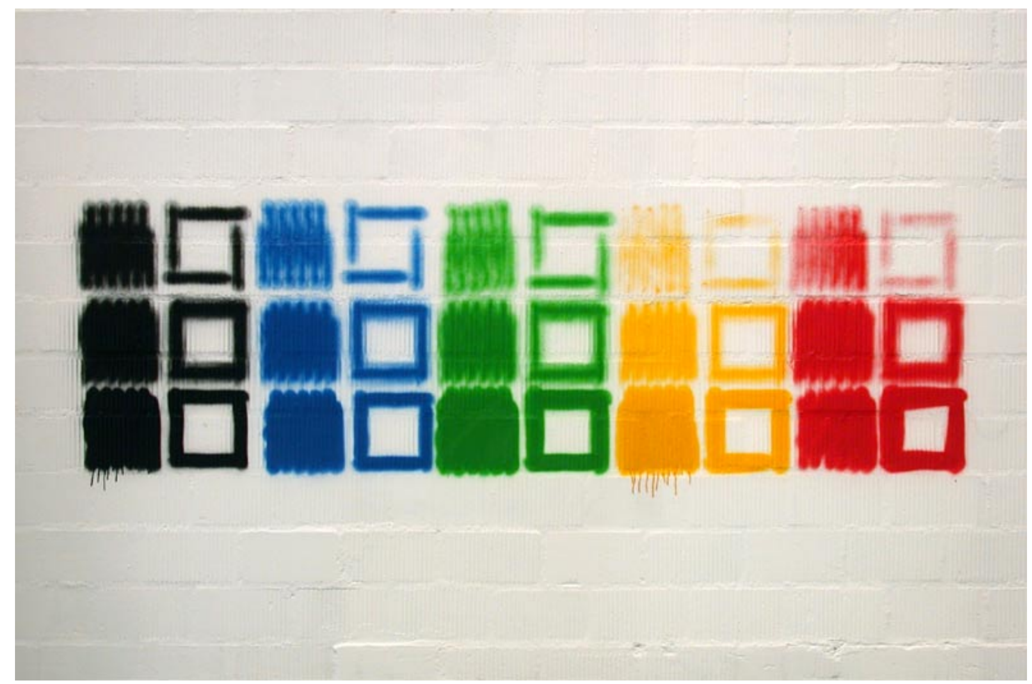
TEST#2: *Result*

TESTING HEKTOR: TEST#3 (COLORS AND CAPS)
DATE: 07.09.02

AIM: Test different colors and caps (products especially produced for sprayers). See how much the thickness of lines sprayed with different caps vary. See whether filling of shapes is possible.
CANS:
– Belton Special, RAL 9005, deep black
– Belton Molotow Premium 033, tulip blue
– Belton Molotow Premium 066, juice green
– Belton Special, RAL 9005, signal yellow
– Belton Molotow Premium 013, traffic red
CAPS: Skinny cap, Banana cap, Fat cap.
OBSERVATIONS:
– *Hektor* crashed badly during the calibration, got two cracks, and lost a screw during spraying.
– The skinny cap does not work very well. During the spraying, it got blocked, and it takes more time to push the cap (resulting in bigger offsets).
– The Belton cans generally have quite a high pressure, even they are suspected to have less pressure than other cans made for graffiti sprayers.
– The RAL colors (black and yellow) drip with the fat cap.

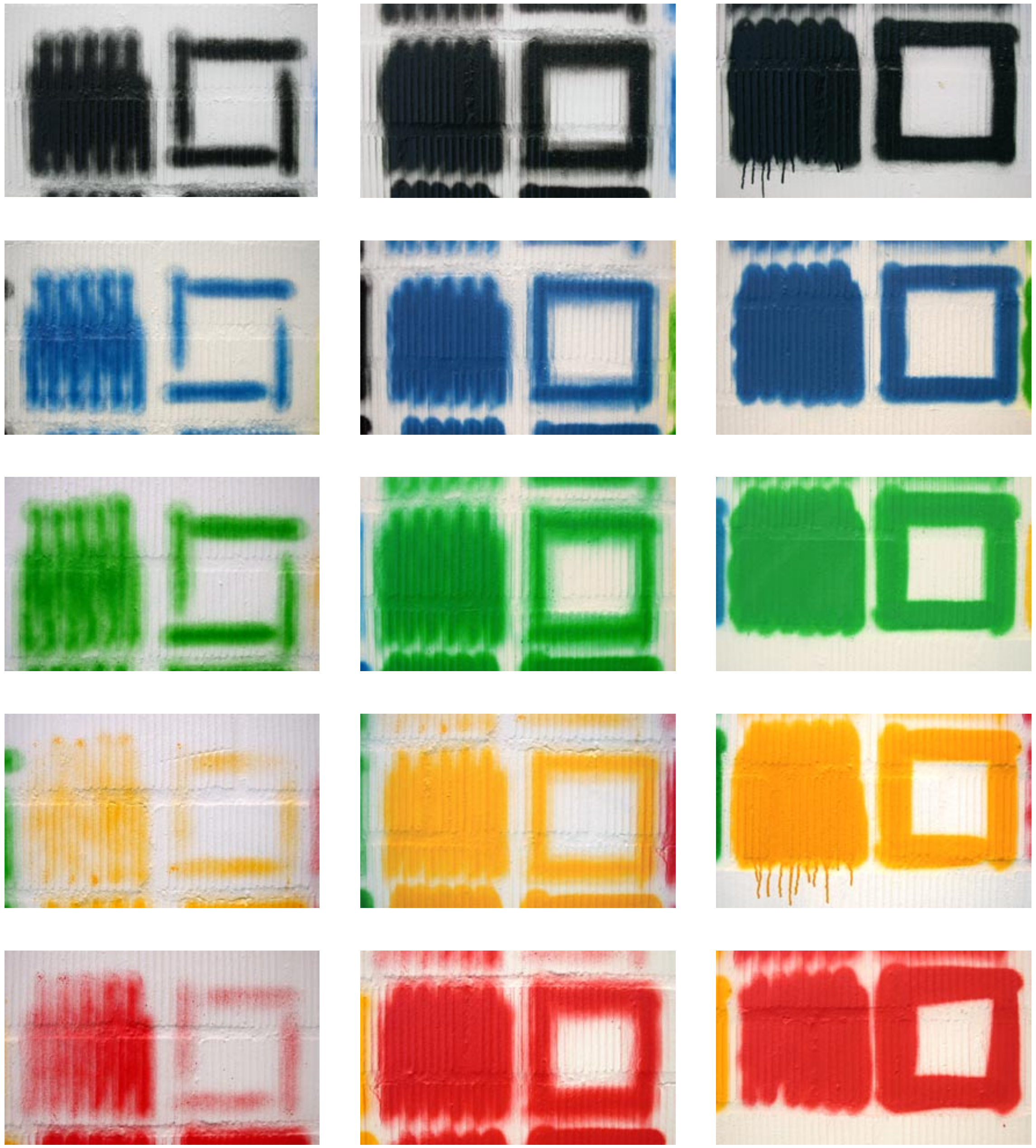


TEST#3: *Paths*



TEST#3: *Result*

TESTING HEKTOR: TEST#3 (COLORS AND CAPS)
DATE: 07.09.02



TEST#3: *Skinny cap, Banana cap and Fat cap*

TESTING HEKTOR: TEST#4 (GRADIENT)
DATE: 11.09.02

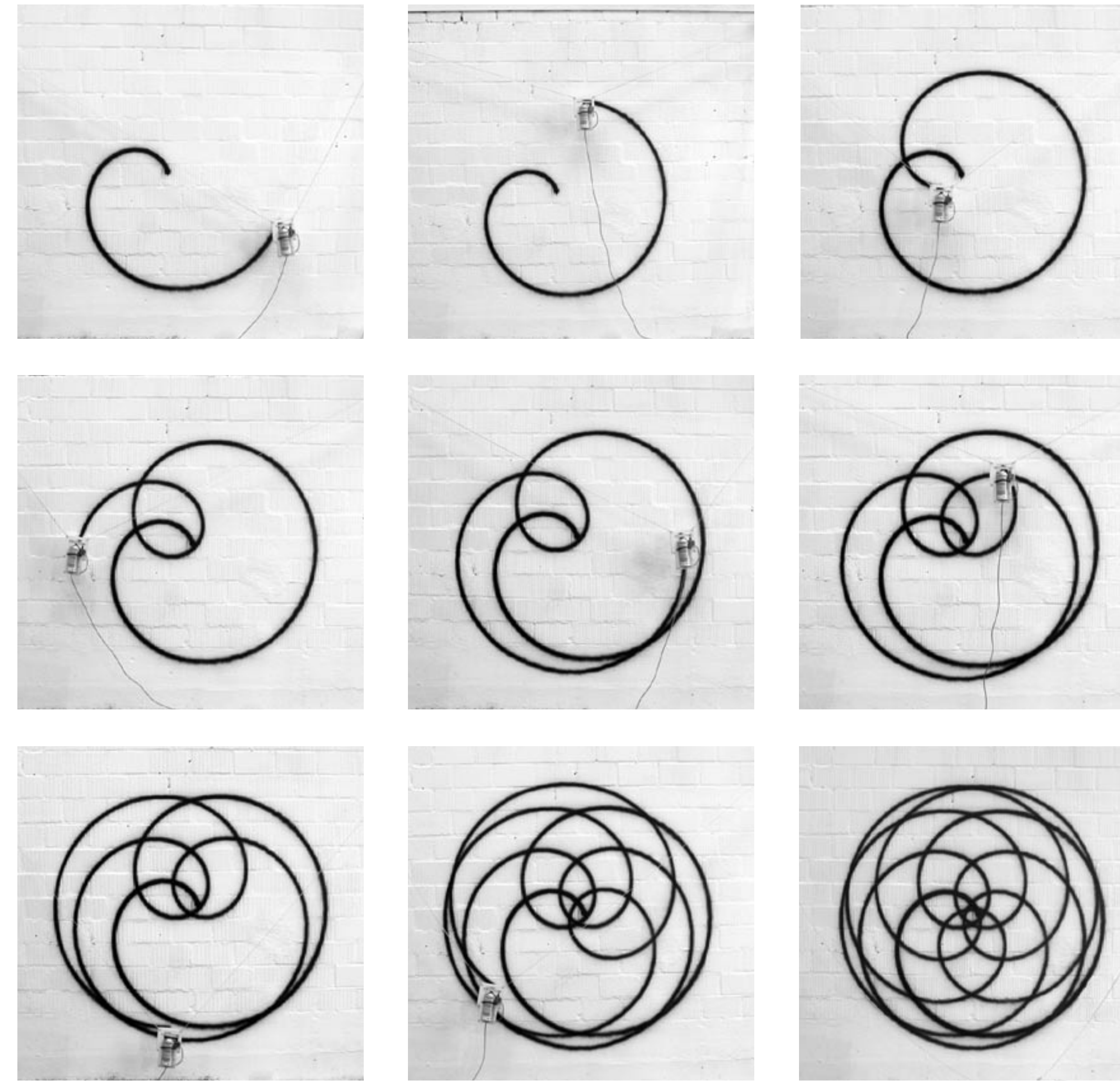
AIM: Create a color gradient without adjusting the can's pressure (which is not possible up to now).
CANS:
- Belton Molotow Premium 033, tulip blue
- Belton Molotow Premium 013, traffic red

CAP: Standard cap
OBSERVATIONS: A mistake was made while planing the test: The gaps between the blue lines should have been filled with red lines, instead of only spraying the inverted blue pattern in red.

TEST#4: *The failed gradient*

TESTING HEKTOR: TEST#5 (SPIROGRAPH)
DATE: 11.09.02

AIM: Spray a spirograph, a complex shape which does not contain any edges, to see the precision *Hektor* is capable of.
CAN: Dupli Color, RAL 9005, deep black matt
CAP: Standard cap
OBSERVATIONS: The result is very precise, a much more complicated spirograph would have been possible.

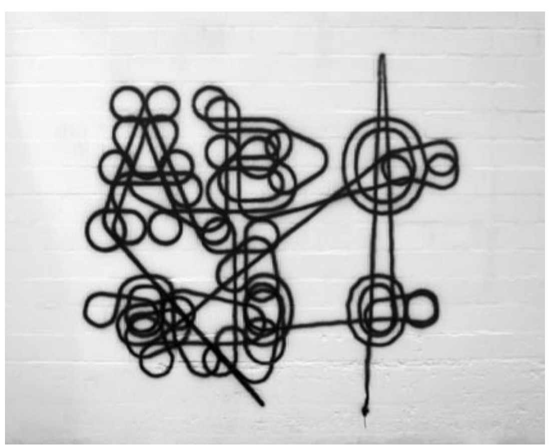


TEST#5: *Sequence of Hektor spraying the spirograph*

TESTING HEKTOR: TEST#6 (PATHS)
DATE: 11.09.02

AIM: Test the refined path finding algorithm by letting the can spray arbitrary forms (letters) without stopping between the segments.
CANS: Migros Acryl Aqua Color, RAL 9017, deep black matt
CAP: Standard cap
OBSERVATIONS:

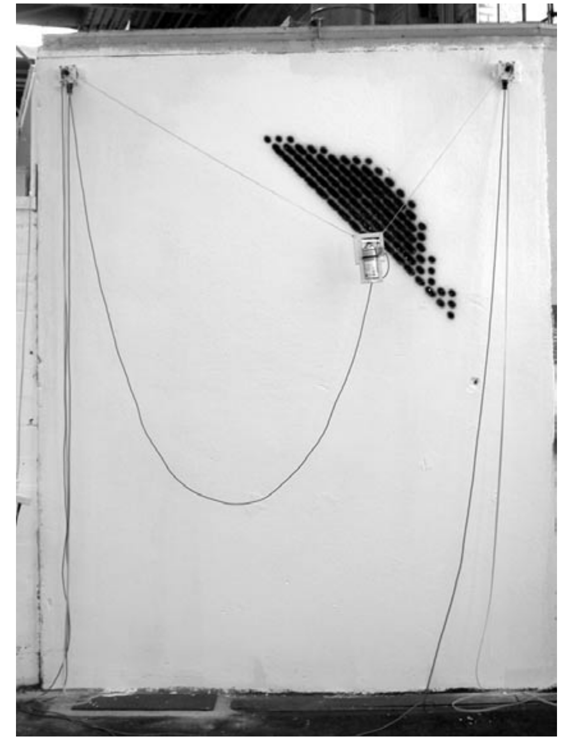
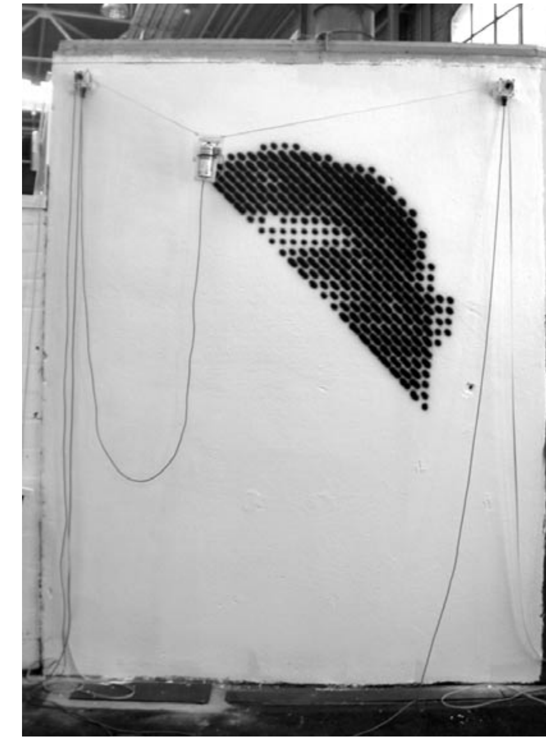
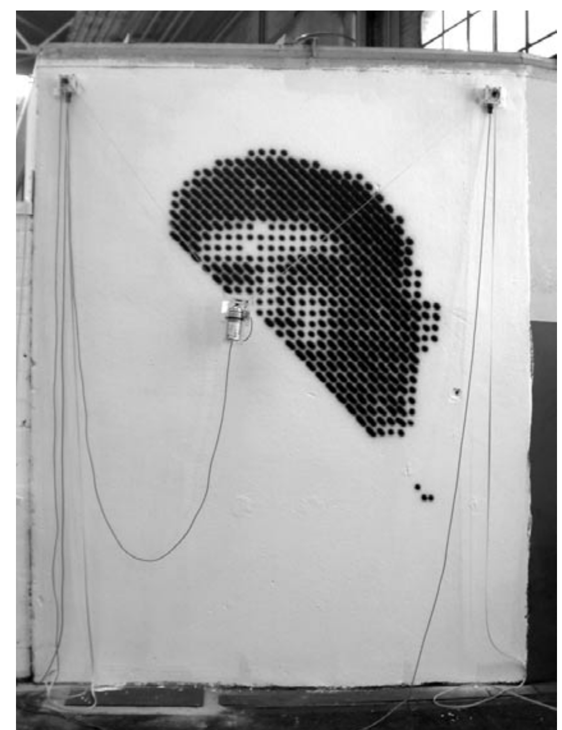
- The paths added by *Hektor* are smooth and don not lead to shivering.
- The cheap Migros can with the standard cap works very well, the lines are not to thick and the pressure not high.
- A bug in the software at the end of the pass caused the can move very quickly up to the top of the wall and down to the bottom, where it stopped moving but did not stop spraying.

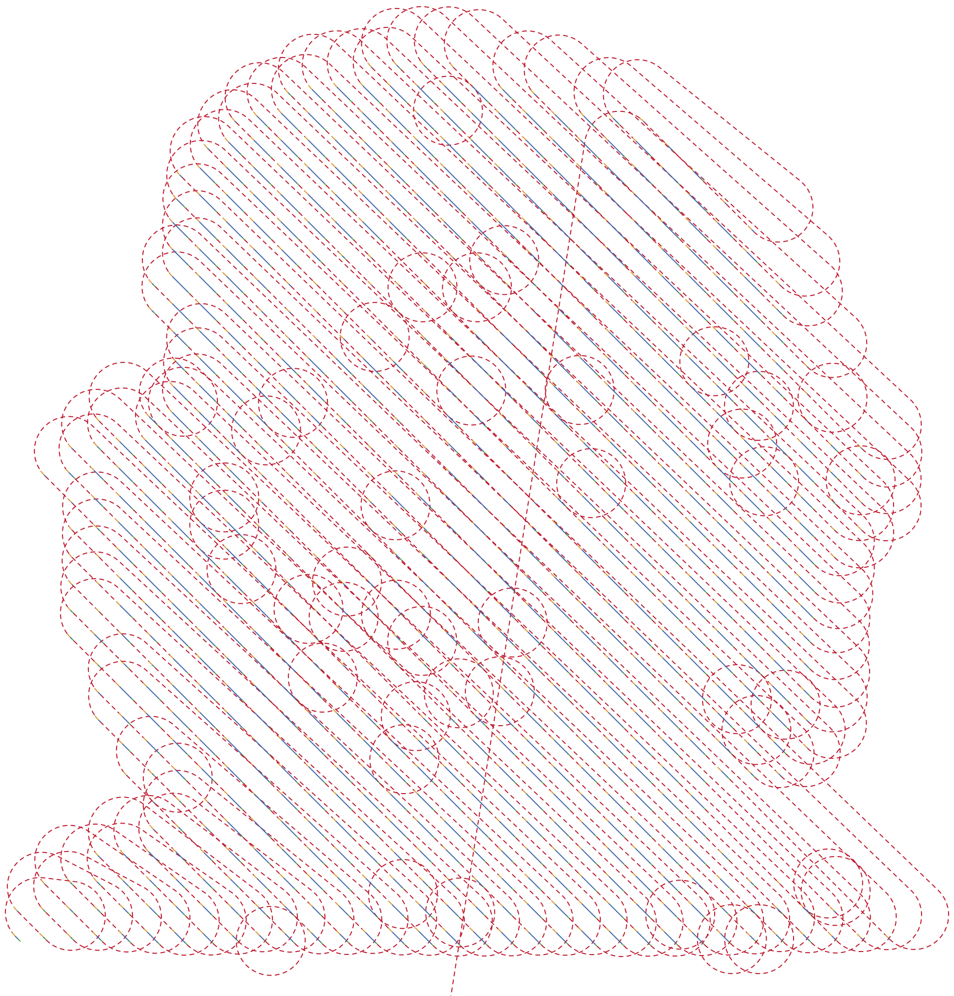


TEST#6: *Result*

TESTING HEKTOR: TEST#7 (CHE)
DATE: 13.09.02

AIM: Try to spray a rastered image with diagonal lines of different length. Diagonal lines have been chosen because they generally seem be more precise in the difficult parts of the sprayable area than horizontal or vertical ones.
CANS: Migros Acryl Aqua Color, RAL 9017, deep black matt
CAP: Standard cap
OBSERVATIONS:
– The path finding algorithm adds unnecessary loops which slow down the whole process.
– Rastered images work very well.
– The result is obviously not sprayed by a human.

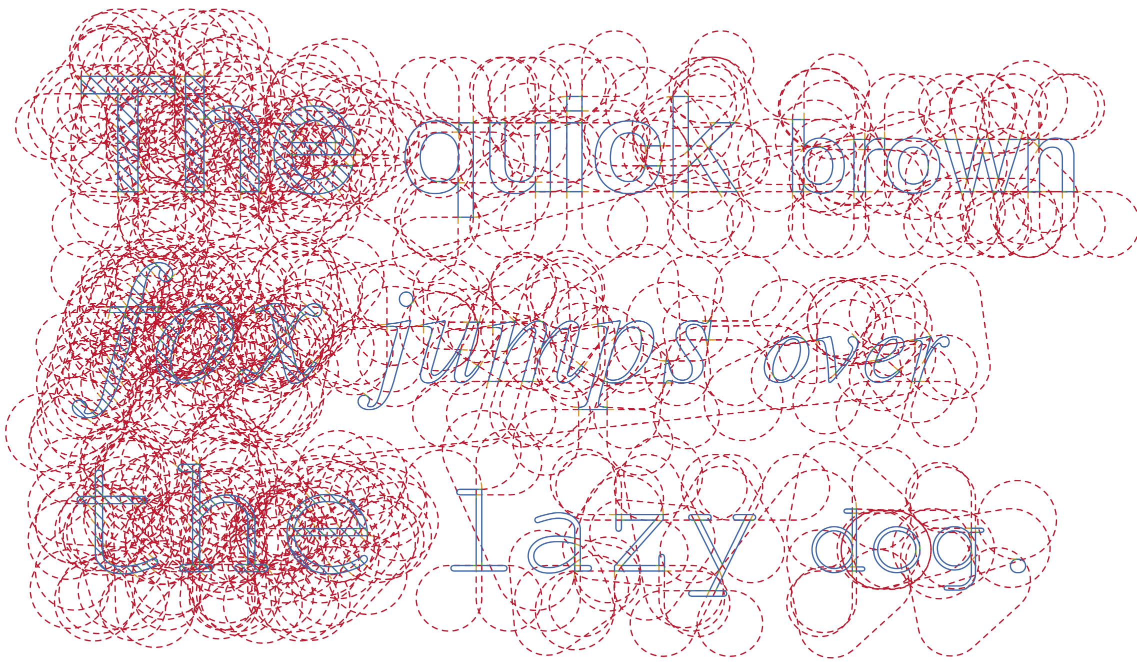




<u>TESTING HEKTOR</u>: TEST#8 (TYPOGRAPHY)
<u>DATE</u>: 13.09.02

<u>AIM</u>: See how well *Hektor* sprays typography. Three different typefaces (*Helvetica Neue, Times, Courier New*) in three different sizes are tested, the words in the biggest size are filled with *Hektor's* filling algorithm.
<u>CANS</u>: Migros Acryl Aqua Color, RAL 9017, deep black matt
<u>CAP</u>: Standard cap
<u>OBSERVATIONS</u>:
– Typography works very well.
– The offset compensation algorithm does not work in all areas: The word *quick* still has offsets, because the can moved very quickly there.
– The lower left and right corner is problematic, the shivering is to strong.
– The filling took to much time because the lines have not been drawn in the right order. Automatic sorting should be added.
– Strong dripping happened in some words, but not in others. It seems to be a problem with the surface and the Migros can.

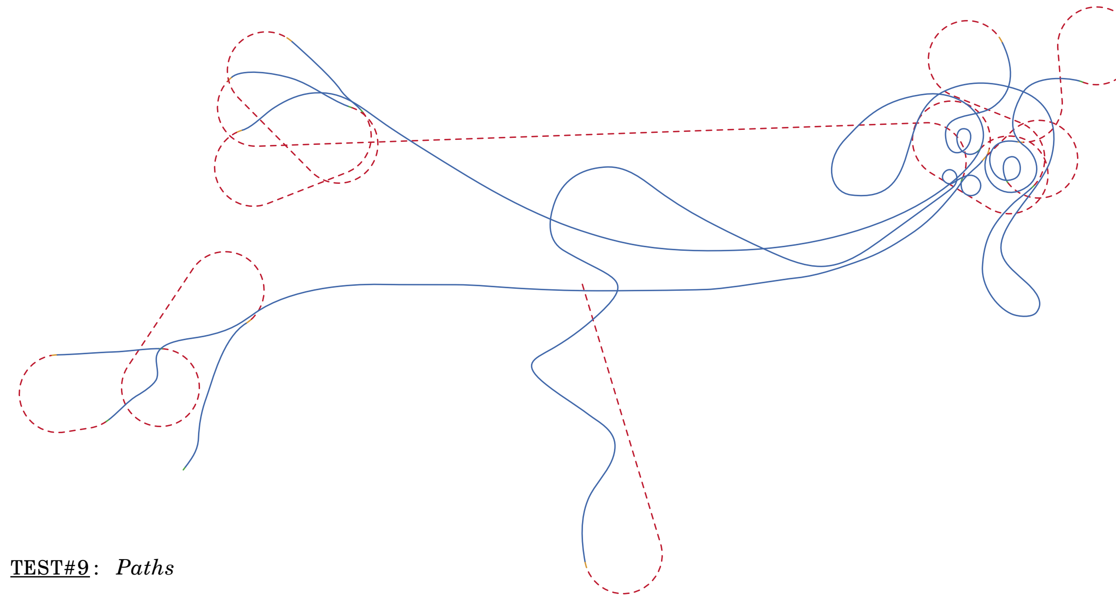
<u>TEST#8</u>: Close-ups of the result


The quick brown
fox jumps over
the lazy dog.


The quick brown
fox jumps over
the lazy dog.

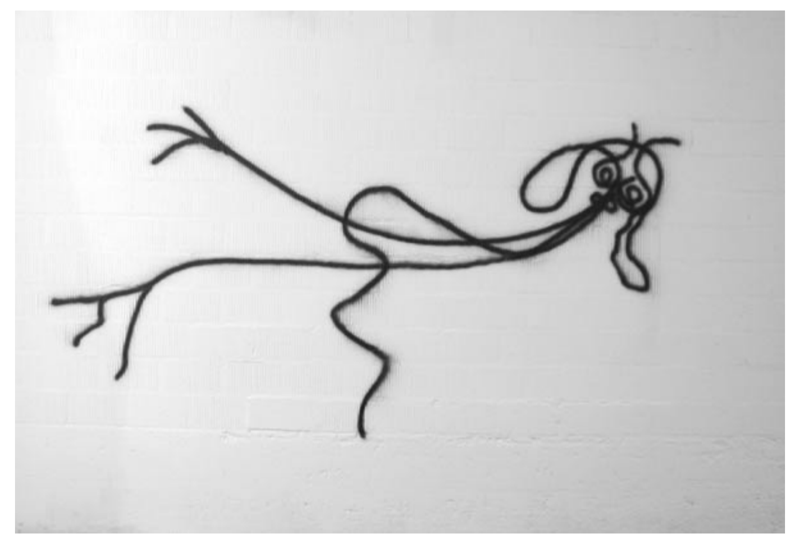
TESTING HEKTOR: TEST#9 (NÄGELI)
DATE: 13.09.02

AIM: See how a human drawing is sprayed. A drawing of Nägeli, the *Sprayer of Zurich*, was chosen.
CANS: Migros Acryl Aqua Color, RAL 9017, deep black matt
CAP: Standard cap
OBSERVATIONS:
- The expression of the original is lost, because the can moves quite constantly.
- *Hektor* adds its own characteristic style, e.g. when shivering while spraying the hair, and mixes it with Nägeli's style.
- No one would notice that it was not sprayed by a human.

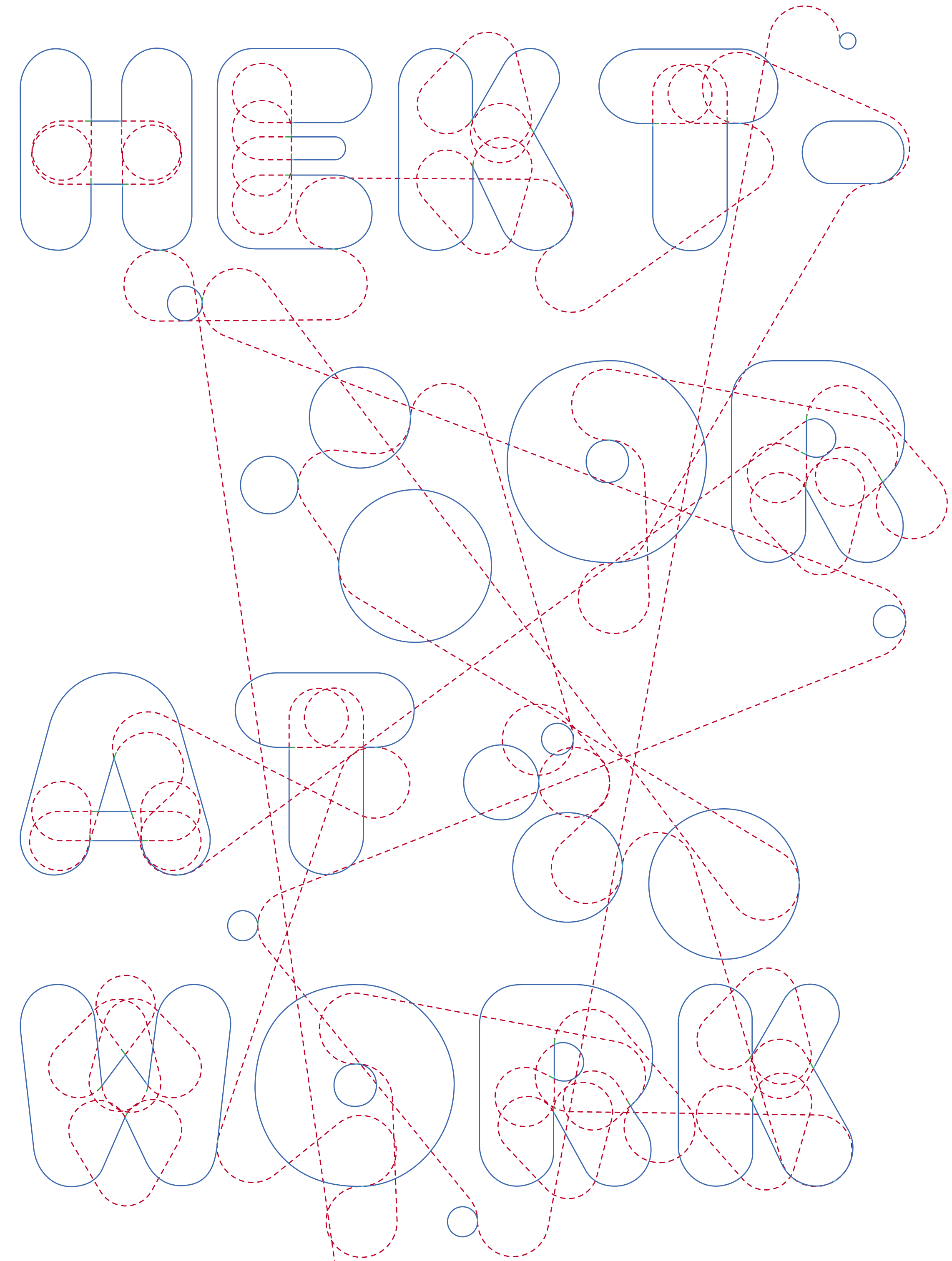


TEST#9: *Paths*

TEST#9: *Nägeli's original*



TEST#9: *Hektor's copy*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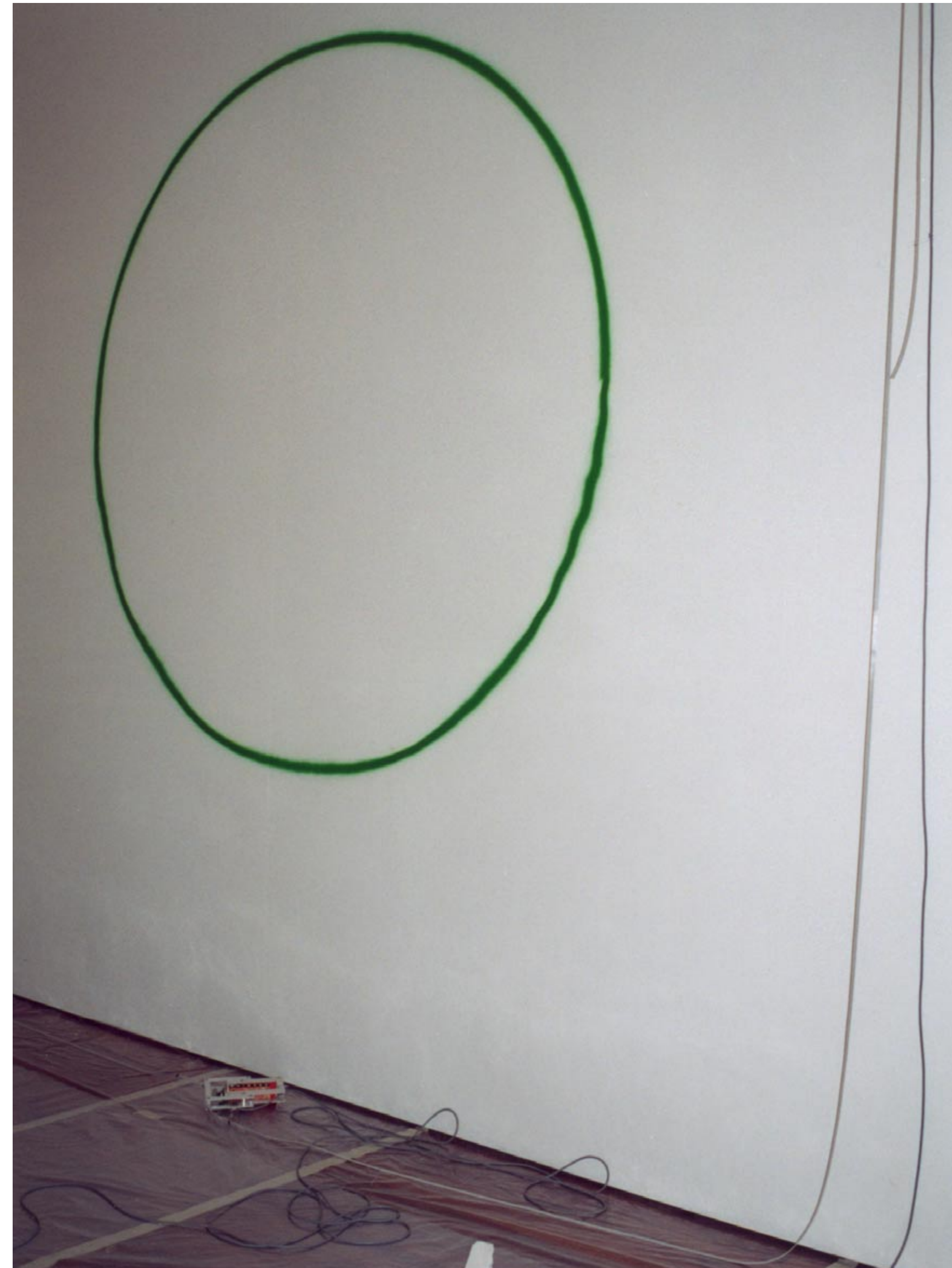
HEKTOR AT WORK: KUNSTHAUS ZÜRICH
DATE: 08.09.02 – 10.09.02

TASK: The work on *Hektor* was hardly finished when Cornel Windlin asked us whether we would like to use *Hektor* to spray one of his contributions to the exhibition *Public Affairs* in the *Kunsthaus Zürich*, a wall painting on a four meter wide and high wall. So just a few days before the exhibitions's opening, we did first tests on that wall and hardly knew what to expect, because it was the first time we were able to spray on a wall of that size. The tests (sprayed in green and red) persuaded Cornel Windlin that the quality was high enough and two days later, after the painters had repainted the whole wall, we sprayed the final piece. This action was also filmed, see chapter *Filming Hektor*.

CANS:
- Belton Molotow Premium 066, juice green
- Dupli Color, RAL 3000, signal red matt
- Dupli Color, RAL 9005, deep black matt

CAPS: Standard cap, Fat cap

OBSERVATIONS:
- Even in this large size, circles and diagonal lines work very well.
- The fake drips on the lower side shivered a lot, even at a very low speed.
- Filling of letters done by hand works better and is sprayed faster than automatically generated filling.
- According to the peoples reaction, *Hektor* could be used as an exhibition piece itself.

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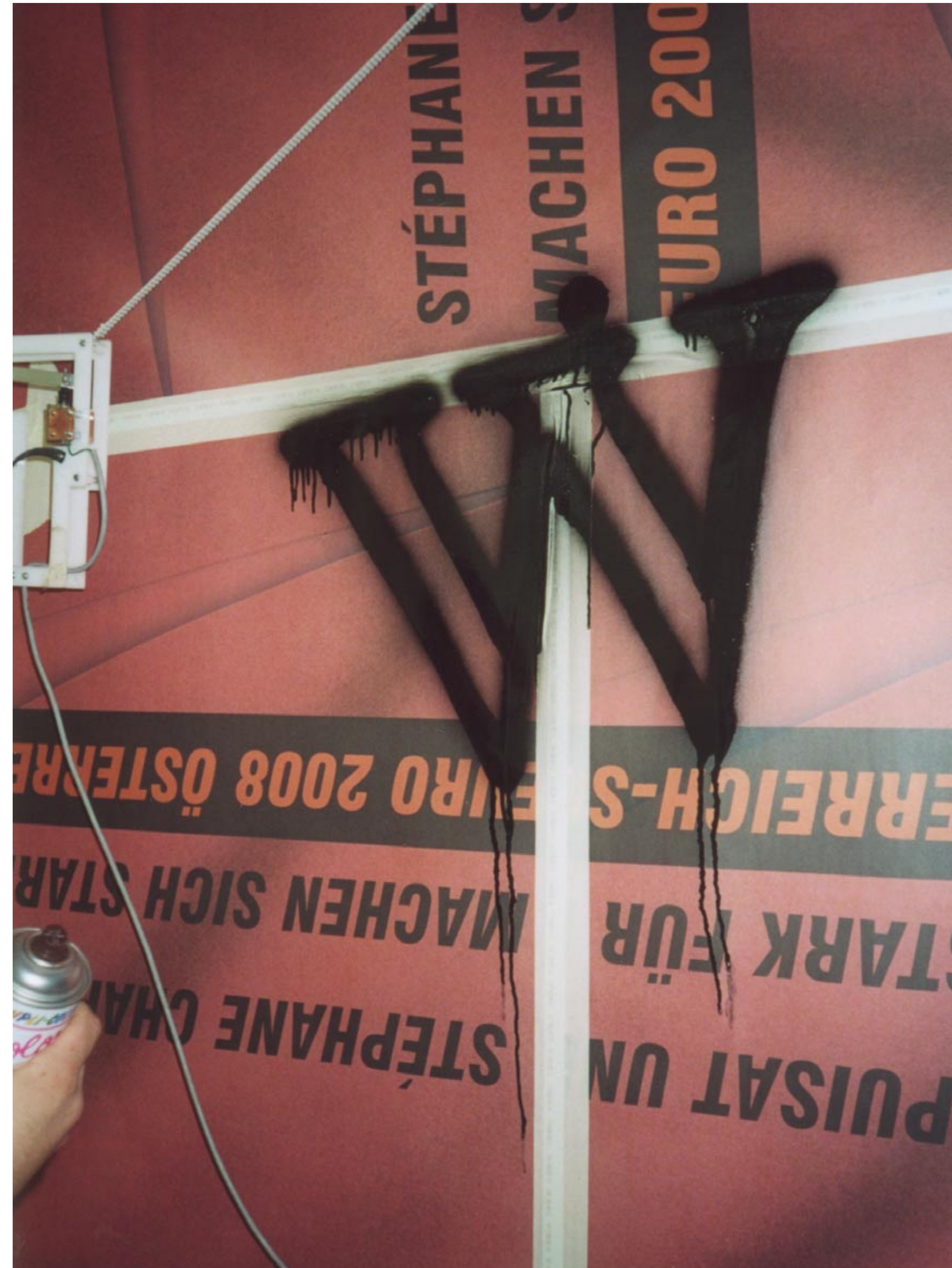
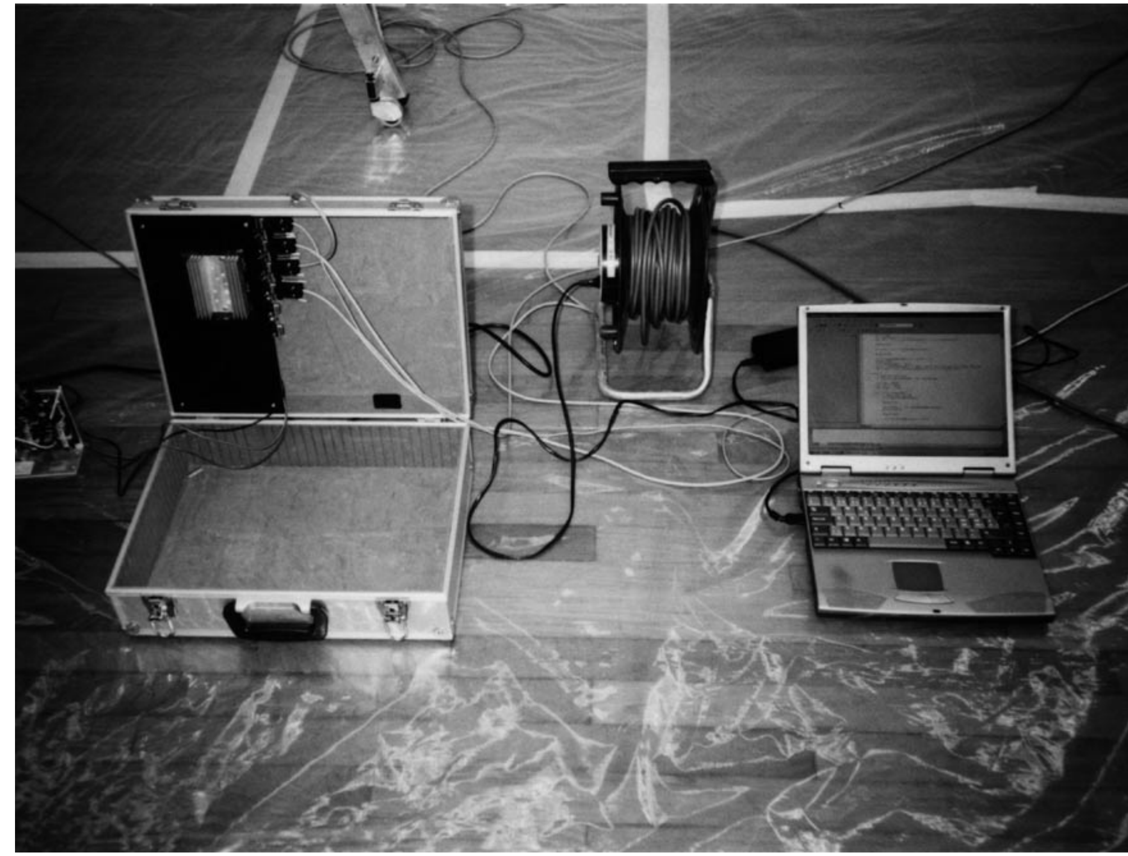
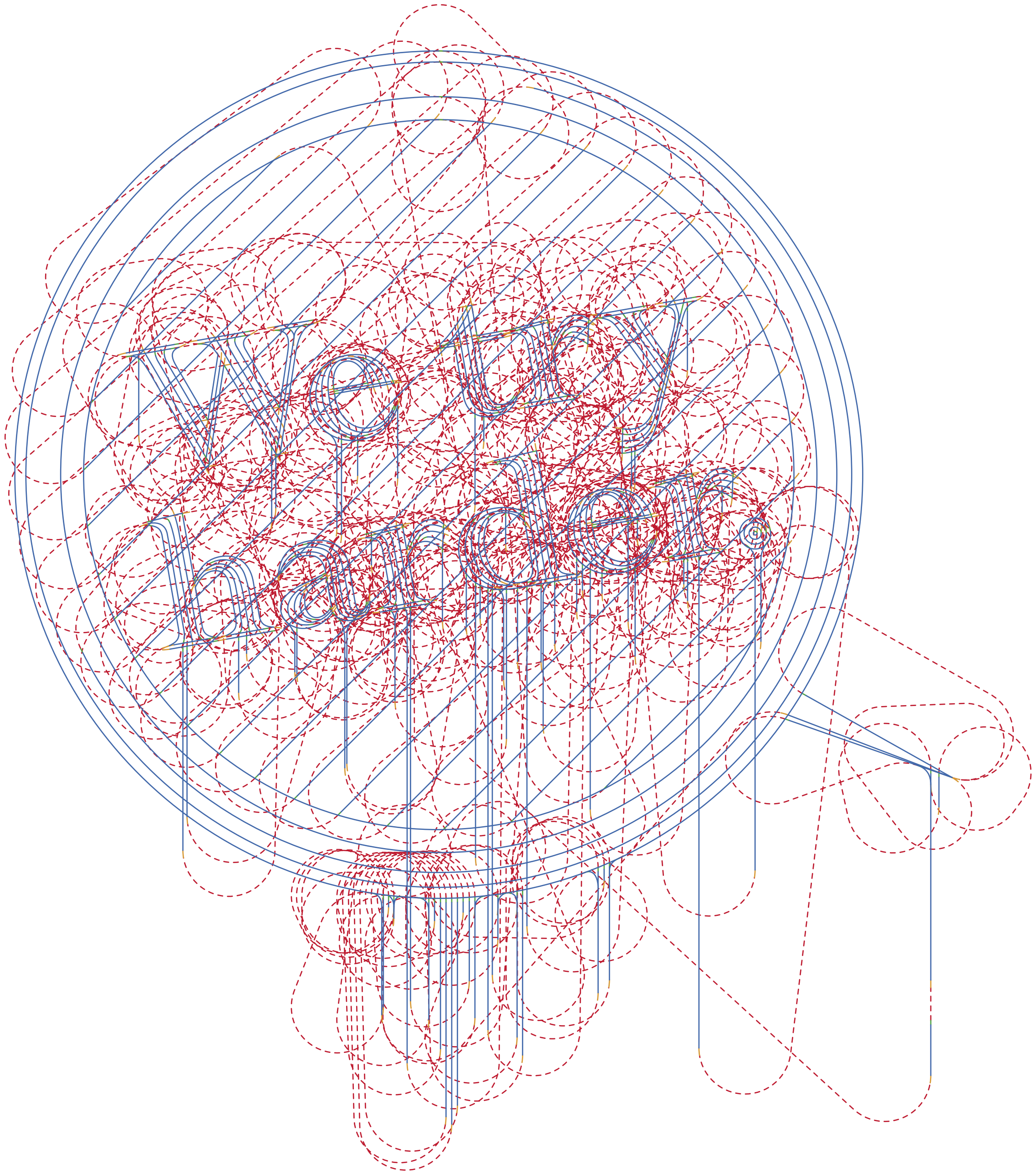
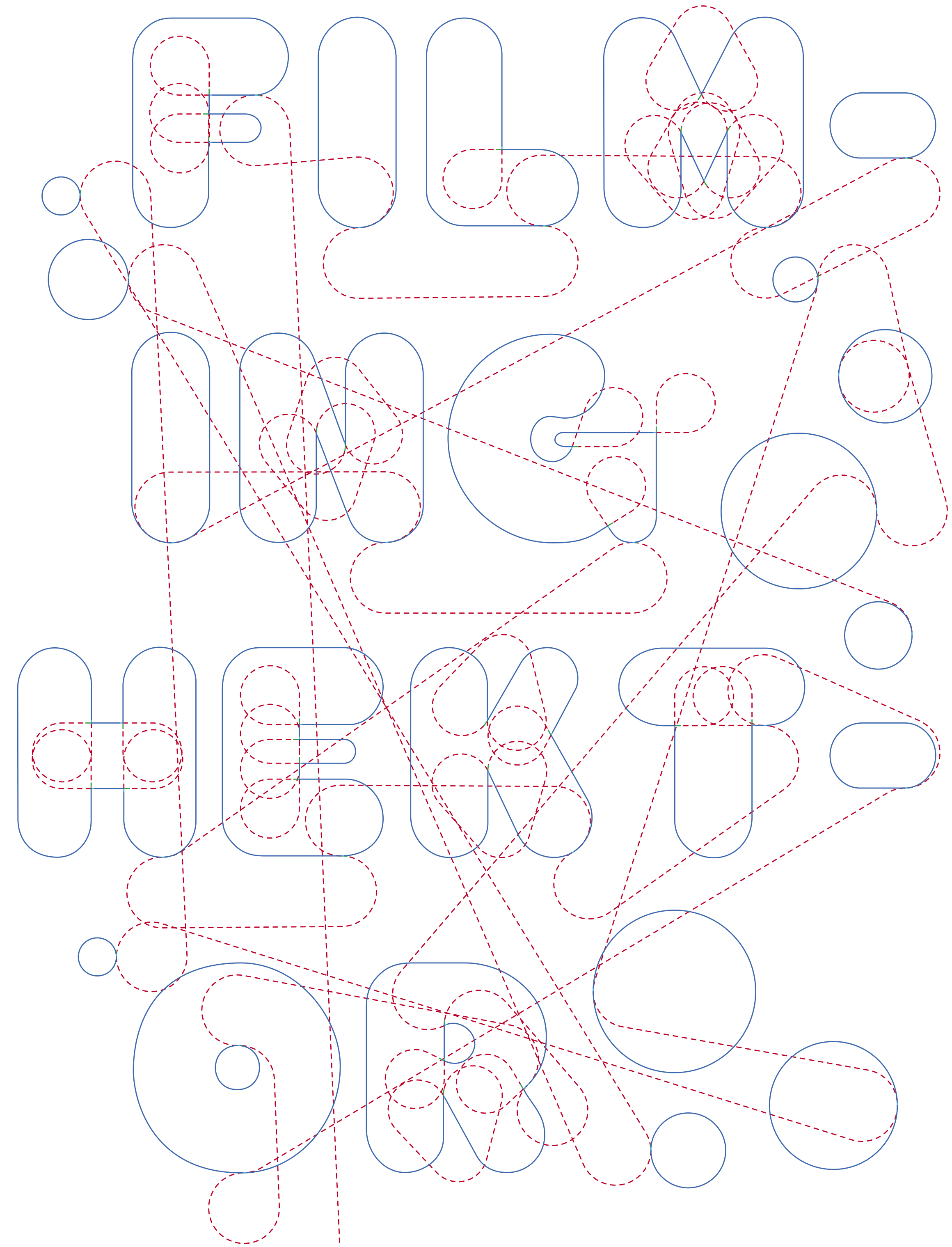
STÉPHANE CHAPUISAT UND C
MACHEN SICH STARK FÜR DIE
EURO 2008 ÖSTERREICH-SCHW


STÉPHANE
MACHEN S
EURO 200






We try
harder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FILMING HEKTOR: HEKTOR IN THE KUNSTHAUS, ZÜRICH
DATE: 10.09.02
