Brushstrokes in the Digital Age

INTERDISCIPLINARY RESEARCH IN PAINTING AND ROBOTICS

by Liat Grayver 2016

A painting robot is the focal point of the collaboration between the artist Liat Grayver and the research team headed by Oliver Deussen at the University of Konstanz. The act of painting is disassembled and deconstructed before being translated into the realm of digital creation, where it is executed by the e-David.

The whole of artistic activity can be described as an instance of self-regulation. Order in painting is traditionally achieved through the self-regulation of the painter and by external intervention. It is necessary to distinguish between— and balance— those characteristics relevant to the realm of individual artistic perception and those that are external to the artist's motives, intentions and preferences.

Printmaking, drawing, painting, photography, generated data and robotic technologies are tools used in my artistic practice to explore, retain and express visual information in relation to the digital and machine-based world we live in today. My work explores the different ways the body and mind perceive not only the visual objects themselves (such as painting), but also the process through which they are created — what is seen as a whole (form) and what is felt as energy (vector).

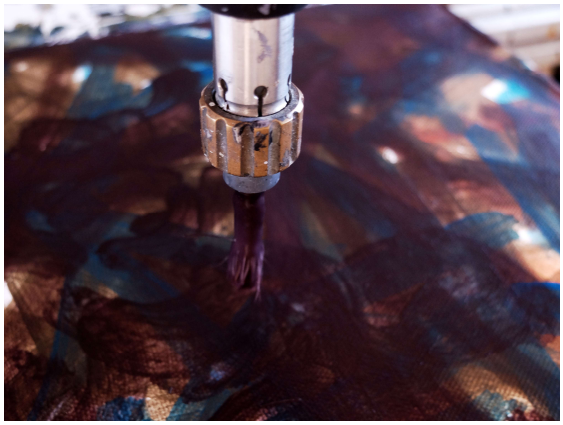


Image 1. Brush operated by the e-David painting robot at the University of konstanz.

During the working process, *passive* materials (canvas, paper, wood surfaces, etc.) react to my *active* manipulation of materials upon them; both the passive and active elements are equally and reciprocally important to the process as well as to the finished work. Using and mixing different media in one work creates a rich context in which I explore the tension between marks that are made with bodily gestures and those made with different degrees of technological intervention. A work may consist of, for example, human and robotic brushstrokes, prints, photopolymer of digital painting and photographs on unmounted canvas.

Putting a mark of paint on a surface is an intuitive gesture that holds within it the *intention* of the work more than it represents the finished image. The finished work narrows down visual information to its essential gestures and primordial symbolism, exploring collective perception, producing and communicating classical and local iconographic characters encountered in the visual and literary domain.

Putting a mark of paint on a surface is an intuitive gesture that holds within it the intention of the work more than it represents the finished image.

Following the completion of my graduate programme in summer 2015 I began to contemplate the general contemporary situation of painting and, more specifically, my own practice. And so for the first year of my post-graduate studies I dedicated myself to the exploration of the technological aspects of painting. I returned to the elementary questions of painting, seeking to reflect on the relationship between image and *objectness* of the medium within the context of our technological era.

The practice of digital image-making represents a new manner by which images can be created whose sources are not derived from painting or photography, but rather arise through the writing of computer code, and are

therefore not based on existing images of things. Such an approach makes it possible to deal with the cultural and psychological implications of our environment through symbols. This particular manner of creating images can of course encapsulate a huge amount of information, emanating from the most diverse sources — for example, fractal models from nature, physical phenomena and mathematical laws — that can then be translated into the visual domain. However, despite the widespread prevalence of digital image-making today, hardly any research has been conducted into the practice of translating images created via a computer simulation into the physical world.

The painting robot developed at the University of Konstanz in southwestern Germany is a pioneer project in this field and is presently the only one with a *visual feedback system*. Much more than just a printer capable of reproducing a flat image, the e-David creates unique works through the application of paint strokes that are irreproducible in terms of their colour blend and the materiality of their layering. The possibility of visual feedback brings up many questions within the contemporary discourse on deep learning, artificial intelligence and robotic creativity.

Images 2a–c. Simulation of an oil paint roller path using the Artrage software (left), 2016; photopolymer print of the simulated oil paint (centre), 2016; dry point and photopolymer print on rice paper mounted on canvas, painted over with oil paint (right), 40 x 50 cm, 2016.

e-David — Robotic Painting at the University of Konstanz

Since October 2015 I have been in contact with Professor Oliver Deussen, who since 2010 has been developing the e-David, a robotic Drawing Apparatus for Vivid Interactive Display, at the University of Konstanz. Subsequent to our first encounter at MIT (Massachusetts Institute of Technology), I visited Prof. Deussen and his team at their lab in Konstanz, so that we could continue to discuss and re-evaluate the potential use of the robot from an artistic and creative perspective. This was followed by an invitation to return to Konstanz for a one-month working sojourn with the robot and the lab team. Over the course of June 2016, I also explored various approaches to integrating computer languages in the processes of painting and creative image-making.

My engagement with the technical conditions of creating images — digital as much as traditional print- and paint-based — has greatly influenced my conceptual understanding of the painterly process in historical and contemporary practices, and has “left marks” on the evolution of my own artistic activities. Stimulated by the experience and by the exchange between informatics and the robotic world, I found myself to some degree compelled to challenge and reconceptualise the foundations of my painterly practice, starting with the bodily movement of the single brushstroke all the way to questions concerning control and loss of control in the creative process.

Working with the e-David

When I first witnessed the e-David at work during a preliminary visit in January-February 2016, I was fascinated by the paths the robot chose to distribute strokes on the sheet, once it began to structure a painting. They seemed to me, as a trained painter, to be illogical and strange, even arbitrary. At the same time, they stimulated a curiosity to understand the logic behind it, and made me conscious of the fact that the particularity of robotic painting is that it permits us to completely rethink in new terms the practice of painting — to paint in a way that no painter would ever consider doing, to engage with decisions about forming and deconstructing an image, and to instigate and explore new approaches to the structuring of the task order in the working process.

On the e-David's working table, there is normally an extra sheet of paper to the right of the painted image (Image 3, right; Image 4). After the robot has dipped the paintbrush in the paint container, it first directs the brush to this sheet in order to wipe off excess paint. Approximately two to three paint strokes are made on this surface (the number can be programmed) before the robot continues working on the actual painting (Image 3, left). Right from the start I could perceive a complex pattern on the "abstract" sheet without really *recognizing* anything.

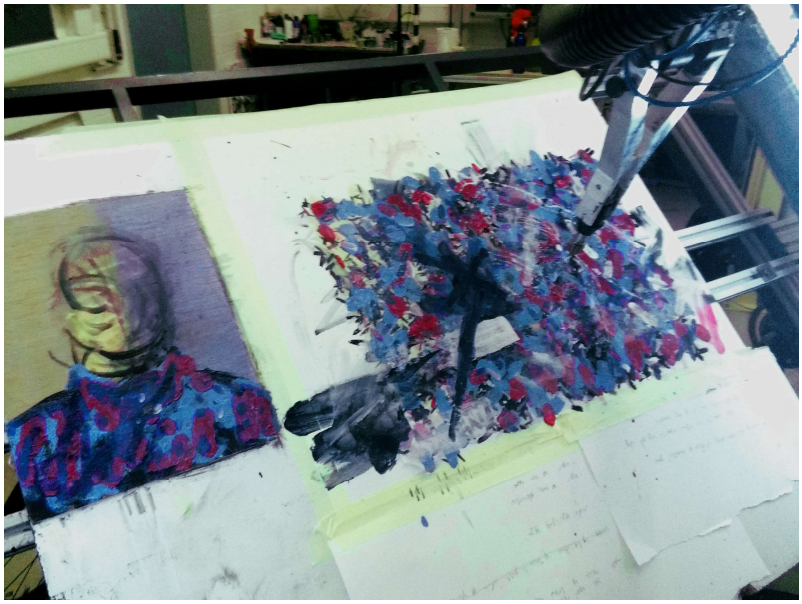


Image 3 (left). The e-David at work. Sheet on which excess paint is wiped off of the brush (right) and the actual painted image (left), June 2016.

Image 4 (right). Paint strokes to wipe off the excess paint from the brush. All strokes have the same parameters of size, position, stroke length and direction, but are the result of a "random" location algorithm. The colours correspond to those used in the painted image. Acrylic on paper, 60 x 40 cm, January 2016.

The characteristics of the residual paint sheet's visual construction inspired me to investigate chaos and order (entropy in visual creation), as well as to focus my work on control and loss of control in robotic and traditional painting.

While working with the e-David, I responded to and worked creatively with both of the sheets equally — the actual "image" as well as the sheet with the residual paint. In order to reinforce and underline the random factor in visual chaos, I splattered paint drops from a brush and added gestural brushstrokes to the painting that was created as a result of the programmed random algorithms (Image 5).

Image 5. *Entropy N1*-generated robotic brushstrokes using intuitively chosen and manually installed paint colours, and hand-applied splattered paint drops, glaze and gestural brushstrokes. Acrylic on paper, 95 x 80 cm, June 2016.

Collaborating with Professor Deussen and his PhD candidate Thomas Lindemeier, I then explored further possibilities to exploit the painting robot creatively, and reflected on ideas about the ways in which these could be implemented in the form of software and hardware. A number of questions of wider impact arose as the result of our collaboration: When and why would a semantic method of defining the object in the image be used? Is it an advantage or a disadvantage to paint semantic objects without having a pre-existing cognitive understanding of them? How could I use abstract forms, grammatical structures or mathematic models to achieve more complex surfaces? How would computer language be used to express the intentions of a composition? When and why would different painting styles be used?

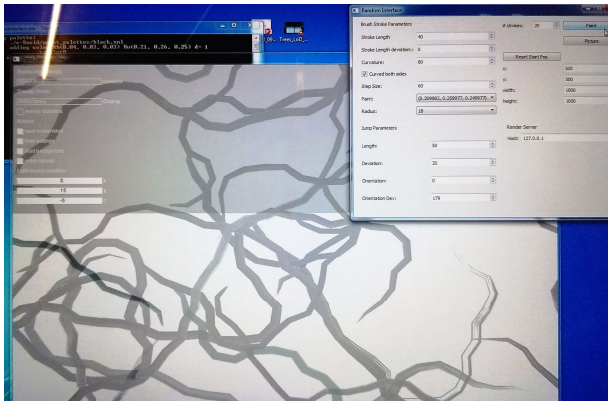
Further, on a technical level, we had to take into consideration how different materials would react with one another. For example, how could different colours be mixed on the canvas or on the palette? How should the size of the brush be set, and when is it necessary to add glaze? We would have to develop a range of distinct, individual brushstrokes (controlling the velocity and the *z*-axis) whose characteristics are analogous to those made by human painters in the "real world", in order to be able to pre-define when, in which order and for which tasks each stroke is to be used. In doing so, we are basically defining and categorizing singular parameters within a library of painterly "acts" and "perceptions", in order to create a grammatical structure for the "language" of robotic painting.

All of these questions — qualitative technical aspects, creative and æsthetic value, etc. — would need to be defined by the team and saved in the visual feedback of the robot as parameters, as *rules*. This led us to questions of control: To what degree should the robot's actions be controllable by humans? Should the robot make autonomous decisions? If so, at what stage? How would we evaluate the output of the robot (with such binary values as good/bad, or yes/no?) and how would these evaluations be saved to its memory such that the e-David would be capable of using this information "correctly" so that it could make new decisions about its actions in the next run?

Image 6. Exhibition view; "Pinselstriche im digitalen Zeitalter Interdisziplinäre Forschung in Malerei & Robotik" at the Halle 14, Februar 2017 Spinnerei Leipzig. Liat Grayver and e-David Team.

Making Abstract Painting: Thinking in Vectors Instead of Pixels

At the beginning of my sojourn in June 2016, I observed the e-David's painting process for object-oriented (realistic) images, and intervened in the mechanical aspects of the process — changing brushes, paint viscosity, colours, etc.—to observe the robot's reactions, informed by the visual feedback process. It seemed to me that the operation reflected more of a drawing character than painting — e-David constructed the image in a pointillistic manner, using short strokes that resembled pixels, and not out of surfaces and vectors (Image 14). I wanted to change this approach and therefore decided to paint images using complex surfaces composed through looped strokes with varying degrees of randomness.



With the notion of constituting a vocabulary of brushstrokes, I spoke with Lindemeier and asked him to write an appropriate programme for it (Image 7). With the help of this programme it became possible to control the parameters of the paintbrush and the level of chaos and order in the output. Once the parameters in the programme were set, I could manage and evaluate the preliminary results in the simulation shown on the computer monitor, before actually sending the command to the robot.

I then painted the series *Just Before it Snaps* of abstract images using this programme (Images 9–10). The resulting images are investigations into abstract thought and experimentations with composition as energy fields that were configurations of vectors (Rudolph Arnheim's study on composition in the visual arts). I was looking for the places or "border areas" in which the balance between *coincidental* and *intentional* brushstrokes created harmony on the visual surface.

Image 7. The painting programme GUI, showing the simulated brushstrokes, brushstroke parameters (XY starting position, stroke length, stroke length deviation, curvature, step size) and jump, or node, parameters (length, deviation, orientation and orientation deviation Image 8. Exhibition view; Brushstrokes at the Digital age", Fresh Paint art fair. Museum for Natural History Tel Aviv, 2017.

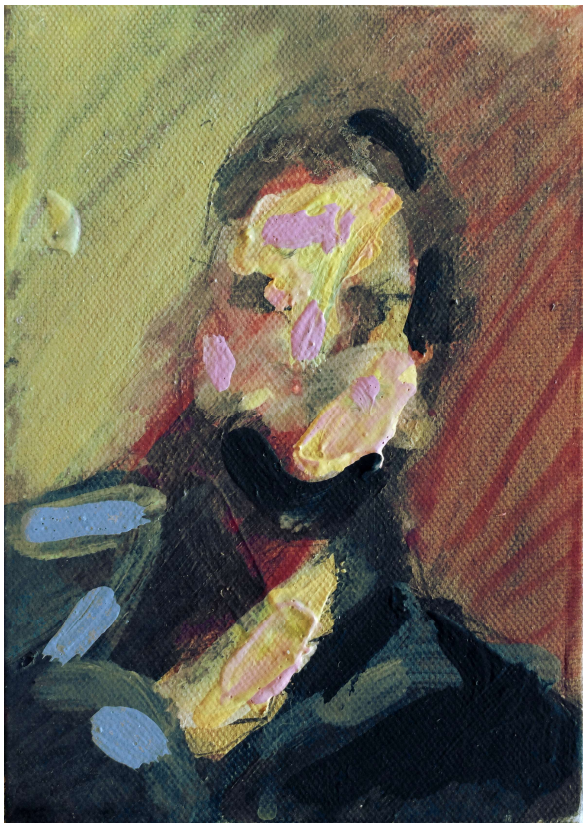
From another point of view, these images functioned as experiments to test out the different painting materials the lab had been using. Normally, while painting, the materials are controlled by the painter in a sort of interactive “ping-pong” situation. With the e-David robot this is not, however, the case, as *all* of its actions must be predetermined and given to it as commands. The robot does not, for example, notice if the paint is dripping or has dried out. And it is exactly this kind of thing that fascinates me, because it stands in opposition to “normal” thinking and allows for the emergence of new, uncontrolled and surprising brushstrokes!

Images 9 (left) and 10 (right). Just Before it Snaps N.5 & N.1; Robotic paintings created at the end of my first working sojourn. Acrylic on canvas, each 30 x 40 cm, June 2016.

Portrait Painting Using a Robot

In the final days of my first working sojourn at the University of Konstanz, Lindemeier and I decided to paint the first portrait again, but using the new learned and programmed brushstroke information. We decided to use a zigzag path. Instead of a semantic, object-oriented method (as with the first attempt, Image 14) that divided the photo into thematic painting layers and sectors (shoulder, head, mouth, eyes…), I structured the image in the form of large colour surfaces that reflected the composition: shadow and light, coldness and warmth, transparent and obscure paint layers and sectors (Image 15).

I mixed the necessary colours in advance and place them in the robot's paint containers. In this case, we didn't yet programme the robot to autonomously choose the paint containers, but rather exchanged them manually between each colour layer. (In the future we plan to use the visual feedback loop of the system in order to leave the decision to the robot about which of a predetermined selection of paint containers to use.) I decided this time to work with three colours — green-yellow, blue and red — with each colour in three tone increments — light, dark and transparent. I used a large, round brush that was in the lab at that time, in order to simplify the detail of the output — more colour fields as opposed to dots. The painting was mostly done using the same brush size; however, at the end of the process I outfitted the e-David with a smaller brush to lay in a few dark accents.



Images 11 (left). Sketches of the portrait photo in my sketchbook. Pencil crayons on paper, June 2016.

Image 12 (right). Colour study for the portrait painted by the artist. Acrylic on canvas, 10 x 15 cm, June 2016.

The stylistic difference between the two paintings is immediately apparent (Images 14 and 15). Both paintings were extracted from the same photo but implemented quite differently. Each image transmits the visual information in a completely different manner. One is characterized by semantic forms reflecting a high level of control, the other by abstract forms with a very low level of control.

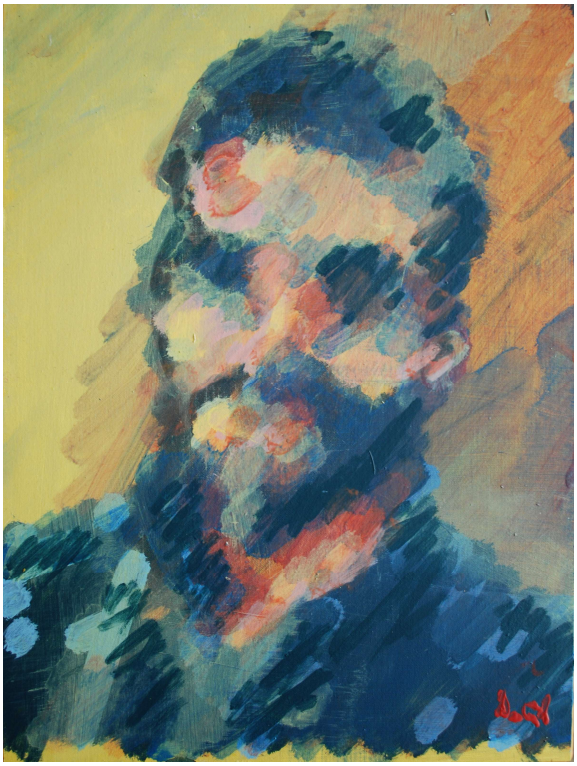


Image 13 (bellow left). Digital photo, edited with Photoshop.

Image 14 (left). Robotic painting created at the beginning of my working sojourn in June 2016. Acrylic on canvas, 30 x 40 cm.

Image 15 (right). Robotic painting created at the end of my working sojourn in June 2016. Acrylic on canvas, 30 x 40 cm.

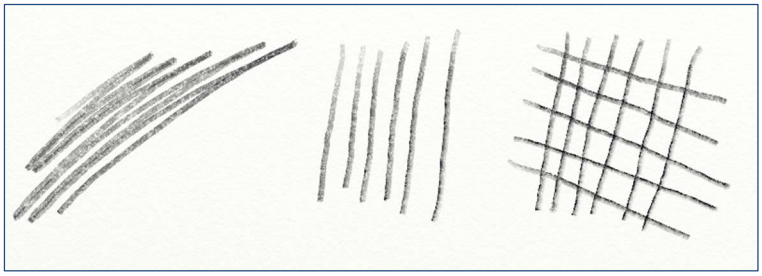
Grouping Singular Lines into Forms Using Nodes and Centre Points

In November-December 2016 I returned to the University of Konstanz to undertake another working sojourn in order to continue to develop the research begun in June 2016. The early abstract works done with the e-David (Images 9 and 10) in June 2016 were programmed such that it would treat the entire surface of the painting equally (overall composition). Singular lines were used to construct the paintings, with each new line created according to given (programmed) variables. The first line is positioned according to a pre-determined starting point, and the location of each subsequent generated line is calculated in relation to the line painted before it. While working on the portrait we had already introduced into the system a strategy of dividing the painting into *masks* of colour areas using brushstroke patterns — *sets* of individual brushstrokes — in contrast to an approach using singular strokes. Masks are applied to fill in a section one colour at a time, according to pre-defined light and shade characteristics. The computer generates a set of strokes that are connected or related to each other due to their *proximity of action*, corresponding to the painter's bodily movement when performing similar tasks.

I created a set of paintings using limited sets of zigzag and straight lines, as well as a grid pattern formed by intersecting brushstrokes (Image 14). In order to give the patterns an organic and complex surface feel, and to break the precision and mechanical appearance of the repetitions, I defined the specific character for each set according to the following parameters: orientation of the set, curvature of individual lines within the set, centre point of the painted masks, angle of the meeting point of the two lines, number of strokes, and proximity between lines— all of which are subject to a degree of randomness.

This grouping of lines into blocks of paint enabled me to incorporate the concept of a *centre point* as a parameter for the computer when generating a painting. This way, the brushstroke patterns are generated to be located either around or emanating from a pre-defined position (Image17).

In order to avoid the creation of a closed composition with poor visual tension, I defined several centre points in a single painting. By experimenting with different colours and brushstroke characteristics (settings), the centre points can be made to support each other as visual *nodes* in the painting composition (Images 18 and 19).



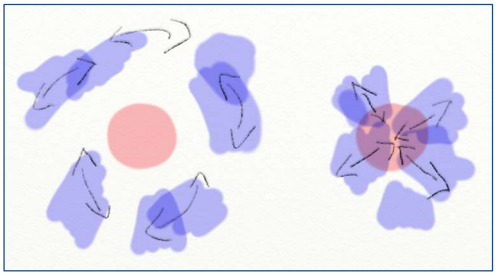
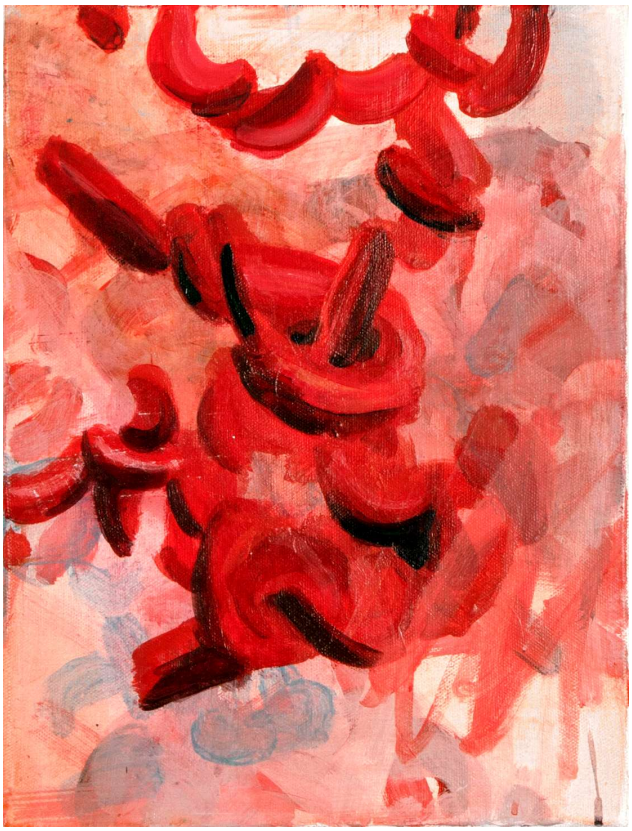


Image 16 (left). Preliminary illustration of brushstroke patterns: zigzag, straight lines and grid.

Image 17 (right). Preliminary illustration of brushstrokes located in relation to centre points.



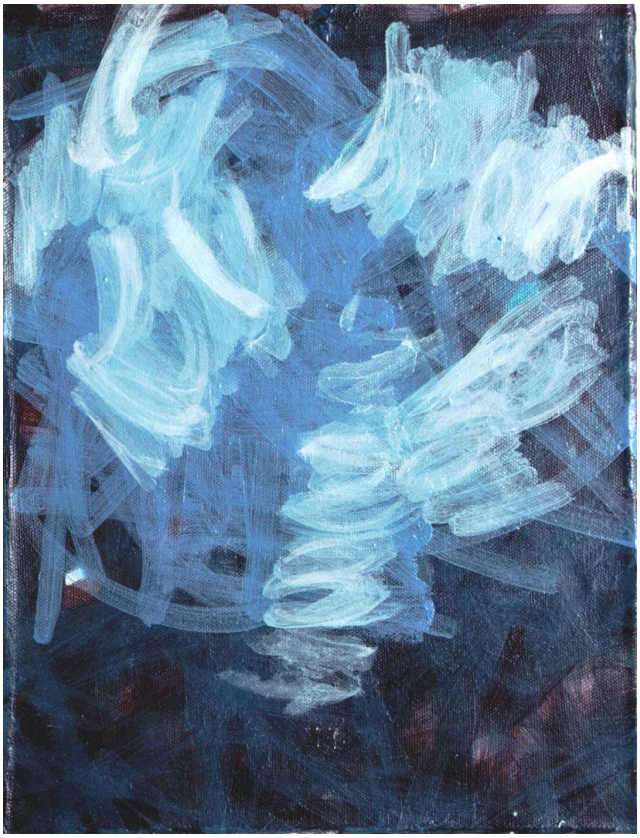


Image 18. *Resisting Gravity in Red*; Painting generated with lines oriented around several centre points. Acrylic on canvas, 50 x 40 cm, October-November 2016.

Image 19. *Resisting Gravity in Blue*; Painting generated with the use of brushstroke patterns and centre point. Acrylic on canvas, 50 x 40 cm, October-November 2016.

Image 20: Exhibition view: PENDORAN VINCI. Art and Artificial Intelligence Today, curated by peer to space, 2018, at NRW Forum Düsseldorf, photo © NRW-Forum Düsseldorf / Bozica Babic

Perception of Brushstrokes Made by an Unconscious Body

Saving information in the painting process and creating, when needed, a distance between the painter and the painting (the painter is simultaneously the viewer and the executer) are two features that computer- and robotic-based painting offers the artist. As a painter and a consumer of art I wondered if I would be able to recognize brushstrokes done by a robot in a more complex, generated work. I wanted to play with this idea by generating strokes that appear gestural but are executed in a way that only a machine is capable of doing, namely, with *exact* repetition.

Six Variations on Gestural Computer-Generated Brushstrokes, done in October-November 2016, is a series of computer-generated sets of brushstrokes that reflect the quality of spontaneous hand movement inspired by the practice of Japanese calligraphy (Image 21). Using the e-David, I repainted the same generated path again and again, each time on a new canvas, knowing that this kind of exact repetition of movement could never be achieved by a human hand.

Each of the four variations is an execution of the same path with an identical velocity. The works are, however, varied and can be distinguished from one other due to the use of different brushes and changes in the value of the colour, as well as variations in the viscosity of the paint and the number of times the robot was instructed to load the brush with new paint.

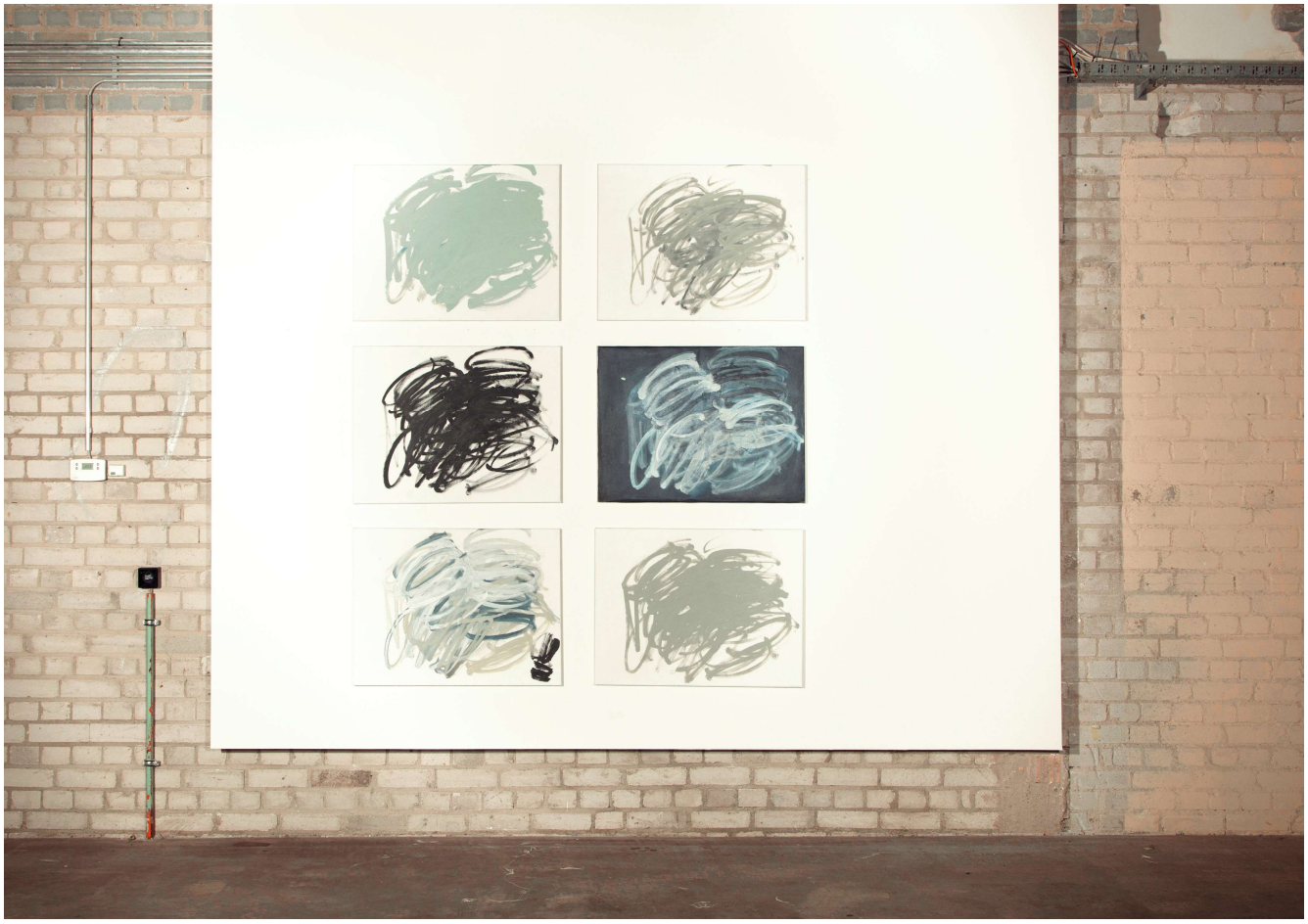
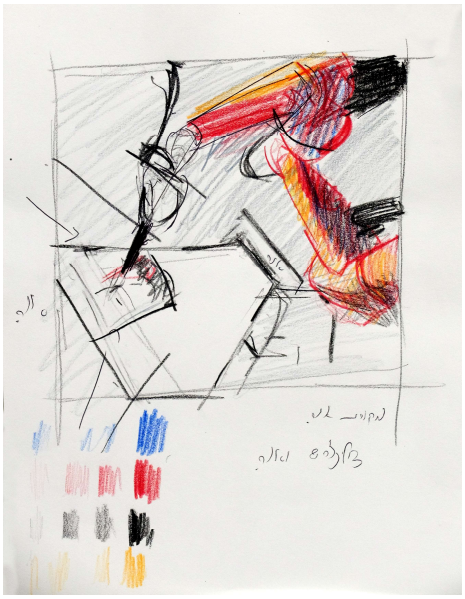


Image 21; Exhibition view; “Pinselstriche im digitalen Zeitalter Interdisziplinäre Forschung in Malerei & Robotik“ at the Halle 14, Februar 2017 Spinnerei Leipzig. Liat Grayver and e-David Team.

For *a Repetition of a Gesture* (Image22), I used the same generated path as in *Four Variations on Gestural Computer-Generated Brushstrokes*, but applied the repetition using a layering method. Sometimes the paint didn't have enough time to dry, and so instead of the brush applying a new layer of paint, it actually scraped some of the paint off the canvas, creating some surprising and pleasing surface effects. To distinguish the layers from each other and to give the painting some visual depth, I applied different painting techniques (glaze, colour variation, viscosity variation) and juggled with the information saved on the computer — for example, stopping the robot and restarting it at different points in the process, breaking and reassembling the loop action into fragments.

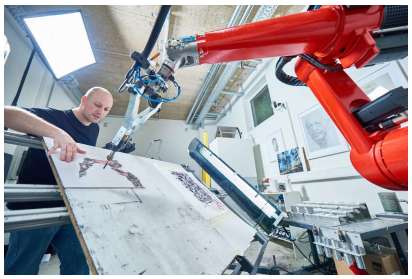
Image 22. A Repetition of a Gesture. Acrylic on canvas, 60 x 80 cm, October-November 2016.

e-David Self-Portrait



Painting is a practice in which a complex architecture is constructed of separate sections that interact with each other as a whole in the form of a unified composition. While working on the *e-David Self-Portrait* (Image 27), I became aware of the need to divide the painterly process into different categories, looking into the different paths of the physical act (characteristics of individual brushstrokes) and cognitive decisions (semantic vs. abstract recognition of geometric forms) that the painter uses in the process of decomposing and reassembling visual information and material elements into a painting. More than that, the ability to save each step in the painting process, to compartmentalize and conglomerate information and action in different constellations, opens up a new field in the painting domain, which explores the *space between* abstract and figurative painting.

The *e-David Self-Portrait* is based on a photograph of Lindemeier working with the robot in the lab (Image 21). I first made a colour pencil sketch based on the photograph, incorporating various decisions about perspective and composition (Image 23). This sketch was then used as a reference to prepare a working image on the computer using the image editor Gimp (GNU Image Manipulation Program). I deconstructed the photographic image into areas delineated by *masks* that were, in contrast to the colour field masks of the previous portrait, defined by geometric forms (Image 25). During this stage, I rearranged and manipulated the structural elements, namely the geometrical forms (as opposed to semantic, recognizable objects, or definitions of colour) to create the final working image that the e-David would use to create the painting. Finally, using both the source image and the sketch as references, I continued to create the masks and programme the brushstrokes interactively during the execution of the painting. This made it possible to have each individual mask executed with a different colour and an appropriate set of brushstroke patterns. This layering, combined with the incorporation of the colour fields into the geometric masks are what allowed us to develop a degree of depth in the painting that we had not previously been able to achieve (Image 26).



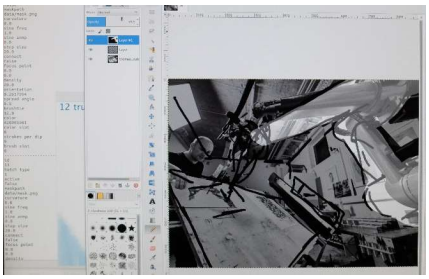


Image 23 (above, right). Sketch for the e-David Self-Portrait. Colour pencil on paper, 21 x 30 cm, November 2016.
Image 24 (left). Photograph used as a source for the e-David Self-Portrait. November 2016.
Image 25 (centre). Breaking down the source photo into masks using Gimp.
Image 26 (right). Brushstrokes pattern in the computer simulator before the command is sent to be executed by the e-David

Image 27. *e-David Self-Portrait*. Acrylic on canvas, 60 x 80 cm, November 2016.