Performatively Materiality

A DrawBot for Materializing Kinetic Human-Machine Interaction in Architectural Space

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This paper presents an exploration of movement as a design material to evidence human-machine interaction in an architectural space. An autonomous robotic vehicle with environmental sensory capabilities interacts kinetically with people by recognizing their emotional states from their body postures. A drawing device installed in the vehicle leaves a trace on the floor as a material testimony to the mutual dynamics. The complex yet surprisingly intuitive choreographic interaction of the machine and its social and physical environment blurs the boundaries between drawing, machine, and performance. In general, the project conceptualizes movement as a design material, drawing as a performative action, and social interaction as a physical force, all of which can be enhanced or mediated by digital technologies to produce results with aesthetic value.

Keywords: Human-Machine Interaction, Drawing Machine, Performance Design

INTRODUCTION

Automatic drawing machines are mechanical devices that produce drawings by moving pens or other drawing instruments along predefined paths or patterns. Their captivating appeal lies as much in the aesthetic qualities of the intricate outcomes as in the rhythmic and hypnotizing movements generated by the drawing process. While traditional drawing machines - such as the popular Spirograph toy - rely solely on harmonic movements driven by physical forces, contemporary drawing machines take full advantage of electronics and computer technologies to expand the range of movements, driving forces, and outcomes. Digital technologies allow drawing machines to be responsive and interactive with their surroundings, transforming the drawing process from being a predetermined fixed result to being a negotiated action between the machine and its interlocutors. As the interaction increases in complexity, the boundaries between artifact and performance become more blurred.

Inspired by the beauty of traditional drawing machines, and motivated by the opportunities of contemporary human-machine interaction technologies, this project starts with the aim of producing a machine that uses the complexity of human behavior and initial environmental conditions as driving forces to produce drawings in architectural spaces.
Particularly, we present an autonomous robotic vehicle capable of interacting kinetically with its social and physical environment in a mutually conditioned relationship. The vehicle, equipped with multiple sensing capabilities, can detect the physical and geometrical characteristics of its surrounding space, and also communicate with humans by recognizing their emotional states through their body postures. Based on these environmental and social conditions, the vehicle moves autonomously but responsively, leaving behind a mark on the floor produced with a drawing tool. Thus, there is a dialectic relationship between the vehicle and the human in which the movement of one affects the other, conditioning each other in an unintuitive way that forces both to explore space. While the movement is futile, the trace remains permanently imprinted on the architectural space as an aesthetic vestige of the choreographic dialectic of the performative experience. This project re-conceptualizes movement as a design material, drawing as a performative action, and social interaction as a physical force, that all may be enhanced or mediated by digital technologies to produce outcomes with aesthetic value.

BACKGROUND
Re-thinking Drawing Machines
Automated drawing machines most likely originated in the fifteenth century, motivated by the revolutionary advancements in mathematics, geometry, mechanics, and arts of the Renaissance. Examples range from the simple ellipsographs and pantographs, to the lesser known helicographs (for volutes and spirals), antigraphs (for mirrored drawings), and cyclographs (for arcs and circles). Conchoidographs and cycloidotropes (for roulettes) -the antecessors of the famous Spirograph toy- and harmonographs and pendulographs (for harmonic oscillatory movements) were more complex apparatuses developed soon after (Garcia, 2013). In general, these devices are based on stationary mechanisms that follow predefined cyclic movements determined by physical forces, such as harmonic pendulums. Their graphic outcome is highly determined by the mechanical behavior with little space for interaction with the human operator. In fact, the relationship between the machine and the operators is static and unidirectional, determined solely by the expert’s control over the device.

Contemporary digital technologies offer an attractive opportunity to revisit these devices and explore other drawing driving forces that transcend the merely mechanistic. For example, Newswanger (2012), Howsare (2012), and Clarholm (2014) developed devices based on traditional drawing machines, but taking advantage of electric motors and computer numerical control (CNC) systems. A slightly more radical innovation can be observed in the hanging devices designed by Noble (2011) or Bynoe (2013), who utilized Arduino boards and the full range of contemporary electronics to create devices capable to draw with fine precision, but at the same time, to interact closely with their users.

A substantial different approach was taken by a number of artists who explored the potentials of wheeled robotic devices as drawing machines. The vehicles are typically built with two wheeled servomotors controlled by Raspberry Pi or Arduino boards and attached pens or brushes. Some of them move following a predefined scripted pattern (Pigford 2013) and others incorporate sensors to react to external conditions (Adenauer & Hass 2011). To us, this added capability -reacting to environmental conditions including people- is a revolutionary break-point that completely redefines the idea of drawing. By transforming the drawing machine into a responsive device, the value of the drawing lies no longer only in the aesthetic attributes of the outcome, but also in its representational meaning as physical record of an experience of interaction between the machine and its environment.

**Kinetic Human-Machine Interaction**
The terms Human-Machine Interaction (HMI) and Human-Computer Interaction (HCI), were coined to describe the study of how people communicate and
interact with machines and computers (Card et al. 1983). As an extension, kinetic human-machine interaction refers specifically to systems for which movement is the language of communication. In recent years, this approach has attracted the interest of architects, designers, and artists, who see an appealing opportunity for exploring the relationship between body, movement, and space in creative and expressive ways (Fogtmann et al. 2008, Jensen 2007, Larssen et al. 2007, Levisohn 2011, Loke and Robertson 2009, Moen 2007).

Current technology allows for a wide range of kinetic interaction, both gestural and full-body. A common approach is using optical technologies that capture light data (video, infrared, etc.), which is then analyzed for differences in time that may indicate movement. An archetypical example is the Kinect, a motion detection device originally intended as a peripheral for Microsoft Xbox 360, but which is widely used in interactive installations (Caon et al. 2011, Kang et al. 2011, Shiratuddin and Wong 2011, Cheng et al. 2012). A different approach is the use of position sensors (accelerometer, gyroscopes, tilt sensors, etc.) to capture spatial data which is then analyzed for patterns that may indicate movement. Depending on the level of precision and complexity required for the kinetic interaction, this approach can involve installing devices on the subject’s body (Buechley and Eisenberg 2008).

In these projects, “machine” is not necessarily understood as an independent device that is separated from the human body, but more as a significant part of it, even if physically detached or remotely pulled through the agency of both. There is always a co-dependence between the two and a sense of confusion about the boundary. A number of art projects and installations exemplify this tension. The works of Rebecca Horn - such as Unicorn (1970-72) and Finger Gloves (1972) - could be examples of how body extensions and the environment relate to each other through movement, equilibrium and gravity. Michael Heizer with Circular Surface Planar Displacement (1969), instead, uses a motorcycle to produce large scale modifications on the surface of the desert. The human-machine interaction is still present when looking at the traces in his series of perfect-looking circles drawings: there is an embodied mastered knowledge on the speed and traction of the motorcycle and its turning radius through the use of his own anatomy in order to achieve such conditioned results.

**METHODS**

The implementation of the project can be understood as the crossing between eighteenth century drawing mechanical apparatuses based on harmonic movements (Garcia 2013), Braitenberg’s autonomous vehicles (1986), and wearable technologies for human-computer interaction based on gestural detection (Hartman 2014).

The vehicle was built based on a standard kit of a wheeled Arduino robot with two continuous-rotation servos and a pivot ball. The basic movements of the vehicle (forward, backward, and rotation) were controlled through the relative speed and rotational direction of the servos, previously calibrated to match microsecond values to actual RPMs. Four environmental sensors were installed on the vehicle: a photo-resistor on top, an infrared tracking sensor on the bottom, an ultrasonic distance sensor on front, and a magnetometer at its center. Additional turn on-off buttons and signaling LEDs were also incorporated to ease its operation. For detecting and tracking the movement of the human performer, we designed a simple wearable Arduino-based system with three tilt sensors (hands and head), a magnetometer, and a pressure sensor under a foot. This combination of sensors was proven to be sufficient to detect a wide range of position configurations and movement patterns (see Figure 1). To communicate the vehicle and the human, two radio-frequency (RF) modules were installed as transceivers. A mini XY joystick was also added as a safety measure to remotely drive the vehicle in case of need. Two servo motors installed on the back side of the vehicle were used to control the position, orientation, and pressure of...
(various) drawing tools, with a drawing precision of about 1% for linear movements and 2% for rotary movements.

The operation of the vehicle was determined by a series of predefined movements that were triggered by different combinations of values of the postural sensors in the human performer and of environmental sensors in the vehicle. Using psychological theories of body language, sixteen basic body postures were associated with presumed emotional states and consequent specific movements in the vehicle. For example, an aggressive posture in the human triggered a backward movement in the vehicle. The movements were not totally determined by the person, but altered by environmental conditions. For example, ambient light could act to indicate direction of movement, or floor color could indicate safe rest areas. Thus, the final movement of the vehicle was the result of a set of combinatorial rules. For example, if the human performer held an inactive posture for too long, the vehicle could change the movement rules in order to stimulate a new dynamic between them: perhaps the vehicle could escape from the light, forcing the human performer to approach, lean, and cast a shadow to keep it still. Programming the vehicle was straightforward, considering the relative simplicity of the movement rules. The code was implemented as a constant loop of two steps: first, collecting measurements from all sensors, and then, a series of mutually exclusive if clauses covering the full range of movements.

We performed a series of three progressive preliminary tests to evaluate and develop the functionality of the system (see Figure 2). Once operational, a final pilot performance was planned and conducted. A human performer provided with the body sensing system but no knowledge of the vehicle’s behavior was asked to interact freely and spontaneously in a 400 sq.ft. area which included a bench, two spotlights, and a 100 sq.ft square of white powder on the floor. A sponge brush was attached to the vehicle as “drawing” device.
RESULTS AND DISCUSSION
The final performance showed that the vehicle interacted dynamically with the human performer in an unpredictable, but not random manner. At least three “assumed emotional states” (surprise, fatigue and aggressiveness) were effectively activated during the exercise. The performer was able to decipher the relationship between light, shadow and movement affecting the drawing machine. She managed to use her own movement as a control variable to guide the robot to move towards her and/or over the powdered area. Thus, the final “drawing” corresponds to the traces and footprints on the floor left by both the vehicle and the performer, a proof of a mutually choreographed correlation between the machine, the human, and the environment.

The maturity of the final iteration of the drawing is evidenced by the accumulation of synergy between the two performers after a considerable period of time. The drawing left on the floor is more than just a consequence of the brush sweeping the white powder back and forth. It speaks for an aesthetically unexpected representation of the combined efforts between the person, the vehicle, and the contained space. The drawing becomes a testimony of the specific moods of the performers (human, machine), but also of the architectural environment they occupy. However, it is also not a simple choreographic notation that allows the reproduction of the performance -in the literal sense of choreography as the written form of a sequence of movements (as in dance, sport or military)- but is meant to evoke a sense of the mood of the performance. Jagged lines may indicate a stressful interaction, or circles may be sign of ecstatic happiness. The drawings convey not only movement, but also leave room for emotional interpretations.

During the exercise, a different material with a colored pigment was randomly added to alter the performance outcome through a less binary opposition between the ground black background/floor and the white powder. Although this decision did
not alter the behavior of the vehicle, it added a different component that sustains a more provocative collection of results.

This project raises interesting conceptual questions that can be framed in a more general ongoing contemporary debate around the extensive limits and thresholds of design by/on the human and non-human (Colomina & Wigley 2016). Maybe the most evident disciplinary question is the redefinition of drawings as a performative action in space that challenges the traditional notions of representation. Drawings, in architecture, often mediate between what the philosopher Nelson Goodman categorizes as autographic -arts where the presence of the author is fundamental to the realization of the work, like painting- and allographic -arts where the works can be reproduced by different people multiple times without the presence of the author, like theater plays- (Allen, 2000). Architecture drawings are, in fact, far more speculative and puzzling tools than the plain result which becomes visible through different forms of media. In this project, the tension between the autographic and allographic is explicit: the drawing is the result of a complex interaction not only between the machine and the performer, but also between the vehicle's programmed movements and the uncontrollable environmental factors. It is impossible to clearly define whether the trace is more controlled by the human, the environment, or the machine.

The project questions the aesthetic limitations and potentials embedded within the idea of (machine) control. Is the human performer who is guiding the vehicle by casting shadows over it? Or is the vehicle and the environment conditions (i.e. the position of the lights in the room) that are causing the user to move in a different way in order to get the vehicle underneath the shadow? At some times, it seemed that the vehicle governed all interaction, in the same way as a little boy crawling freely leads his mother behind him. Indirectly, the vehicle forces the human performer to interact actively with the environment, and consequently, to be aware of specific details of the architectural context: the direction of the lights, the color of the floor, the level changes. Indirectly, the work proposes an alternative form of art production which could position notions of authorship in a more environment sensitive paradigm.

The empathetic relationship developed between the performer and the machine -although both entangled in a socially awkward form of communication- was a remarkable discovery that we initially had not expected. It was not the individual human body or its psychological reactions what could explain variations in the line traces, but the person's empathy towards the machine's sensing capacity. This was clearly manifested through the coexistence of responsiveness and incomprehension between the performer and the machine. This is a remarkable clue which could be developed further in order to make the drawing and the perception over the experience much richer.

Finally, this work also brings up questions of how to position the outcome with regards to architecture and art as close fields. In our view, it could be read as mediating between an art and architecture project, since it discusses the possibility of describing the results only as an aesthetic product but also as a spatial intervention affecting human behavior. Yet, we argue that this idea of solely an ‘aesthetic product’ could be strong enough to become the driving force of an architectural investigation. Nevertheless, the system of values through which we could judge the experience is not the same that an art critic or architecture critic would adopt.

Figure 4 during the process
CONCLUSIONS
In this paper, we explored the use movement as a design material to evidence human-machine interaction in an architectural space. By using a drawing vehicle with environmental and social sensory capabilities, we produced abstract drawings on the floor that are a confirmation of how the immersive experience of basic emotional reactions and programmed sensing can transform a particular space, environment or setting into a relevant aesthetic material.

Our initial goal of building a drawing vehicle was successful in terms of functionality. Still, a more robust machine would be needed in further experiences with extreme environmental conditions (e.g. liquids or non-smooth surfaces), large-scale territorial contexts, or socially diverse environments.

The project lead us to re-think our own notions of materiality, which could also be intangible as we see it merely as movement. Indeed, we designed a flexible material with which to explore actuation, sensing and interface. Although at first it may seem that digital technologies play a central role in this type of architectural projects, we consider their position as essentially instrumental, only as a means to generate or mediate new spatial experiences, whose greater value relies in the phenomenological quality of the interactive experience. In this sense, the results of the indexed performative, social and physical aspects of
the aesthetic product end up being almost entirely subjective.

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