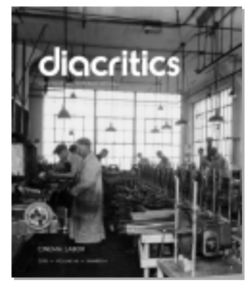
Cinema's Automatisms and Industrial Automation

Mal Ahern



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CINEMA'S AUTOMATISMS AND INDUSTRIAL AUTOMATION

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Film theorists from Jean Epstein to André Bazin to Stanley Cavell have located cinema's unique qualities in its capacity to produce moving images "automatically," or with limited assistance from human hands. For Bazin, the camera's ability to generate imagery without human intervention gives cinema a privileged relationship with "reality"; for Cavell, it renders a humanistic "world"; for Epstein, it provides a non- or anti-human mechanical vision.[1] Dziga Vertov praises the camera's potential "as a kino-eye, more perfect than the human eye," capable of feats of perception unavailable to the unaided human.[2] Cinema's automatic powers have been the object of criticism and even fear.[3] In his 1915 novel *Shoot!*, Luigi Pirandello describes the way that cinema's mechanical processes transform even the man behind the camera into a sort of automaton, "nothing more than *a hand that turns a handle*."[4] Photography and cinema's mechanical bases have even led some critics to claim that these media are not true art forms, and inspiring others in turn to defend cinema against the charge that it is "nothing but the feeble mechanical reproduction of real life."[5] Despite their many differences, what these and many other twentieth-century theorists share is a fascination with cinema's automatic nature. And for many, this automatism is the source of film and photography's unique relationship to contingency.[6] The camera's mechanical vision sometimes admits accidental imagery or records unexpected events; in these moments, cinema seems to sidestep some of the culturally sedimented modes of visual representation found in hand-drawn images. Human absence is essential to the view that mechanical causality forms a necessary link between a photograph and its referent: "Between the originating object and its reproduction," Bazin writes of photography, "there intervenes only the instrumentality of a nonliving agent."[7]

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>> The Mechanical Model

Toward the end of the twentieth century, cinema and photography began to incorporate computer-generated imagery and animation into lens-based and mechanically produced images. The ascendance of such hybrid forms challenged the "mechanical model" of cinematic and photographic uniqueness, causing many critics to return with renewed interest to the question of cinema's specificity.[8] Arguing for a decisive break between the analog and the digital, Lev Manovich claimed that digital cinema could no longer promise to offer "deposits of reality" but instead functioned as "a subgenre of painting."[9] Other critics, such as Tom Gunning, emphasized the continuities between photographic media and the manual arts of drawing and painting, looking to hand-altered photographs and early special effects as precursors to digital hybridity.[10] In the early 2000s, many scholars read the writings of Bazin and Cavell with new eyes, arguing that these classical film theorists saw cinema's automatic nature not simply as a means of representing an antecedent reality, but as producing new objects and aesthetic practices.[11]

These debates on cinematic ontology, which flourished in the moment of analog cinema's demise, have largely subsided now that cinema's hybrid and ever-shifting nature has become the starting point, rather than the conclusion, of any statement on film. More pressingly, our current media landscape teems with new varieties of nonliving agent that classical film theorists could have scarcely imagined: algorithms and bots that, while they are unrecognizable as film, draw on the familiar dream of producing infinite images without the labor of human hands.[12] This situation (the immanently hybrid nature of cinema; the proliferation of new forms of "automatic" visual production) suggests that human presence or absence is not a sufficient means of distinguishing the photographic or cinematic from other modes of image-making. Any discussion of cinema's "automatic" nature must account for the fact that every film—indeed, every image—is the result of multiple working processes, multiple modes of human and machine production.

Keeping these developments in mind, this essay offers an alternative way of understanding film and photography's automatic processes, one that situates them within a broader definition of recording. The profound difference between the hand-drawn and the photographic, I argue, does not have to do with a distinction between human presence or absence, between the eye and the lens, or between the manual and the mechanical. Rather, it has to do with distinctions between repeatability and variability, rigidity and flexibility, stasis and dynamism. It has to do, most precisely, with the relative presence or absence of dynamic feedback in the image-making process. A visual recording, as I will define it, is any image generated by a process that does not dynamically react to the image it produces in the course of producing it. Going further, I will suggest that any mode of material production or inscription can generate recordings. There are thus as many kinds of recording as there are ways of removing feedback from processes of material production. (Indeed, I have chosen the term "recording" for its capacious quality. I mean to leave space for sensory registers apart from the visual, in the hopes of working towards a definition that can include recorded sound, among other objects.)

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Understanding recording media in this broader way allows us to return to the central, animating questions and terms that generated much of the best classical film theory—trace, evidence, contingency, even reality itself—while avoiding the reductive logics of medium-specificity that hold ever less relevance for fine art or mass culture.[13] It allows us to view the distinction between the mechanical and the manual as continuous, revealing not only where film and photography incorporate manual gestures, but also aspects of drawings and paintings that we can understand as mechanically recorded. I will draw on the concept of mechanical automatism so important to classical theories of film and photography, putting this in conversation with cybernetic theories of automation that circulated widely in postwar North America and Western Europe. I do this to suggest that deep similarities link recording devices and another technological innovation characteristic of the Industrial Revolution and its aftermath: the automated factory.

Feedback, after all, is a concept intimately related to the definition and historical realities of industrial automation. The practical origins of the concept lie in the self-correcting servomechanisms that governed turning gears and steam engines since the eighteenth century.[14] With mid-twentieth-century advances in computation and electronics, mathematicians sought to extend the principle of self-regulation to objects that traced smooth trajectories—such as missile arcs—through more complex systems—such as oceans and atmospheres.[15] Whether mechanical or electronic, feedback systems enabled machines to detect their own positions or outputs, and adjust the speed, force, or orientation of their many parts in order to correct or guide their action. During and after World War II, mathematical models of automatic self-regulation inspired engineers in a number of industries to create labor-saving or even labor-eliminating devices.[16] The popular press enthused that fully self-acting machines would, within a decade, sew dresses, build cars, and print magazines without the intervention of a single pair of human hands.[17] Popular interest in such "machines without men" proliferated alongside mid-century film theorists' celebrations of cinema's automatisms. These disparate discourses sometimes use similar language: Bazin's described photography as a machine that generates objects "automatically, without the creative intervention of man."[18]

Yet I will argue that the automatisms of cinema and other recording media stand in diametric opposition to the feedback-enabled modes of automation that drove military and industrial technology in the mid-twentieth century. In fact, the very *failures* of industrial automation—for it became evident, by the 1960s, that numerical control systems were unable to produce even simple geometric shapes to critical tolerances—can teach us something crucial about the nature of cinematic recording. Recording works for the very same reasons that many twentieth-century automation technologies failed: the lack of an adequate feedback mechanism. We can better understand recording by shifting our focus away from the nature of the medium, and toward the activity of mediation.[19] Cinema, photography, and sound recording are not the only media that produce objects we can consider recordings. Hand-made drawings, factory rejects, and printer's errors can also make sensible traces of their own production if they emerge from inscription processes that lack crucial sources of feedback. We should consider recording not as an ontological property defining a set of media technologies, but as a force of inscription that works across and outside of what we traditionally think of as media.

>> Two Automatisms

I take the term "automatisms" from Cavell's 1971 book *The World Viewed*, which reconsiders the concept of "medium" in light of cinema's technological basis, generic conventions, and aesthetic capacities. Cavell's definition of "automatism" cleaves in two directions. The first describes the mechanical means by which cinema operates: its photochemical basis, its automatic unfurling through the camera, and its projection in front of a spectator who is unable to influence or control the film's process. The second refers to the set of historically and culturally dependent conventions for making and perceiving that define any art form. A medium's physical materials, formal possibilities, stylistic conventions, and range of available subgenres all count for Cavell as its automatisms. The automatisms associated with a medium are not fixed; they can change gradually or suddenly, and when their critical balance shifts, a new medium often emerges. (Think of the appearance of modern easel painting, or the rise of the novel, in relation to the media that preceded them: murals and altarpieces, epic poetry and personal letters.) While cinema's powers of fascination and its capacity to present a "world" rely, for Cavell, largely on its mechanical automatisms, much of *The World Viewed* focuses on the automatisms of convention that have defined the narrative feature film: the emergence of genres and types of films, of particular stylistic flourishes, and of cultural phenomena like that of the movie star.

A combination of these two automatisms—the mechanical and the conventional—guides Cavell's understanding of cinema. Their resemblance becomes clearer in light of David Rodowick's observation that "automatisms act as variable limits to subjectivity and creative agency."[20] While the mechanical automatisms of film and photography "overcame subjectivity," in Cavell's words, by "removing the human agent from the task of reproduction," automatisms of convention limit individual subjectivity by holding it accountable to a broader culture and community.[21] For Cavell, painting's automatisms are the forms and materials that allow a painting to be recognized as such—and so a painter's individual will is limited by her desire to produce objects that other people will recognize as paintings.[22] In this sense, Cavell's account of art's automatisms of convention relies on a notion of cultural feedback—with criticism and acknowledgment providing dynamic limits on artistic production.

Against these automatisms of convention, the mechanical automatisms of recording media provide a productive friction. In the 1950s, 1960s, and 1970s, art's automatisms underwent a series of dramatic shifts that, according to critics like Michael Fried, threatened the stable identity of centuries-old media like painting.[23] Decades later, Rosalind Krauss attributed many of these transformations—and the emergence of new forms such as minimalism and multimedia installation—to painters' and sculptors' growing awareness of cinema as a technological medium. Cinema's obviously aggregate nature—its reliance on multiple technologies and conventions such as the filmstrip, the camera, the projector, and the audience—revealed the similarly aggregate nature of the conventions that had defined media such as sculpture and painting.[24] Put another way, something about cinema's *mechanical* automatisms disrupted the feedback loops of appeal and acknowledgement that had defined traditional art forms. Krauss saw something in *technological* media as inherently disruptive to automatisms of convention, since the material existence of technological media persists even as conventions shift. We might thus understand film technology's impact on the arts through the cybernetic concept of *feed-forward*, according to which material objects created within a cultural context become partially detached from the very feedback loops that created them—and thus exert influence in sudden, belated, and unexpected ways.[25]

In what follows, I want to unbind these two automatisms and speak of the "mechanical automatisms" of recording separately from the automatisms of convention that normally define a medium. I do this so that we can understand recording not as a special category of medium, but as a specific *type of mediation*, one that can occur just as easily in drawing and painting as it can in photography—and just as easily in the factory or the laboratory as it can in the film studio. Here I depart from Cavell's view of cinema, which relies on a strong distinction between the mechanical arts of film and photography and the manual arts of drawing and painting.[26] In the middle of the twentieth century, the arts of recording not only offered a sensory ground on which to critique the technological optimism that attended industrial automation; they also disrupted the systems of cultural feedback that had, for centuries, lent stable definition to painting and sculpture. The structure of recording was also easily assimilated to the manual arts.

>> Automatic Drawing

In 1915, Heinrich Wölfflin commenced his *Principles of Art History* with a parable from the autobiography of the artist Ludwig Richter. The artist and three of his friends sat in Tivoli and all attempted to paint as "objective" a view of the landscape as possible. Each artist, of course, produced a very different picture. The moral of the story, in Wölfflin's words, is "that there is no such thing as objective vision, that form and color are always apprehended differently according to temperament."[27] This tale draws on a long association in Western thought between drawing and painting and the idea of an individual's subjective view of the world.[28] More crucially, Wölfflin's conclusion locates the mediating power that distinguishes the four landscapes in individual human "vision," in the perception of form and color linked to individual temperament. Going further, he suggests that period style can be explained in terms of the cultural universals that, at a given place and time, govern how people see.[29] This way of understanding the art of manual depiction relies on the post-Kantian idea that our faculties of sensory perception are more limited than our rational capacities. In this view, human perceptions, habits, values, and cultures have mediating power and together form a set of distorting veils beyond which exists a "real" world of forces and matter. Indeed, rhetoric surrounding many forms of "scientific" drawing suggested that the technological estrangement of the human senses was a necessary part of objectivity.[30]

The "standard reading" of Bazin and Cavell leverages these associations between painting, subjectivity, and the mediating powers of human vision, arguing that rational machines might provide us alternative views of the world outside our own human limitations.[31] The difference between a drawing and a photograph, in this view, resides in the inherent properties of their media: the human's cultural and biological means of perceiving, on the one hand, and the camera's mechanical vision, on the other. But what if we imagined the difference between recordings and other images as defined not by the presence or absence of a human observer, but by the imposition of a set of restraints that prevents the artist's ability to spontaneously respond to an inscription-in-progress? In the essay "In Praise of Hands," Henri Focillon argues that the artist's ability to dynamically integrate and respond to everything on the page—including the obscure forces of chance and error—is what distinguishes their actions from those of "a machine, in which everything is repeated and predetermined."[32] What separates human artists from machines, for Focillon, is not artists' production of accidental marks, but rather their capacity to reincorporate those errors as though they were intentional.[33] Focillon praises the painter Hokusai in particular for his ability to take "advantage of his own errors and his faulty strokes to perform tricks with them"—a quality that, while sacrificing the direct resemblance between a drawing and a real-life object or scene, captures the higher reality of life's spontaneous flow. The world, Focillon concludes, "must be captured on the fly if all its hidden power is to be extracted."[34]

The dynamic relation between manual gesture and image-in-progress equally informs a radically different kind of art. The surrealist practice of automatic drawing opens a circuit of direct feedback between artist and line, without the friction generated by the imperatives to lifelike resemblance or balanced composition. *Automatic*, here, refers not to automated machines, but to the seemingly automatic generation of image from unconscious—an unimpeded relationship between a material trace and irrational, generative power.[35] Rosalind Krauss has suggested a connection between surrealism and Jackson Pollock's drip paintings, which expand on surrealist notions of automatism to integrate the probabilistic forces of contingency.[36] Yet even as Pollock channeled chance drips and splatters onto his canvases, he did so with open eyes, integrating each gesture into an evolving sense of a composition.

Contrast these visions of artistic dynamism and mastery with another kind of automatic drawing: Ellsworth Kelly's 1950 *Automatic Drawing: Pine Branches* (fig. 1), whose awkward, disconnected curves suggest the hint of its subject, but ultimately fail to cohere into depiction. Kelly's series of *Automatic Drawings* almost perfectly invert the principles of surrealist automatism: in each drawing, Kelly attempts a figurative depiction of a specific object or landscape, but does this either blindfolded or without otherwise allowing himself a glance at the page. Simply by eliminating his ability to see his drawing while he is creating it, Kelly removes the possibility of altering his generative action in response to what he is creating. The result appears uncanny, almost mechanistic, and nothing like the vibrant and expert renderings of other series, like his *Plant Drawings*. Yve-Alain Bois argues that the *Automatic Drawings* represent the artist's attempt to suspend conscious "motor control," an effort he links to the artist's continuing quest to eliminate, or even automate, the artistic work of composition.[37] Soon after his experiments with automatic drawing Kelly started using aleatory methods of composition in a series of geometric collages, providing another way of generating images without individual decision-making.[38]

Kelly's work presaged an entirely new approach to automatic drawing that developed in North America and Europe throughout the 1950s and 1960s, and which sometimes explicitly commented on the hopes and fears that attended the advent of industrial automation. In the mid- to late-1950s, Swiss artist Jean Tinguely created dozens of automatic "drawing machines" that he called Meta-matics. Some of these machines traced furious circles again and again on the same sheet of paper; another, a Meta-matic he nicknamed "Le Grand Charles," produced "drawings by the mile" on an enormous scroll of paper

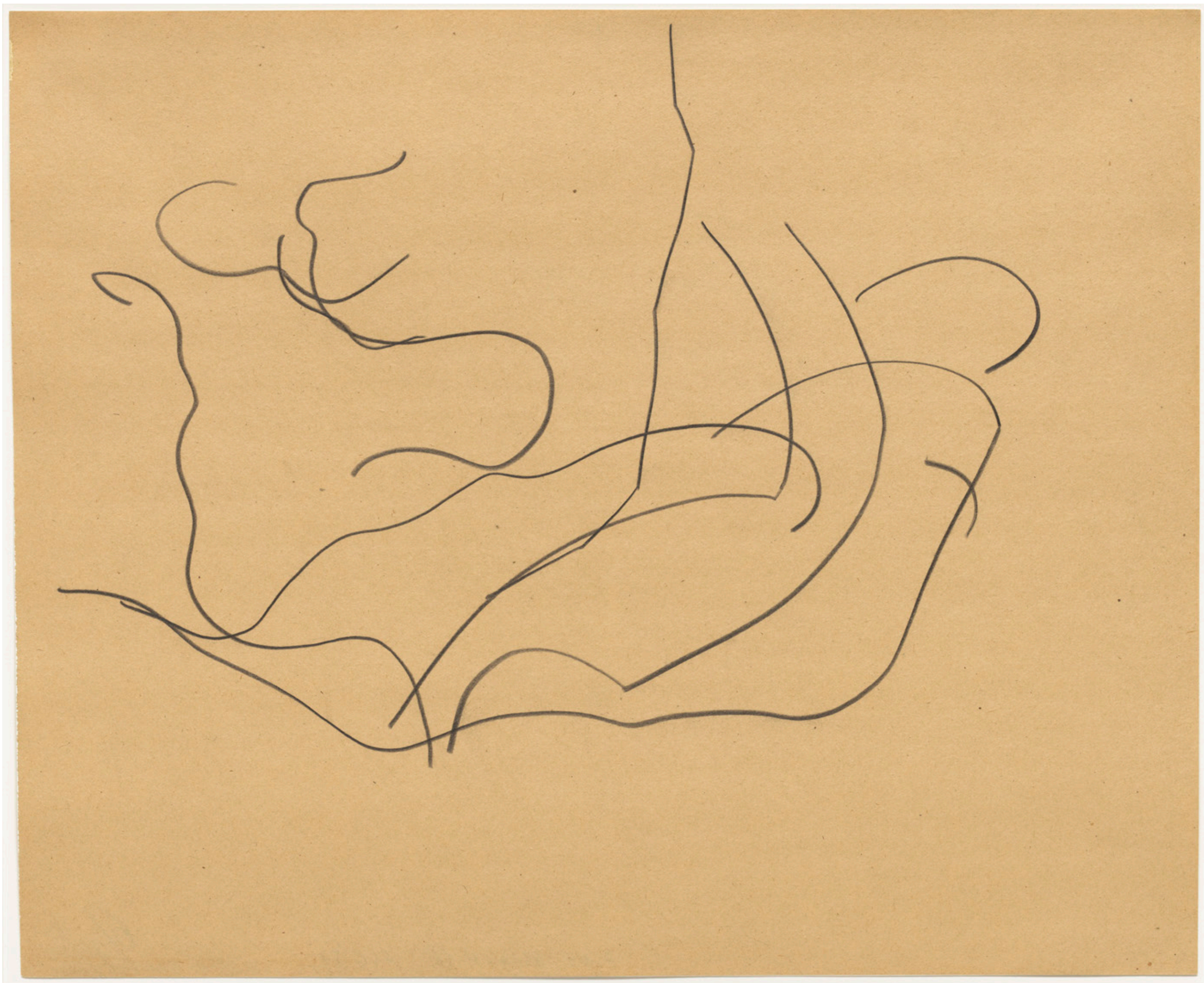
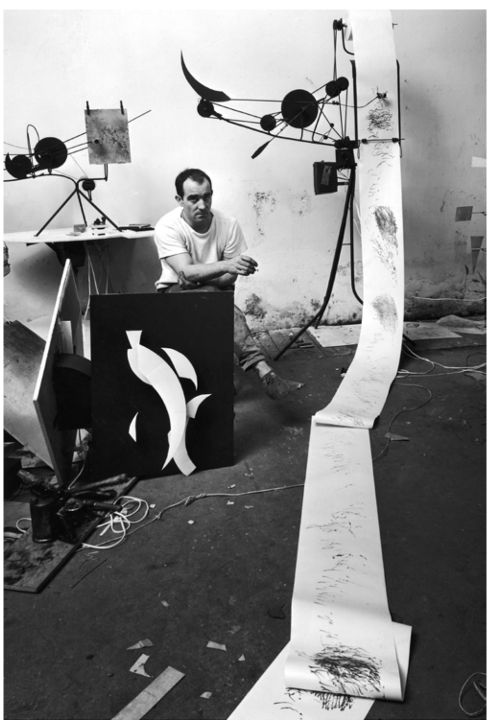


Figure 1. Ellsworth Kelly, AUTOMATIC DRAWING: PINE BRANCHES VI, 1950. Pencil on paper, 16.5 × 20.25 in. The Museum of Modern Art, New York.

that unfurled rapidly past a scratching pen, recalling at once a rotary printing press and a giant strip of film (fig. 2). As Pamela Lee has detailed, many critics viewed Tinguely's machines as fearful anticipations of a future in which industrial automation would make even the artist's creative work obsolete. "The arts themselves risk being automated," one *Paris Match* journalist worried in 1959: "Admirers of abstract painting have learned, with stupefaction, that there exists a machine which can, with the greatest ease, replace the creation of the painter."[39] Indeed some critics regarded Tinguely's and other "drawing machines" of the 1960s in terms that echoed earlier anxieties that photography's powers of automatic depiction would eventually replace painting and drawing.

Yet, as Lee and other critics have observed, Tinguely's machines in fact comment ironically on the ambitions of industrial automation.[40] They were, in her words, "relatively simple machines," and not equipped with the elaborate systems of programmed feedback with which engineers hoped to transform industry.[41] In this failure of feedback lay both their generative power and their critique. A closer look at Le Grand Charles's scroll reveals a series of short, furious arcs. In some sections these lines appear more frequently and closer together, merging and swarming into dense, tangled clouds; in other sections, they scatter like confetti. The overall effect is like that of an errant, useless seismographic recording—which the drawing is, in some sense. Because they lacked the capacity to sense the results of their activity, and subsequently self-correct, the Meta-matics were incapable of producing the same image twice. Though Tinguely's machines operated on a rotational and thus repetitive basis, contingent factors—mechanical vibration, friction, machine wear, and eventual breakdown—led to variation in their output.[42] Tinguely referred to the inevitable variations that such uncontrolled repetition produced as "the functional use of chance."[43]

Figure 2. Jean Tinguely in the studio with "Le Grand Charles," circa 1959
Photo: Robert Doisneau
Getty Images, www.gettyimages.com



A third sort of automatic drawing forms, in a sense, an opposite to the Meta-matics. In 1968 the conceptual artist Sol LeWitt commenced a series of *Wall Drawings*; for each, he gave a group of draughtspeople detailed instructions for drawing an elaborate, precise grid of pencil lines on a gallery wall. Though the draughtspeople employed were able to take full advantage of their senses in order to adjust their mode of working—pressing their pencil harder or lighter, moving it faster and slower, in order to keep it on course—LeWitt's plan restricted their gestures. In theory, LeWitt's *Lines in Four Directions* ought to be a perfectly even grid (fig. 3). But the resulting image pulses with sections that are darker and denser than others, forming an almost rippling, grainy surface. The artist enthusiastically explained that these differences were, in fact, an effect of his imposition of such a repetitive, abstract structure on a contingent encounter of material reality and living beings. "The pressure exerted by the draftsman is not always equal, nor is the distance between lines always the same, accounting for darker areas," LeWitt explained. "These deviations . . . are inherent in the method."[44] Because all walls have "holes, cracks, bumps, grease marks, are not level or

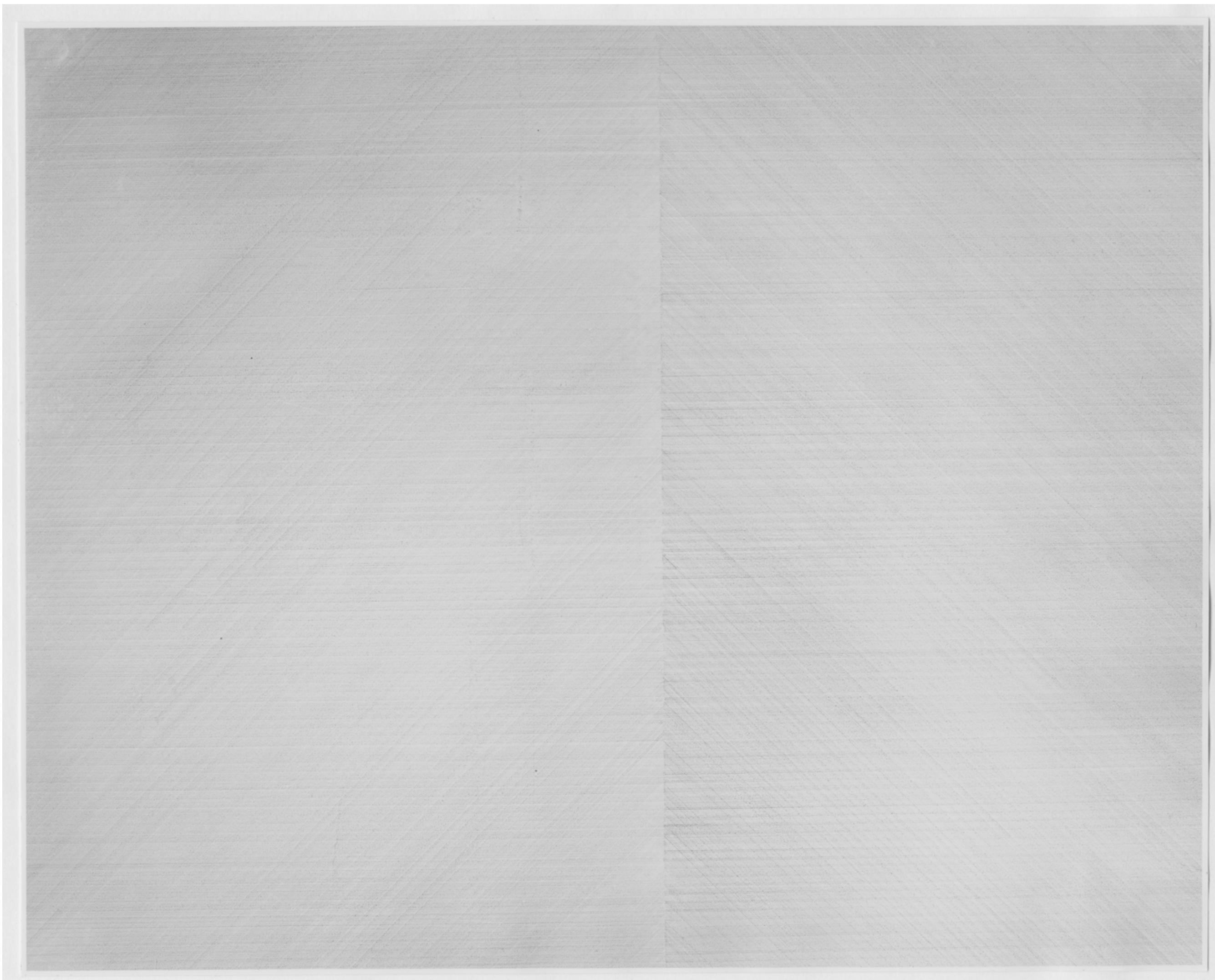


Figure 3. Sol LeWitt
WALL DRAWING: LINES IN FOUR DIRECTIONS, 1969
Pencil on paper, 168 × 150 in.
Installation view of the exhibition "Sol LeWitt,"
February 3, 1978 through April 4, 1978
The Museum of Modern Art, New York
Photo: Katherine Keller

square, and have various architectural eccentricities," and because "each person draws a line differently," LeWitt continued, "all wall drawings contain errors, they are part of the work."[45] By not allowing the artists to alter the direction or extent of the lines they were drawing—by eliminating one of the ways artists are typically able to respond dynamically to an image in the process of creating it—the drawing recorded the wall's texture and the artists' responses to it. LeWitt's widely repeated claim that, for the conceptual artist, "the idea becomes a machine that makes the art" could be understood to mean that the work's plan might, like a camera, provide the means to materialize a contingent encounter.[46]

We might also consider the rule- and chance-based procedures that dominated art-making in the 1960s and 1970s to be a kind of automatic drawing that materializes contingent encounters. Aleatoric composition—used by John Cage and Merce Cunningham, as well as by painters like Kelly—creates visual or sonic articulations of contingency. Aleatoric composition is like the movie camera or tape recorder: it uses rigid, rule-based procedures to capture unplanned movement. A roll of dice indexes the flexing of a hand, the weight of solid cubes, the breeze in the air, the flex or rigidity of the ground they meet—but, having reduced those influences to two digits, the dice roll fails to provide us with legible information regarding its myriad causes. Fred Turner has argued that such artistic experiments with chance share an intellectual ground with theories of industrial automation: aleatoric compositional procedures derive value and meaning in the chance organization of a "probabilistic universe" in which only likelihoods—never certain outcomes—could be predicted.[47] But while the artist develops "automatic" processes that put stable frames around systems in flux in order to lend material expression to the contingencies that constitute the world, the proponent of factory automation sought to eliminate contingencies by detecting and accounting for them as they occurred. The automated factory, instead, sought to create efficient, predictable feedback loops.

Automatic drawing teaches us that the presence or absence of human eyes and hands is not enough to distinguish recording from other kinds of depiction. Just because an image is made by hand does not mean that it expresses an artist's subjectivity or even allows her to spontaneously inscribe her autographic gestures.[48] Simply by removing one avenue for dynamic self-regulation—by closing her eyes while drawing a scene from memory, or drawing ploddingly in one direction only—the artist allows contingencies into her artwork. And, unlike Hokusai, this blind artist cannot respond to and incorporate these materializations of contingency. Both Kelly's and LeWitt's experiments required the artist's willing participation—the willing suspension of choice and freedom. Machines like Tinguely's show what happens when the sensitive mechanical feedback control of human hands and senses is eliminated from artistic production: that, in the absence of feedback, repetition generates variety. In order to truly test this theory—that the lack of a feedback loop in an inscription process generates a recording—we must leave the realm of art, and see how recording surfaces in the factory. The feedback systems designed to permit, say, a blade to cut a straight line through a steel plate, or a printing press to churn out a ribbon of stamps, were built to dynamically respond to and account for variations in materials, machine wear, and the factory's ambient environment. Where those feedback systems failed, the lines these machines traced wavered and wobbled. In failing to respond to the changing conditions in their environment, these machines ended up recording those variations.

>> The Automated Factory and the Limits of Control

At its broadest level, the cybernetic concept of feedback refers to the mechanisms that allow complex systems to self-regulate. Take a classic, and relatively simple, example of a feedback-based technology: a thermostat. In order to regulate the temperature in a house, a thermostat measures an output (the warmth of said house) then feeds that temperature information back into the heating system, which adjusts its intensity in response to the input. Norbert Wiener describes feedback with the relatively mundane example of a car driving down a highway. A car with its steering wheel locked in position will eventually drift to one side of the road or the other; a capable driver will immediately sense this drift and, often without consciously thinking of it, adjust the wheel so as to maintain the car's straight path forward. Cybernetic theory does not distinguish between humans and machines—or between individuals and vast cultural or environmental systems—in its description of self-regulating systems. For Wiener, feedback was feedback, whether "the apparatus" that deployed it was "alive or dead."[49]

At the heart of automation are the very technologies we often associate with recording media: lenses, microphones, photosensitive surfaces. But these sensing devices only allow an automated machine like a self-driving car or a self-correcting mechanical lathe to carve a straight path forward if the information they gather is fed back into these machines in a way that allows them to immediately self-correct.

This equivalence of the human and the technical presumed, however, that mechanical and electronic systems could ever achieve human-like complexity. A fully automated, self-driving car—of the kind that many corporations are attempting to build today—would require not only a suite of devices to detect crucial information about speed and position, but also the capacity to knit this information together, weigh it, make moment-by-moment judgments about how to react to it, and seamlessly implement those reactions in real time. At the heart of automation are the very technologies we often associate with recording media: lenses, microphones, photosensitive surfaces. But these sensing devices only allow an automated machine like a self-driving car or a self-correcting mechanical lathe to carve a straight path forward if the information they gather is fed back into these machines in a way that allows them to immediately self-correct. Postwar advocates of industrial automation tended to overestimate the capacity of contemporary technologies to fulfill these goals. For instance, a 1946 *Fortune* magazine article entitled "Machines without Men" announced that "we have machines that see better than eyes" and "act faster and better than hands"; in contrast to skilled human workers, these machines "never demand higher wages based on the company's ability to pay."[50]

The postwar decades saw the rapid development and implementation of numerical control systems in North American and, later, Western European factories. Numerical control (hereafter NC, as it was commonly called) held the promise that manufacturing processes could be formalized mathematically as lines, curves, and angles in Cartesian space, and then fed directly to machines that would read and execute these plans accordingly. The first and most common application of NC was cutting metal. Previously, skilled machinists needed to read and interpret diagrams supplied by designers or engineers before cutting a given part. The hope for NC was that a set of preprogrammed, mechanical movements could replace these workers—transferring skills, in David Noble's words, "from the hands of the machinist to the handbooks of management."[51] Noble and other historians have shown that most postwar industrialists regarded NC as a union-busting tool with which to undermine skilled workers' collective bargaining power. Thus motivated, advocates of automation exaggerated workers' fallibility, and machines' exactitude. While individual minds and hands would inevitably misinterpret or misperceive plans, an automated machine, in the words of one advocate, "is 'instructed' to turn out an item of a given quality" and thus "will turn it out with essentially no variation."[52]

This was the promise. It turned out to be nearly impossible to achieve. In his exhaustive history of the development and implementation of NC systems in American factories, Noble methodically shows how numerical control systems failed to eliminate the necessary labor of human bodies and senses from the manufacturing process. One metalworker Noble quotes describes the errors of thinking that led engineers to think they could program a machine to perform even simple tasks, like cutting a straight line in a sheet of metal:

> Moving something from part A to part B, or moving a cutting tool. If you look at it superficially, that's what's involved in machining and you should be able to duplicate it. Computers will do calculations. And you can fix up the machine tool itself with servomotor and logic circuits so that things will move at the direction of the tape that's been given positioning instructions by the computer. The problem is that there are a lot of subtle things in machining. . . . There are even a lot of subtle things in drilling a hole. All you can tell a machine is that you start to drill at this point, you go in so deep and you come back. But you can't tell a machine that if there's a hard spot in the metal it should push through, or if it starts getting overheated it has to back out.[53]

For Noble, the skilled metalworker achieves his own "feedback control" through "sensitive, alert, and experienced hands, ears, and eyes."[54] Machine-based feedback could not match the multisensory and intelligent feedback of the human worker—particularly the senses of a skilled craftsman with a lifetime of experience perceiving and interpreting "variations in tool wear, the 'machinability' of various materials, actual machine performance, or changing conditions."[55] Simply cutting a straight line requires workers to engage in dynamic, moment-by-moment assessment of the ever-changing conditions of the factory floor, as well as the machines and materials in play. Without an adequate feedback mechanism, a metal-cutting machine would cut lines that wavered in response to fluctuations in the materials, machine wear, electrical supply, or even the weather.[56] These wandering, wavering lines traced in metal would index, or *record*, the very contingencies for which the programmed cutting device had failed to account.

Like a seismograph, the errant lines of a metal-cutting machine record the very conditions that throw them off-course—as did the wavering lines of LeWitt's Wall Drawings, or the jittering patterns traced by Tinguely's Meta-matics. Automation advocates in postwar North America and Europe predicted that computerized feedback systems would soon sense environmental conditions and adjust accordingly, just as well as skilled artisans. Feedback, in their view, was what would distinguish true automation from mere mechanization—its less advanced cousin.[57] In reality, even the best feedback systems manipulated machines that were, ultimately, *mechanical*, and thus subject to friction, delay, and entropy.[58] "Electric eyes" failed, or they focused too myopically on a single point; mechanical friction led to self-perpetuating cycles of overcorrection that engineers call "hunting."[59] Automation rarely removed these intransigently physical facts from material production; inadequate feedback mechanisms simply led environmental contingencies to inscribe themselves differently upon the process of material production.

>> Within Every Recording Lies Another Recording

The physical evidence of such failures of industrial automation—the *recordings* such failures generate—is not always easy to find. Quality control procedures prevent the most dramatic examples from entering circulation. The recorded contingencies of mass production are, however, often revealed in four-color, rotary web printing, through the tiny errors of color alignment that printers call *registration errors*. "Web printing" (so called for the long paper spools, or "webs," fed continuously through a rotary press) requires a machine that can regulate the spacing of images along a continuous surface. Color web printing requires this same precision timing, but four times over, with separate impressions in cyan, magenta, yellow, and black that make up the standard four-color (or CMYK) process.[60] To ensure the seamless cohesion of these layers, printers must manage a set of dynamic relations between the discrete unit of the page and the continuous flow of the paper web.

It is easy to assume that an ideally calibrated machine would be able to place each color state of the image precisely on top of the last, so that when a finished web of paper is cut and folded into pages, each image lands dead center on each page, and each color flush with the others. Yet this ideal machine is just that. A 1959 article on web printing returns to Wiener's classic cybernetic example of a driverless car: even on a perfectly straight road, the author states, a driverless automobile will soon waver from its course; similarly, "a printing press with perfectly trammed rolls, perfect bearings and extra fine

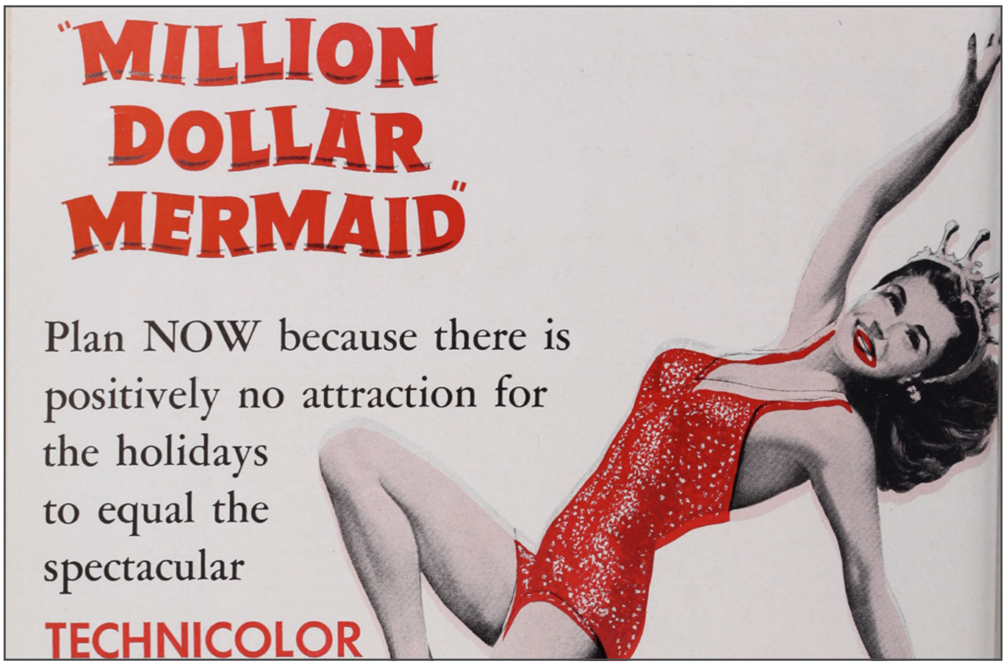


Figure 4. Detail from an advertisement for *Million Dollar Mermaid*. *Film Bulletin*, vol. 20, no. 21 (October 20, 1952), Philadelphia: Wax Publications.

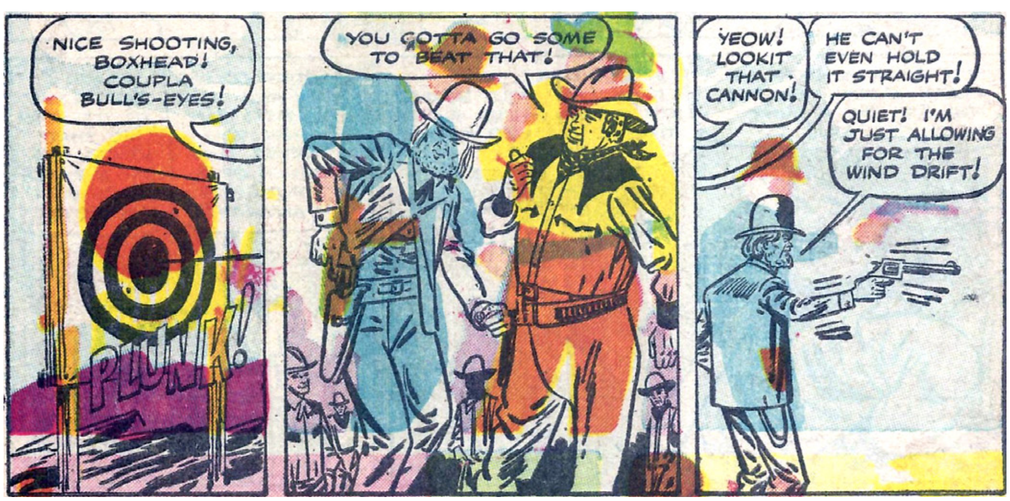


Figure 5. Page detail from *Gabby Hayes*, vol. 1, no. 56 (November 1956), Derby, CT: Charlton Comics. Digital Comic Museum, www.digitalcomicmuseum.com.

tolerances" will nonetheless create images that fall out of alignment if not carefully managed by a skilled and attentive press operator.[61] Unevenly rolled paper or inconsistent ink viscosity could throw off the web's speed or tension; humidity fluctuations on the pressroom floor could cause paper to swell or shrink.[62] In the absence of skilled oversight, these contingencies caused sometimes dramatic errors in the alignment of printed images (figs. 4 and 5). In the same decades, similar, though more subtle, errors of alignment occasionally appeared in Technicolor film prints, which were likewise produced through a mechanized process of multicolor layering.[63] Today, one can occasionally find intercolor registration errors in the print edition of the *New York Times*, which is still produced by the four-color rotary process.

Within every recording, then, hides another, secret recording—a record not of what occurred in *front* of the camera, but of what occurred in the factories and laboratories that reproduce all camera-made images. Hannah Frank has made this argument regarding the animated cartoon and its photographic substrate. In a given frame of an animated cartoon, she writes, an errant line

> might be a gesture of ink, a particle of dust on the cel, a hair in the gate of the camera or the contact printer or the projector. . . . The disturbing presence of scratches, stains, and grain . . . reveal the nexus of social, technological, and economic practices that is the photographic apparatus. . . . Through this obscurity the world comes into view.[64]

Animated *subject matter* is certainly produced autographically—that is, it comprises the traces of artists' manual gestures. But animation is also produced and reproduced photographically. Photography's automatisms allow errors to enter the animated film frame; if we view these errors, as Frank does, with a detailed understanding of the mid-century animation industry and working conditions of animators themselves, these errors might provide a record of the world from which they emerged.

Cinema persistently mixes the automatic and the autographic. To the extent that film and photography produce images "automatically," this automatism is partial, provisional, and riven with conflicts. "Photographic" media (such as Technicolor film) incorporate other manual processes (such as the careful alignment of color layers). "Autographic" media rely equally on photographic and mechanical automatisms.[65] A single cinematic frame can, and typically does, include both autographically produced marks and automatically produced traces. Until recently, discussions of film's hybrid nature—its mixture of mechanical and hand-made imagery—have regarded cinema's automatisms as primarily photographic in nature. Yet other such automatic traces reveal themselves when mechanical processes of image reproduction are allowed to run free—without human oversight or adequate feedback mechanisms—and so generate errors. Frank, for instance, identifies several such errors as they emerge from the assembly-line nature of cel animation: missing cels and faint smudges.[66] Here, I have suggested that the misalignment of color layers indexes changing conditions in pressrooms and film printing labs. Though traces generated by photographic lenses are more easily recognizable and interpretable, registration errors are, equally, automatic traces, rather than autographic marks.

There are two lessons to derive from this fact. First, the automatism of the recording process does not *belong* to film or photography. The "traces of reality" that film theorists have long treated as their unique possession appear across the entire sphere of material production, and in myriad forms. Other media—printing, drawing, writing, performance—can and do incorporate acts of *recording*. Whether by design (as in Kelly's or Cage's chance-based procedures) or by accident (as in the registration errors that plagued mid-century comic books), any object in any medium can incorporate processes of inscription that generate material traces of the contingent events that troubled its space of production. An act of recording only requires, as I have argued, an inscription process that removes some element of dynamic feedback.

Second, the information recordings provide is always limited and always requires external knowledge and conventions for its interpretation. An individual printing error does not provide much meaningful information about the circumstances that created it: we cannot look at a registration error and say for sure whether it results from fluctuating humidity or from an error in the programming of a feedback mechanism. To look at a printer's error and to *sense* specific events that occurred in the pressroom would require us to develop entirely new ways of looking at, and interpreting, images.[67] Yet, as a recording, the registration error already does plenty. It points to human absence, and to an absence of feedback in the sphere of production—even if this absence is simply the lack of quality control that allowed a poorly printed image to enter circulation. The registration error thus makes some part of its own production sensible to its viewers, just as, for Bazin, a photograph "shares, by virtue of the very process of its becoming, the being of the model," no matter how blurred, distorted, or "lacking in documentary value" that photograph may be.[68]

Joel Snyder and Neil Walsh Allan have criticized the "mechanical model" of photography for just this reason: because, consistently applied, the mechanical model suggests that a photograph so overexposed as to be "utterly featureless" will, nonetheless, represent the world.[69] Such an utterly featureless photograph indeed tells us nothing of the pro-filmic scene: the world in front of the camera. But it does offer evidence of a very specific interaction between photochemical stock and light. For instance, we know that, at some point, a piece of film was dramatically overexposed. The information such a photograph yields is not about a pro-filmic world, but about the photograph's own process of coming into being.

Seen this way, cinema's automatisms do not start and stop with the lens-based photographic image, nor with the photosensitive surface that captures it. Many different processes can generate the material traces I call "recordings." Even if we restrict our view to 35mm analog cinema, we can identify many mechanical and automatic processes that generate sensible traces—from the production of film stock, to laboratory process, to the drive mechanisms that maintain the steady flow of celluloid through camera and projector. Each of these processes provides its own sort of lens through which we can perceive material traces of production. Each of these processes might generate recordings. When a projector suddenly throws the cinematic image wildly out-of-frame, this error may index a flaw on the film print, an electrical surge, or a worn sprocket on a projector. In every case, it points to an absence of feedback: to the fact that a projectionist was unable to dynamically respond to the contingencies that troubled the projection booth.

In 1960, one skilled projectionist compared the automatically projected film to "a canvas painted by machine."[70] He meant to suggest that the intelligent viewer should be interested in neither. Yet the very same year, Jean Tinguely exhibited his Meta-matics in Paris; in subsequent decades, experimental filmmakers such as Paul Sharits and Lis Rhodes would use the film projector's automatisms to develop material traces that did not capture an antecedent world via photographic lens, but made sensible and material aspects of the projector's own working process. In doing so, these artistic endeavors remind us that any form of automatism can, as I will conclude, produce new ways of rendering contingency sensible. They also suggest that cinema and other arts of recording offer a means of visualizing the failures and limitations of industrial automation.

>> Conclusion: The Mechanical Production of Contingency

In Pirandello's *Shoot!*, the automated printing press appears as the ominous sign of the obsolescence of human labor. Early in the novel we meet a vagrant violinist who supports his musical career (and his drinking habit) by moonlighting as a tramp printer. One day, a press that had always given him work in the past claimed to no longer have need for him. When the musician emphasized his desperation, the press manager grudgingly offered him a new sort of job, one he had initially considered beneath even a vagrant's dignity. The violinist entered a small, silent room and saw it:

> A new machine: a pachyderm, flat, black, squat; a monstrous beast which eats lead and voids books. It is a perfected monotype, with none of the complications of rods and wheels and bands, without the noisy jigging of the font. I tell you, a regular beast, a pachyderm, quietly chewing away at its long ribbon of perforated paper. "It does everything by itself," the foreman said to my friend. "You have nothing to do but feed it now and then with its cakes of lead, and keep an eye on it."[71]

The musician found this work so degrading that he vowed to give up drinking and to seek stable, respectable employment, which he found as an accompanist in a cinema. Yet on his first day of work he faced yet another sinister gadget: an automatic player piano. His new boss asked him to get out his violin and accompany the machine. "Do you understand?" the musician's friend asks in the course of recounting the tale. "A violin, in the hands of a man, accompanies a roll of perforated paper running through the belly of this other machine!"[72]

Two media, two machines, and two long rolls of perforated paper. Facing each, the violinist trained his human senses to inhuman rhythms—and went mad in the process. *Shoot!*'s narrator, the cinematograph operator Serafino Gubbio, fares slightly better with his own rotational medium. As he turns the crank of the hand-operated camera, he adjusts his physical and perceptual rhythms to the machine's demand for constant, endless rotation. And while he develops what he considers to be the key quality the apparatus demands—impassivity in the face of dynamically unfolding, even shocking events—he still claims that his craft ultimately lies in his subtle speeding up and slowing down of the filmstrip's unfurling. When an onlooker predicts that the operator's job, like the printer's, will soon be automated out of existence—there must be, he says, "a way of making the camera go by itself"—Gubbio agrees. But he argues that this future camera will need to "regulate its movements according to the action going on in front of the camera"—like a human operator would.[73]

A few decades before cybernetic theories of feedback control emerged, Gubbio already imagines an advanced feedback mechanism that could sense what was going on in front of the camera and automatically adjust its frame rate in response. Of course, such feedback mechanisms never developed. Automatic drive mechanisms, which first appeared in amateur and newsreel camera models in the 1920s, forced the filmstrip past the lens and shutter at a consistent speed. For a time, professional camera operators remained faithful to hand-cranked models, arguing that an elastic frame rate allowed the operator to smooth, control, and inflect on-screen motion, which automatic cameras rendered as jerky and undirected.[74] Their claims were largely forgotten when the transition to synchronized sound finally ossified cinema's frame rate, locking the filmstrip's unfurling to a steady, mechanical pace of twenty-four frames per second. Without the dynamic feedback of the human hand—which could not help but respond in real time to events taking place in front of the camera—cinema generated something new: for the first time, cinema produced a consistent measure of the speed of pro-filmic events. Watching a hand-cranked film, one could not be absolutely sure if the acceleration of, say, a train onscreen—or of Charlie Chaplin's manic work at an assembly line—was fully attributable to the "real" acceleration of those objects in pro-filmic space, or the result of a camera operator's subtle manipulations. But by removing the camera operator's ability to spontaneously and dynamically alter frame rate, the automatic drive mechanism created a new cinematic trace: a new epistemology, and a new sensation, of speed.[75]

Cinema's mechanical automatisms, here, produce something that looks quite like an objective record of an antecedent "reality." But this record, too, is an artifact of the production process. A film of a speeding train or of a working body only captures one minute aspect of the subject's movement: the part that renders itself material and sensible in its encounter with the mechanical automatisms of the automatic-drive camera. We trust a film's record of a subject's speed in part because we understand how a film camera works, but more importantly because we have a vast number of other films, all recorded similarly, to which we can compare it. A stable frame rate—which lacks dynamic flexibility and feedback—functions, then, like the controls of a scientific experiment. If we peer through the lens of these stable, unchanging mechanical automatisms, we can perceive the dynamic changes they throw into relief.

This is equally the case with any inscription process that lacks feedback, from the wavering lines of LeWitt's *Wall Drawings* to the similarly divergent paths that a metal-cutting machine might trace in steel. These inscriptions are recordings to the extent that they lack or suppress a feedback mechanism. We perceive and interpret them *as* recordings to the extent that we understand *where and how* these processes suppress dynamic feedback. Moreover, all of these recording processes—like most productive processes—situate their acts of recording within other kinds of material creation. Elements of dynamic feedback sustain all human artifactual production: cinematographers follow motion with their cameras; conceptual artists plan their aleatoric compositions; quality control teams destroy faulty products. Recordings are only ever partial. To understand the nature of recording we must look beyond the medium (beyond its overall manual, mechanical, or electronic character) to the multiple and diverse productive processes that constitute it. We must ask whether and in which cases the multiple humans and machines that labored to make a given image used feedback systems to self-regulate their productive processes.

This may allow us to better understand the new and hybrid forms that proliferate in contemporary visual culture. Digital tools offer vast opportunities for manual gesture and dynamic feedback to enter the recording process, from computer animation to the runaway feedback loops of neural networks like Google DeepDream. These techniques nevertheless coexist with others, such as motion capture and digital rotoscoping, that partially suppress feedback to generate something like cinematic recordings.[76] The shift in attention I have suggested—from the ontology of the medium to techniques of mediation—might allow us to further differentiate, within digital image production and circulation, between varieties of feedback, including those that allow or exclude human intervention. We might view the human absence in algorithmically produced images as occasion to ask what these images record, what new forms of contingency they produce. For, viewed closely, recordings can reveal something of the working conditions in which images are made: the entanglements of human labor, mechanical automatism, and programmed automation through which images come into being.

Notes

I would like to thank Francesco Casetti, Karen Pinkus, John David Rhodes, and Mark Rodgers for their helpful comments on earlier versions of this essay.

1 See Bazin, "The Ontology of the Photographic Image"; Cavell, *The World Viewed*; Epstein, *The Intelligence of a Machine*.

2 Vertov, *Kino-Eye*, 15.

3 See Francesco Casetti, "Why Fears Matter."

4 Pirandello, *Shoot!*, 8.

5 Rudolph Arnheim, *Film as Art*, 34.

6 See Mary Ann Doane, *The Emergence of Cinematic Time*.

7 Bazin, "The Ontology of the Photographic Image," 13.

8 I take the term "mechanical model" from Joel Snyder and Neil Walsh Allan, "Photography, Vision, Representation."

9 Manovich, *The Language of New Media*, 294–95.

10 Gunning, "What's the Point of an Index? or, Faking Photographs."

11 See Daniel Morgan, "Rethinking Bazin," and D. N. Rodowick, *The Virtual Life of Film*.

12 For one such discussion of machine-generated and -readable images see Trevor Paglen, "Invisible Images (Your Pictures Are Looking at You)."

13 Doane provides a thorough history of the ways in which modernist concepts of medium specificity have motivated and limited discussions of photographic indexicality (see "The Indexical and the Concept of Medium Specificity"). Similarly, Tom Gunning has suggested that film theory's discourse on indexicality has failedto account for the animated film, and for the increasingly hybrid techniques with which film mixes animation and photography (see "Moving Away from the Index").

14 "Throughout the eighteenth and nineteenth centuries, automatic control technology remained mechanical in theory and practice. . . . With the emergence of electrical technology and the use of electrical motors to generate and control motion, mechanical theory gave way to electrical theory and electrical servomechanisms" (David Noble, *Forces of Production*, 48).

15 "During World War II, the theory and practice of electrical servomechanisms were advanced simultaneously in the military rush to develop radar-directed gunfire control systems. . . . But the work led also to the formulation of design procedures, based upon mathematical models, for electrical control systems" (ibid.). See also Peter Galison, "The Ontology of the Enemy," 255–56.

16 According to Amy Bix, much of the initial push toward labor-saving technology was a reaction to perceived or actual wartime labor shortages (*Inventing Ourselves Out of Jobs*, 237–38); as Noble argues, postwar efforts to eliminate skilled labor were part of a systematic program to undercut the bargaining power of organized labor (Noble, *Forces of Production*, 2–9).

17 E. W. Leaver and J. J. Brown, "Machines without Men," 165.

18 Ibid.

19 On the shift from medium to mediation see Richard Grusin, "Radical Mediation."

20 Rodowick, *The Virtual Life of Film*, 42.

21 Cavell, *The World Viewed*, 23.

22 Ibid., 101–17.

23 See Fried's 1967 essay "Art and Objecthood."

24 For Krauss, this disruption quickly created an infinity of other recursive structures—other art forms, other "mediums"—whose self-referential frameworks she regards as distinct from the broader, more fractured field of technological communications media (*A Voyage on the North Sea*, 24–27).

25 For evolutionary theorists, *feed-forward* describes the effect that "sedimented cultural systems" (such as certain lithic technologies) were able to exert in evolution as systems that "came to stand *within culture*, *but detached from the coevolutionary feedback* from which they arose" (Tomlinson, *A Million Years of Music*, 44). Mark B. N. Hansen uses the term to describe how technologies outside of human consciousness nonetheless reorient individual, phenomenological experience (*Feed Forward*, 140).

26 Cavell stood by this distinction so forcefully that he insisted that animated cartoons were, quite simply, not movies (*The World Viewed*, 168). See also Ryan Pierson, "On Styles of Theorizing Animation Styles."

27 Wölfflin, *Principles of Art History*, 1.

28 In Hegel's *Aesthetics*, it was precisely the individualized viewpoint of a particular place and time that distinguished the "modern" art of post-Renaissance painting from the two epochal media that preceded it—classical Greek sculpture and ancient Egyptian architecture (*Aesthetics*, 518–19).

29 This leads Wölfflin to his even more famous conclusion: that "vision itself has its history, and the revelation of these visual strata must be regarded as the primary task of art history" (*Principles of Art History*, 11).

30 See, for instance, the scientific drawings of Sir John Herschel, which were made with the camera lucida—an optical tool that, like the camera obscura, assisted artists in creating "objective" renderings of landscapes. See Larry Schaaf, *Tracings of Light: Sir John Herschel and the Camera Lucida*; and Daston and Galison, *Objectivity*.

31 The so-called standard reading of Bazin, as Daniel Morgan describes it, understands photography "in terms of a commitment, via the mechanical nature of the recording process of the camera, to the reproduction of an antecedent reality" (Morgan, "Rethinking Bazin," 445). Morgan identifies this standard reading in several key interpretations of Bazin, including in Christopher Williams's summaries of realist film theories in *Realism and the Cinema*, 35–36, and Noël Carroll, *Philosophical Problems of Classical Film Theory*, 108–9.

32 Of photography, Focillon admitted, "Perhaps I have before my very eyes an example of a future poetic expression; but as yet I cannot people this silence and this waste land" (*The Life of Forms*, 182).

33 His sentiment recalls musician Brian Eno's advice, in his 1975 card set, created with Peter Schmidt, "Oblique Strategies," to "honor thy error as a hidden intention."

34 Focillon, *The Life of Forms*, 176.

35 See the exhibition catalog *André Masson: Line Unleashed*.

36 Krauss, "Horizontality," in Bois and Krauss, *Formless*, 94.

37 Bois, *Ellsworth Kelly: The Early Drawings, 1948–1955*, 23.

38 Bois, *Ellsworth Kelly: The Years in France*, 9–36.

39 Quoted in Lee, *Chronophobia*, 114

40 This lack of adequate feedback technology, according to Lee, "ironized the process of automation" by opening up the machines to a "*constructive*, or edifying failure" (ibid. 113–15).

41 Ibid., 113.

42 "In machines intended for practical use the engineer tries to reduce the irregularities as much as possible. Tinguely is after the exact opposite. His objective is mechanical disorder. His cog-wheels are so constructed that his cogs continually, [sic] jam, and and start again. His couplings lack every kind of precision except that of chance. . . . They are chance in action" (K. G. Pontus Hultén, "Vicarious Freedom or On Movement in Art and Tinguely's Meta-mechanics," in *Jean Tinguely: Méta*, 41).

43 Tinguely, "Wacky Artist of Destruction" (*Saturday Evening Post*, April 21, 1962); quoted in Lee, *Chronophobia*, 113.

44 This text comes from a set of handwritten instructions LeWitt created for *Wall Drawing #3*; reproduced in Gary Garrels, *Sol Le Witt*, 167.

45 LeWitt, "Doing Wall Drawings"; LeWitt, "Wall Drawings."

46 LeWitt, "Paragraphs on Conceptual Art," 80.

47 Turner, "Romantic Automatism," 9.

48 I take the term "autographic" from Nelson Goodman, *Languages of Art*, 113–15. Here I use it specifically to refer to what Rodowick calls "the arts of signature" (*The Virtual Life of Film*, 14).

49 Wiener, *The Human Use of Human Beings*, 26.

50 Brown and Leaver, "Machines without Men," 204.

51 Noble, *Forces of Production*, 33.

52 David Woodbury, *Let Erma Do It*, 7. Advocates for automation repeatedly claimed that such technology would solve the problem of rampant human error. Motion study pioneers Frank W. Gilbreth and Lillian M. Gilbreth emphasized in all of his studies that no human movement could exactly repeat another. See Siegfried Giedeon, *Mechanization Takes Command*, 47. See also Gilbreth and Gilbreth, "A Fourth Dimension for Measuring Skill and Obtaining the One Best Way to Do Work."

53 Machinist interview in Noble, *Forces of Production*, 345–46.

54 Ibid., 80.

55 Ibid., 344. By the time Noble concluded his study in the 1980s, there was still no truly "scientific" way for NC technology to cut metal to critical tolerances—a fact that workers had been complaining about since NC systems were implemented in the 1950s.

56 In the words of one machinist Noble interviewed: "Drills run. End mills walk. Machines creep. Seemingly rigid metal castings become elastic when clamped to be cut, and spring back when released so that a fiat cut becomes curved, and holes bored precisely on location move somewhere else. . . . Any change in one of many variables can turn the perfect part you're making into a candidate for a modern sculpture garden, in seconds" (quoted in ibid., 245).

57 Many industrialists used the term "automation" to refer to any programmed machines, or, indeed, any technologies that aimed to replace skilled laborers with machines. John Diebold, widely known for popularizing the term "automation" in management circles, distinguished "controlled-loop" automation from the less-advanced case of "Detroit Automation," which, in Diebold's words, was "really just advanced mechanization but to a very high degree" ("Automation," 635).

58 Marshall McLuhan, for instance, argued that automation represented "the invasion of the mechanical world by the instantaneous character of electricity" (*Understanding Media*, 349).

59 "Here you had a first glimpse at feedback's worst enemy, the effect called 'hunting.' Since a mechanical control mechanism always has mass and friction, it is always a trifle *late* in compensating for an error. If it is sluggish enough it may be so late as actually to apply its correction in the wrong direction, thus increasing instead of decreasing the error. If it is less sluggish it may still be late enough so that the correction is carried too far, thus demanding a second correction in the opposite direction. This leads to oscillation. The control constantly 'hunts' for the zero-error condition but never quite finds it" (Woodbury, *Let Erma Do It*, 35).

60 The black layer is the "key" image; hence the acronym CMYK.

61 Parrish, "Presses and Presswork," 249.

62 Matt Buchanan, "An Apparatus for Treating the Air."

63 In the early 1950s a few industry publications complained of poor registration on Technicolor film prints—an inevitability as the process scrambled to keep up with an increased demand and new widescreen formats like Cinemascope, which created problems "of matching up the images in the processing" ("Think Technicolor Can Lick Printing Troubles but Other Labs Hope," 7).

64 Frank, "Traces of the World," 37.

65 Many twentieth-century print processes involved the transfer of images into relief or intaglio plates using photosensitive chemicals and darkroom processes.

66 See Frank, *Frame by Frame*.

67 While a single registration error may tell us little about what, precisely, went wrong in the pressroom, imagine myriad versions of the same image, all in error: animated, like frames of a film, they might just depict the printing web's gradual or abrupt lateral drift, a sudden jam, a missing layer of ink.

68 Bazin, "The Ontology of the Photographic Image," 14.

69 Snyder and Allen, "Photography, Vision, and Representation," 162.

70 "Monthly Chat."

71 Pirandello, *Shoot!*, 27.

72 Ibid, 28.

73 Ibid, 8.

74 A 1920s edition of the manual *Motion Picture Photography* recommended that professional camera operators carry both automatic and hand-cranked cameras. While the automatic camera required less time for setup, the hand-cranked camera allowed the operator to "lag" on important subjects while letting others "speed by" (Carl Lewis Gregory, *Motion Picture Photography*, 358, 364).

75 The distinction between hand-cranked and automatic drive mechanisms recalls that between the chronophotography of Eadweard Muybridge and Étienne-Jules Marey: Muybridge's famous study of a horse in motion was engineered to produce photos at a rate that was controlled by the pace of the horse itself; Marey, by contrast, produced his motion studies using a mechanical shutter opened and closed according to a relatively stable rhythm; he claimed that his method yielded more scientific data because of its capacity to measure changes in speed (Marta Braun, *Picturing Time*, xvi).

76 If viewed with a keen understanding of the labor and technology that constitute them, such recordings could provide windows into the space of production, as Mihaela Mihailova has demonstrated in an exemplary essay on motion capture, "Collaboration without Representation."

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