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PLACE STUDIES
IN ART, MEDIA, SCIENCE AND TECHNOLOGY

Historical Investigations on the Sites and the Migration of Knowledge

VDG

Encoding Motion in the Early Computer: Knowledge Transfers between Studio and Laboratory

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Digital art in recent decades has seen a proliferation of creative practices based on motion capture. In computer games, feature films, interactive installation and new musical interfaces, the sampling of movement for transcoding into multiple media is now taken for granted by artists and audiences alike. Yet the expressive potential of this fundamental operation of new media goes far beyond simple mapping of gesture to fixed graphic or sonic dimensions. As Brian Rotman has suggested, the disaggregation, or deterritorialization of human motion cuts it free from the "place, time, context, circumstances, physical form, and presence of its performance".[1] It becomes a *discrete temporal object*, and as such enables analytic access to movement itself (as distinguished from its implicit representation in cinema), which in turn permits both radical compositional processing in new media artworks and its incorporation within hybrid assemblies of human and artificial (non-human) agents.Formulated in these terms, the freeing of motion from its embedded origins in the body may occasion nothing less than a new kind of "gesturo-haptic" writing, as Rotman has put it, notationalizing movement in the same way as alphabetic writing did speech.[2]

In this article, the wider media-theoretic implications of motion capture will provide a conceptual backdrop against which to consider the earliest attempts to encode motion for expressive purposes in computer animation during the 1960s and early 1970s. It focuses on a little reported episode in the early history of computer art, reconstructing the conditions of innovation of a single aspect of motion capture – hand drawn gesture for "picture driven animation" developed by Ron Baecker at the Lincoln Laboratory at the Massachusetts Institute of Technology. The institutional setting where the inventive work occurred – first at MIT, then in a second stage at XeroxPARC, will be contrasted with several contemporaneous sites for experimental development (artist-in-residence projects at IBM and AT&T's Bell Labs), where animation was programmed using more algorithmic or conventional frame-by-frame methods. The text begins with a brief media-archeology of the discrete temporal object, then turns to a narrative account of Baecker and his colleagues' work between 1966–1974. The conclusion interprets the subsequent sidelining of the promise of the original research in relation to the dominant trajectories of computer graphics research after 1975. In a brief epilog, a contemporary new media art work integrating hand-gestural motion capture will be described as a remarkable instance of the nascent conception of gesturo-haptic 'writing'.

Discrete Temporal Objects

A media-archeological perspective on the "cultural topos"[3] of the discrete temporal object lies far beyond the scope of this article. It is relevant, however, to briefly acknowledge the highly imaginative grouping of precedents in Sigfried Giedion's 1948 classic *Mechanization Takes Command: A Contribution to Anonymous History*. In a chapter surveying "movement, scientific management and contemporary art" from the 1880s to 1920s, Giedion notes the common concern for representing the pure form of movement in the work of physiologist and chronophotographer Jules-Étienne Marey, and the scientific management analytics of Frank and Lilian Gilbreth.[4] These were not discrete temporal objects in the sense that computational motion capture is a distinct media artifact. Marey's 1885 photographic trajectory of a crow's wing, for instance, uses techniques not dissimilar from current motion capture; and the Gilbreths, much influenced by Marey's precedent, applied the idea to time and motion studies in the workplace. Both separate inner dynamics from any effort to "reproduce naturalistically an outside object".[5]

Two other antecedents bear mention before turning to detailed discussion of early digital motion capture. First is a media-theoretic reflection on musical notation, which, as Kittler noted, is one of the oldest means of "capturing time".[6] Yet seen from the present perspective, notation is more than just a form of symbolic recording; it is a "rationalization of acoustic experience", in the phrase of music philosopher Hugues Dufour, a means of disaggregating entrained bodily motions into a symbolic code that proved to be highly potent in generating new potential for musical construction.[7] Notably polyphonic composition, but more broadly architectonic musical thought grew out of this disaggregation; when understood as "abstract machines", such forms play a part within a complex chain of mediations between pre-compositional thought, compositional inscription of instrumental and vocal performance, and imaginative reconstruction. The chain of mediations occasioned by music notation may be understood to include the notated score itself as a discrete temporal object in a hybrid apparatus of people, instruments, and symbolic representations.[8]

Though not mentioned by Giedion, abstract animation in the early cinema was essentially concerned with the representation of motion as distinct from depiction. Much influenced by the ideal of what is now often called "visual music"[9], artist-animators such as Eggeling, Richter, and Fischinger also established a sole-author mode of production in diametric opposition to the fragmented work flow of industrial animation, in which the creative and reproductive tasks are hierarchically distributed among a large number of individuals. The practice of camera-less animation, in which marks are inscribed directly on celluloid, was developed by subsequent experimental animators such as Norman McLaren and Len Lye. McLaren in particular played an important role in the articulation of animation as an improvisatory, intimate, and anti-authoritarian art form, liberated from the Taylorized reproductive processes of conventional cel-animation.[10] In a 1956 talk, McLaren gave an influential definition of animation that makes explicit the conception of the distinct temporal object.

> "The mobile element of film can almost always be broken down into two components, the form of the moving object and the motion itself (divorced from the particular form it is expressing itself through); for instance a photographed man, a cartoon man, or even a simple triangle or a blob, can all leap in such a way that the viewer has an impression of joy, sadness, youth or old age. If examined carefully frame by frame on a motion-picture strip, the various movements expressing joy will be found to have a common characteristic; similarly, the various movements of a tired leap will all have common factors of timing, tempo, acceleration, and deceleration. So the motion can be spoken of as separate from the particular thing, shape or form that moves."[11]

Interactive Computer Graphics at Lincoln Laboratory

The groundwork for interactive computer graphics occurred at the Lincoln Laboratory at MIT during the 1950s, driven by the SAGE project, an American military program for air defense and real time automated battle control. This was the first time a computer was used to control a large geographically distributed system, and to support real-time surveillance of the North American airspace, unprecedented graphic interaction techniques were developed. These included display monitors (then called scopes) and pointing-selection devices (called light guns) permitting the selection of virtual objects. Out of this technological foundation, within a top-secret military base, a new approach to human-computer interaction emerged in the late 1950s, built around the research platform of the TX-2 computer. Fabled in the lore of computing history, the TX-2 had 70,000 words of memory, more than twice as much memory as other large machines of the day, and was as large as a medium sized room. TX-2 had every known gadget for interaction – switches, knobs, push buttons, tablet, light pen, and display.[12]

By the early 1960s, a broader civilian generalization of real-time computing had grown up at MIT and spread to the wider Cambridge environs. These more general implications had been appreciated at an early date by psychologist J. R. C. Licklider, whose 1960 article "Man-Machine Symbiosis" was closely informed by the concrete experiences he and his circle had of the earliest real-time graphics systems at the Lincoln Lab. In this influential text, Licklider articulated with striking clarity the ideal of a symbiotic partnership between men and computers, mediated by software and interface devices to facilitate "formulative" thinking. What he termed the "third space" – an intermediate zone of symbiosis – would, Licklider forecast, come to "constitute a dynamic, moldable medium that can revolutionize the art of modeling. Trial-and-error procedure ... to permit non-programmers to use the computer to help formulate the terms of new problems, not just use it to solve problems already formulated."[13] As Paul Edwards has noted, "Man-Machine Symbiosis" rapidly achieved the status of a reference point in computer science ... the universally cited founding articulation of the movement to establish a time-sharing, interactive computing regime."[14]

Licklider was also very interested in the potential for "computer graphics as a medium of artistic expression". In a paper of this title given in 1968 at the Metropolitan Museum in New York, he pronounced his view that "the main role in which the computer can serve art ... is that of a new medium of artistic expression".[15] Licklider, the theorist of computing, turned to Ernst Gombrich as authority to make the argument that "the representation with the greatest verisimilitude is not often the best means or medium of communication. Good graphical communication is more a matter of linguistic expression than it is of pictorial reproduction."[16]

In terms of technical advances on the TX-2, the most influential was Ivan Sutherland's Sketchpad "an interactive design tool for the creation, manipulation, and display of geometric objects in two or three dimensional space. The system permitted operators to sketch with a light pen on the face of the monitor, change the position and size of objects, duplicate objects, and paste them into an evolving design".[17]

Prominent among the next crop of results after Sketchpad was a system for "interactive computer mediated animation", implemented as a dissertation project in Electrical Engineering at MIT by Ronald Baecker between 1966–69. In interviews conducted for this article, Baecker acknowledged he was greatly influenced by the breakthroughs in user-interactivity demonstrated by Sutherland's Sketchpad, and by Licklider's vision of human computer symbiosis.[18]

Separately, Baecker was also drawn to and inspired by the experimental film culture of Harvard University's Carpenter Visual Art center. Baecker was in particular impressed by the range of experimental techniques and creativity found in the work of Norman McLaren, in which he saw "incredible richness of motion control; simple motion over complexity of imagery". Baecker would later enlist support for McLaren's definition of animation in his dissertation as "not the art of drawings that move but the art of movements that are drawn. What happens between each frame is more important than what exists on each frame. Animation is therefore the art of manipulating the invisible interstices that lie between the frames. The interstices are the bones, flesh and blood of the movie, what is on each frame, merely the clothing."[19]

Baecker started "to think what could you do to couple an artist directly to the computer?" He was invited to show a simple animated stick figure in 1967 at the New York chapter of E.A.T. Experiments in Art and Technology, a forum for meetings between artists and engineers. At the EAT meeting, Baecker met Michael Noll, a Bell Labs researcher who had done some early animations for scientific visualization. Noll introduced Baecker to Eric Martin, an animator then teaching at Harvard, just down the street from Baecker at MIT. Martin would later express his artistic credo in these terms:

> "Animation is the graphic art which occurs in time. Whereas a static image (such as a Picasso etching or complex graph) may convey complex information through a single picture, animation conveys equally complex information through a sequence of images seen in time. It is characteristic of this medium, as opposed to static imagery, that the actual graphic information at any given instant is relatively slight. The source of information for the viewer of animation is implicit in picture *change*: change in relative position, shape, and dynamics. Therefore, a computer is ideally suited to making animation 'possible' through the fluid refinement of these changes."[20]

Martin worked with Baecker at Lincoln Labs every Sunday for more than a year. His role was to use the system and to provide suggestions for new functions and to evaluate them as they came online. After the second or third visit, Martin came to a new realization, that this was "a radically different medium." Martin recounts:[21]

> "The imagery was very limited. We'd draw a ball with 7 dots. We both strongly agreed that what was important was not what was in the frame, but what was in the behavior. Ron was happy to put aside pictorial detail, and to focus on motion. This

> is what I realized was radically unique, and it has to just come to you, this kind of realization – the idea of motion as distinct entity. Before, in traditional animation technology, motion wasn't a separate thing, it was implicit, embedded in the images as such.
>
> The light bulb went on, how it went beyond the constraints of previous film animation. I asked Ron, would it be possible to create a motion that would have its own integrity, would be a separate thing? The next week, Ron had implemented it. It was possible to draw a path."

Baecker expressed the moment of co-discovery in similar terms:

> "I was very much influenced by Eric, the minimalist school of animation ... look at what you can do with 3 dots – if 3 dots move well, on that you can base a story ... My insight was that if you could draw images you could also draw motions. Putting all that together became the Genesys package and picture-driven animation, operational by summer 1968."

Martin considered the idea of drawn motion as a distinct digital entity as a mutual discovery, arising from a sort of attunement between the artist-user and the engineer-designer. Thus Martin was more than an early user of the system; he was in part responsible for its model of interaction. Martin:

> "It was a co-evolution, co-invention. We worked well together, we clicked. I was enormously sympathetic to his idea that this kind of simplified method of animation production was going to have incredible potential in hundreds of fields."

Defined as P-curves (parameter curves) in Baecker's thesis, the importance of this contribution was, in the textbook account, to permit the "substitution of a visual program for a textual one: rather than explicitly writing out descriptions of actions, the animator provides a picture of the action. A P-curve is a parametric representation of the motion (or any other attribute) of an object or assembly of objects in a scene. The animator describes an object path by graphically specifying its coordinates as a function of time."[22]

Baecker also stressed the novel power of trial and error experimentation, not available on film.

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display. He will be led to perfect that aspect of animation that is its core: control of the changing spatial and temporal relationships of graphic information."[23]

Going beyond its use in producing simple animations, also Baecker speculated about the potential for picture driven animation to become a new kind of dynamic iconic language. Such a language would use "dynamic signs [to] move about and develop in self-explanatory ways to express abstract relations and concepts". To be useful in communication and education this would require "the invention and development of new conventions and a visual syntax appropriate for this new medium".[24] This nascent idea of gestural "writing" will come back at the conclusion of this paper.

Baecker was also able to get support from Lincoln Lab to hire an artist to be filmed using the system. This artist, Lynn Smith, recounts that after a brief introduction she was able to work on her own, managing to produce an independent unauthorized film with Genesys. As an artist improbably working in a high-security military base, she had no idea what was going on there; nor did higher authorities know what she was doing.[25] The demonstration film was shown at conferences and spread the reputation of the Genesys system within the growing counter-cultural computing community of the early 1970s. For Ted Nelson, an enthusiastic promoter of graphics computers as "dream machines", the basic elegance of Baecker's system was that "it made everything work the same way, through control by screen diagrams. [He] had simplified the animation problem in a clear and simple way".[26]

Artists-in-residence at AT&T Bell Labs and IBM

Parallel to Baecker's artist-oriented research on animation at Lincoln Labs, several other projects were underway at major U.S. corporations. During the mid-1960s, AT&T and IBM were at the height of their prestige as high technology companies, and operated substantial research programs exploring new applications for computing. Both firms invited experimental artists to work on new systems with staff engineers, and the results of these residencies pose revealing comparison with the MIT work based on interactive computing.

The Communication Science Division at Bell Laboratories was the site of key innovations of the information age, notably the transistor, satellites, and information theory. The division engaged a diverse group of behavioral scientists in fundamental research about human vision and hearing, so as to better understand the technical requirements for their codification and transmission. The earliest languages for computer music and animation were developed there by 1965. Ken Knowlton was author of the BEFLIX animation language, which treated the entire viewing area as a rectangular array of dots. The language included powerful expressions for the use of algorithms to generate image patterns. BEFLIX was conceived to be an elegant general language, in which the power of the syntax lay in the complexity of results that could be produced using simple rules. This afforded a certain experimental approach, in which the programmer would specify the rules and then see what would come out. Knowlton used the program to make some demonstration films by 1965.[27]

Also at Bell Labs was Billy Klüver, co-founder of Experiments in Art and Technology, and one of the main producers of the 1966 9 Evenings of Theater and Engineering, in New York City. The systems presented in this showcase, using custom built sensors, optics and electronics, were designed by Bell Labs scientific volunteers. In this research culture conducive to collaboration with artists, Knowlton began working with filmmaker Stan VanDerBeek in 1966. VanDerBeek was a prolific technological experimenter himself, and brought to his work with Knowlton a pronounced utopian vision that visual art using new technologies could provide new means of crossing cultural barriers between peoples.[28] He understood the mosaic-based patterning properties of the BEFLIX language to be similar to the structure of the human mind itself, thus providing a potential for direct communication that went beyond traditional imaging media.[29]

Knowlton's own desire was to develop the language in new directions, arising out of what he imagined to be the exceptional creativity of the artist. The general language would, he thought, become more specific and precise, through iterative cycles of experimentation with the artist. However, running on a batch-processed, IBM 360 mainframe computer, the BEFLIX language was not amenable to trial-and-error use. Knowlton tried to teach VanDerBeek to program BEFLIX, and when this failed, he developed a set of macro commands specifically for the artist to generate patterns based on letterforms. Still, the aim of iterative language co-development was unsuccessful, according to Knowlton, though the series of films they created, *Poemfields*, were widely exhibited and now are taken as significant milestones in computer animation.

The IBM interest in experimental animation appears to have arisen out of a less specific creative context than that of Bell Labs. John Whitney, Sr., a well-established film-maker, was invited to be IBM's first artist-in-residence in 1966, in order to help the giant corporation "explore the aesthetic potentials of computer graphics", at a time when it was looking for new applications for computers.[30] Whitney had already established an art-house and commercial reputation for films produced using re-purposed WWII analog military hardware in the 1950s to provide programmed control over image dynamics. Therefore, the work he did was already formalized to a large degree; the programmer who implemented software for Whitney saw his task as providing an interface to a single complex equation with 60 parameters running on a batch-processed IBM 360 mainframe. Whitney would tweak the parameters till he had an image he liked, then specify a series to be photographed in order to produce a sequence. No motion testing was available to the artist, nor was the software itself conceived as a malleable object to develop in the process of its use.[31]

As Whitney became familiar with the interface, he began to see it "like a piano", albeit one that he needed to wait half a day to hear the results. It is not surprising, in this sense, that in the course of his digital production Whitney turned to music theory to form the basis of the motion dynamics. A shape was like a musical tone, and a sequence like a melody. He considered sequences of melodies as analogous to phrases, and parallel sequences to polyphony.[32] With his celebrated series of computer films produced at IBM, *Permutations*, Whitney began a search for what he considered to be operative laws, grounded in European music theory, for the regulation of a new form of visual music based on "digital harmony".[33] The harmonic relations, based on what he thought were visual equivalencies to consonance and dissonance, were far removed from the need for any kind of improvisatory gesture or emergent property.

In contrast to the research culture of Lincoln Lab, informed as it was by Licklider's theorization of real-time "formulative thinking", the settings at IBM and Bell Labs provided artists with no means of previsualizing motion sequences. In the first case, algorithmic power predominated in the vision of the developer; in the second, it was sequential specification of single frames. Batch processing of punch cards in both corporate settings in effect precluded support for the improvisatory work flow afforded by the hand-guided gestural drawing system at MIT.

Art Demos for Interface Research at XeroxPARC

In 1973 Baecker's work also attracted the interest of Alan Kay at Xerox Palo Alto Research Centre. PARC, founded in 1970, is now acknowledged as the site of several of the key innovations of the modern computer, including Ethernet, laser printing, and centrally for this article, the now standard Graphic User Interface for the personal computer.[34] Alan Kay was a versatile and charismatic character who had been a professional musician and earned a PhD in computer science from Utah, where Ivan Sutherland amongst others had relocated the leading edge of graphics research. By 1974, Kay's Learning Systems Group at PARC was well along in putting together the basic hardware and software components for what would become the personal computer. Building on several sources, notably Sutherland's Sketchpad, Douglas Engelbart's SRI work on interfaces, Seymour Papert's research at MIT on end-user programming, Kay was interested in supporting a research project on animation as one among several applications of the new Alto personal computer prototype and programming language, SmallTalk, which was then still untested by real users. The interface on the Alto included what would become the standard graphic interface: icons, windows, menus, and a mouse for selection and manipulation of objects.[35]

Under Kay's sponsorship, Baecker put together a group to re-implement and improve Genesys in SmallTalk. His three-person group included Eric Martin and a programming assistant from Toronto. Developed over two summers at PARC, 1974–75, Baecker's new program, re-christened Shazam, was a notably successful demonstration of what Kay would later report on as "Personal Dynamic Media" in the now classic article by this title.[36]

Kay's vision was, and is, of a creative computer literacy that combined the discipline of explicit text-based symbolic programming with an intuitive iconic direct manipulation of visual objects. For Kay and his associates, Shazam served as an ideal illustration of what interactive computing could become.

> "Animation, music and programming can be thought of as different *sensory views* of dynamic processes. The structural similarities among them are apparent in Small-Talk, which provides a common framework for expressing these ideas."

Two details of the developments made to Genesys in the PARC environment are worth underlining here. First is the notion of displaying two simultaneously active windows with several different views of the same dynamic process. While one window was showing a looping preview of the animated object, the user could operate on it in real time in the other window.[37]

Second, this was a clear instance of Kay's hope that SmallTalk could serve to program applications designed for easy use by artists, as well as for project-level extensibility. Baecker, in a 1976 paper, thus wrote: "A suitably skilled animator may himself determine aspects of his *animation system*, only if the system is not a fixed set of commands but an extensible, truly open-ended programming language".[38]

While Shazam was a relatively small program, the most developed of the early SmallTalk projects, according to Kay, was David Smith's PYGMALION, "an essay into iconic programming".[39] As such, Baecker's interactive animation system was a prime demonstration that programming a computer need not limited to textual coding: it was, for Smith, at "the core of Pygmalion's model of articulate communication".[40]

Subsequent Trajectories of Computer Graphics Research

MIT, IBM, and Bell Labs were not the only collaborative environments where artists experimented with motion graphics in North America before 1970. While they will not be described here in detail, other work at the National Film Board of Canada, and at Ohio State University provide further points of comparison with Baecker's picture driven animation. The Canadian work used the computer to automatically interpolate between hand-drawn images.[41] At Ohio, influenced in part by Genesys, animators could control moving objects with an array of knobs and buttons, somewhat akin to the kind of direct manipulation available to composers with the analog synthesizers of the day.[42] For present purposes, it will suffice to note that these early explorations of art animation using the computer were to a large degree subsumed within two technological trajectories of growing power from the late 1970s onwards. The first of these "Holy Grail" research programs was photorealism as representation ideal, and the second was the Graphic User Interface itself with its eventually ubiquitous adoption in all personal computers.

The progressive ideal of photorealist depiction in both industrial and academic research was articulated as early as 1965 by Sutherland, who wrote that "the screen is a window through which one sees a virtual world. The challenge is to make that world look real, sound real, feel real".[43] With a rapid sequence of inventions, including the frame buffer, a host of rendering algorithms, and improvements in raster displays, resources turned to the computationally intensive, non-real time production of images responding to the photorealist agenda. As one of the Canadian engineers wrote in 1990, "the general trend in animation was to exploit high quality rendering of complex surfaces with reflective properties, which required massive computation, were intractable to responsive interaction, yet produced spectacular visual effects but ultimately were dull animated logos".[44] Another perspective on this shift is provided by Dan Sandin, inventor of an early digital image processing tool in the 1970s: "In the early 1980s (with the exception of space roaches in video games), computer graphics stopped moving in real time. Frame buffers gave us photographic realism, but computers could not move enough bits fast enough to animate in real time."[45] Myron Krueger's Videoplace[46] stands apart from this tendency in the media arts field, as almost the exception that proves the rule.

The GUI can also be interpreted today as a strong example of an innovation that gained momentum as it was widely diffused, excluding alternatives that may have been equally viable at the outset, and coming to acquire a perceived sense of inevitability. For example, elements of the initial interaction system demonstrated by Engelbart in 1968, including a two-hand "chord keyset" as well mouse, were excluded from the familiar mouse and standard keyboard locked-in to the standard

GUI.[47] Similarly, according to HCI authority Bill Buxton, Baecker's picture driven animation provided an existence proof for a general interaction style that "has significant relevance to future marking interfaces...[but] today's computers are singularly unsuited for handling this kind of rapid, simple articulation of spatial/ temporal relationships".[48]

By the turn of the millennium, both of these powerful trajectories had begun to run out of steam. Notably, in graphics so-called non-photorealist rendering became a leading research topic as the perception spread that many of the original "hard problems" had been solved.[49] In interaction design, a host of new research paradigms are being actively pursued, based on underutilized modalities (e.g., voice, touch, gesture). As one possible guide for interpreting these new directions, and to relate them to the earliest work on hand-drawn interaction, it will be useful now to return to the Rotman conception of gestural-haptic writing.

Looping Back

At the same time as photorealist and the GUI paradigms have ceased to provide an agenda for fresh new research, motion capture is starting to be understood in more radical media-theoretic terms. Rotman differentiates between notational and capture media, suggesting that while the former "notates the signifying sounds produced by organs of speech", the latter "offers gestures the same kinds of mobility, dislocation and freedom from the contexts of their production as the notational system of alphabetic writing allowed speech". Rotman points to a possible 'grammaticalization' of sampled motion, which, like words, might be "identified, individualized, examined, replicated, and synthesized as discrete and autonomous objects of conscious attention."[50] Similarly, as Bernard Stiegler has noted, we now have 'grammars' and 'dictionaries' of animated objects, a result of what he terms a "discretization in the domain of animated images".[51]

As previously noted, these notions were anticipated by Baecker in 1969 when he forecast the formation of a linguistic order for discrete time-based gestural communication. Buxton appears to be alluding to similar functionalist application of gestural writing in the field of marking interfaces. We may look forward, though, to a more radical creative envisaging of the prospects for manually produced digital temporal objects, by examining a visionary work of digital art based on sophisticated integration of motion captured data in a framework including artificial agents.

The work, *Loops* (2001–2008), was the result of a collaboration between two artists, Paul Kaiser and Shelley Eskar, and a programmer-researcher, Paul Downie, supported by a commission from the MIT Media Lab.[52] Their work drew on a rich data set produced by Merce Cunningham, who had earlier choreographed a movement work for two hands only. The data captured thereby produces an animated art work that is "manifested through the probabilistic interaction of its distinct parts".[53] Importantly for the present argument, the twenty-two data points set in motion by Cunningham's hands are each given a degree of autonomous agency, in a relational network defined by a simple set of behavioral rules. Neither a simple mapping of hand motion onto graphics, nor an algorithmic animation in the strict sense, *Loops* operates in a complex middle zone between realism and autonomy. The program is not interactive with viewer/users, but runs in live, in effect improvising the rendered images in real-time based on the pre-composed motion captured data-set.

In this work, premonitory as in the best of new media art, the discrete temporal object goes beyond a one-to-one mapping between gesture and media-image. Its discreteness is at another level, becoming an object in a longer circuit of mediations: from a wholly determined product of sampled gesture, the manual motions are given a quasi-autonomy which in turn are used to drive the sensorial result. This work indeed provides a view of what Rotman suggests could be understood as a "new order of body signification"[54], one in which the digital discrete temporal object, first captured and interpreted in the 1960s at MIT, begins to be interconnected seamlessly with artificial agents that have a degree of their own temporal independence. In this new order, movement would not only be grammatised in a quasi-linguistic manner; it would be, as in *Loops*, the occasion for a mutual joining of human and non-human virtuosities.

Endnotes

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