

Exact Imagination and Distributed Creativity: A Lesson from the History of Animation

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ABSTRACT

This paper discusses the introduction of software as a creative medium for animation production at the National Film Board of Canada during the 1960s and 70s. In a creative environment shaped by a strong auteur tradition, in which individual film-makers fashioned new technical set-ups as part and parcel of each new expressive work, the first system for figure based computer animation was introduced and proved out with a highly convincing demonstration film, *La Faim/Hunger* (1973). The techno-aesthetic frame of auteur animation conditioned the collaboration with programmer-engineers so as to sustain an already strongly embedded tradition of individual authorship. The collaborating team seamlessly distributed creative contributions between the roles of director/artist, software programmer, technical animator, and producer. The last two roles were central because they both entailed the ability of a single individual to understand both sides of the technical and artistic creative process, thereby serving as a bridge to the other two more specialized roles (artist and programmer). The collaboration in this emblematic case was a strong instance of “exact imagination”, a concept here introduced to designate a close interdependency between the technical and artistic components of a creative work. A particularly valuable result of exact imagination when distributed amongst collaborators is the production of diverse outcomes – original contributions accepted within multiple disciplinary domains. *Collaborative research today will benefit from the emergent formulation of such an exact imagination, distributed across networks of differentiated creative individuals, and buttressed by enlightened institutional policies.*

Author Keywords

Computer animation, key-frame interpolation, auteur animation, exact imagination, distributed creativity

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INTRODUCTION

This paper is a case study of the introduction of software as a creative medium for animation production at the National Film Board of Canada during the 1960s and 70s. While contemporary digital arts have been investigated in creativity research to some degree, the historical transition from analog to digital methods in particular domains of creative practice has yet to receive much attention. Animation – particularly fine art animation – provides a rich domain through which to study how creative practices were first modeled and computerized, as the pre-digital practices were both highly diverse and strictly conventionalized, and modes of production were both individual and collective. The hierarchical division of labor for cel animation, developed in the 1930s for the production of the classic full animation feature film, was paralleled by a strong tradition of independent experimental animators. The “auteur tradition” in animation was particularly strong in the period from 1950-1975, often in a movement of opposition to the elitism of the industrial system, where there is one producer-director, but upwards of hundreds of subordinate artists and technicians. Norman McLaren, one of the leading auteur animators in this period, expressed his creative credo as:

- “attempting to keep at a minimum the technical mechanism standing between my conception and the finished work.
- handling personally the mechanisms that do remain, in as intimate way as a painter her painting, or a violinist his violin.
- making the very limitations of these mechanisms, when brought in touch with the theme, the growing point for visual ideas.
- making sure of a chance for improvisation at the moment of shooting or drawing.” [1]

This approach to animation, integrating artistic creation with technical experimentation within the context of each new work, requires a particular kind of imagination married with experimental rigor in the devising of production apparatus. This “exact imagination” was typically combined in the person of single individuals, like McLaren, Fischinger and Lye, or very small teams, like the Whitney brothers. [2] In

McLaren's case, with each new animation he produced, an accompanying technical publication appeared, detailing the methods invented for the project. [3] This parallel output is typical of successful practice based research in general, where multiple outputs are produced along both artistic and technical-scientific lines. [4]

ARTISTS AS LEAD USERS OF EARLY COMPUTER ANIMATION SYSTEMS

The base technologies for interactive computer graphics were largely developed in U.S. military research programs, often closely aligned with key universities like MIT, and supported by the Pentagon's aggressive funding of fundamental information processing research. [5] By the mid-1960s, development of civilian applications was underway as well, notably in aviation, architecture, and scientific communication. Many of the same organizations also experimented with artists as lead users of early mainframe animation systems. Broadly speaking, two design approaches towards computer animation were pursued: picture-driven and language-based. The latter specified visual images and their continuity using traditional textual computer programming languages; they depended on the ability to describe visual phenomena mathematically. Picture-driven approaches aimed to assist aspects of the hand-crafted art of animation, permitting the non-specialist artist to draw and ink the cels serving as key-frames, using the computer to coordinate the images and calculate the transitions between the key-frames. [6]

Beginning in the mid-1960s, researchers at the National Research Council (NRC) and the National Film Board (NFB) – both agencies of the Canadian federal government – began to investigate the potential for using computers in filmmaking.¹ In both cases, the Canadian investigators were scientific and technical followers, not leaders. In comparison with their American counterparts, they had very restricted budgets for equipment and personnel, and were therefore acutely aware of the need to select their area of intervention with caution. They began their research by intensively studying everything the Americans had done to date, with the aim of finding unique research problems appropriate to their local work culture, and especially, their restricted means. Though the notable success of this work came from the ways the two institutions found to cooperate with one another, the programs began separately and grew up within research cultures sympathetic to techno-aesthetic experimentation. In the case of the NRC, the Radio and Electrical Engineering department had been the location of groundbreaking research in electronic music since the early 1950s. [8] As for the National Film Board, its Technical Research Program had an ongoing responsibility to monitor the global state of the art in cinema and audio-visual technology on behalf of the Canadian motion picture industry as well as the Government.

¹ Throughout these sections, primary sources are personal interviews with the author as cited with endnotes when quoted, except where otherwise indicated. [7]

During the mid-1960s, when creative investigations of computing began, NFB technical innovation was internationally recognized in recording, projection, editing methods. Both its staff and documentary production units employed resourceful producers who were themselves individually committed to technical experimentation as a regular aspect of production. The range of problems they needed to solve included low-cost production for documentary and scientific filmmaking (often of technical/mathematical subjects) as well as high-profile international expositions – showcases of state-of-the-art cultural technologies.

The NRC researchers, Ken Pulfer, Marcell Wein and Nestor Burnyk, had previously worked on radar and rocket instrumentation, and did not consider themselves even to be “computer people” in 1965, when they decided that making computers usable by “non-literate” people was an interesting problem. (By this they meant, scientists and engineers who would use experimental computational methods in their research, not as routine clients of data-processing facilities.) From the start, they had little interest in the batch-based methods of mainstream computation; indeed their interest was not in number crunching per se, and certainly not the theoretical subject matter of the newly forming discipline of computer science, but in “problem solving in a general sense.” Coming from a background of tinkering with hardware, what that wanted was speed, responsiveness, and in particular immediate graphical display. They made the unorthodox choice of acquiring a general purpose industrial control computer, then designing and fabricating the input-output devices necessary to support their two chosen creative applications: animation and music composition.

The nature of the work process they wanted to support was close to what Schon calls the “reflexive conversation” of any skilled practitioner with her materials. [9] On the supposition that creativity in applied and pure sciences is the same as in art, Pulfer elaborated in a contribution to a new journal on Man-Machine Systems, that “the process involves trial and error, with the creator modifying the mental image of his creation as it takes place. He interacts with his creative medium...in a conversational way, learning the ‘language’ in which he can express himself as he goes along”. [10] Their primary interest was not mainly to develop applications in computer graphics or music as objectives in themselves, but rather “to find out more about the interaction problems in a creative environment.” He recalls their aims as discovering

... how to help physicists and other scientists who were starting to use computers. Some had that kind of mind to program, others didn't. So this wasn't a surprising area for a national laboratory. Going from the needs of scientists to animators and musicians was fine, we were trying to generalize the problem. The scientists were being supported at the regular computation centre; but they weren't being helped the way we were talking about. [11]

Reviewing what had been achieved to date in the U.S. labs, they determined early on that there was little challenge in using the systems themselves to create proof-of-concept demonstrations; indeed, they found the artistic quality of much of the engineer-programmed art efforts pretentious and embarrassing. Their own latent creativity was, it appears, never idealized, nor the computer taken as lowering conventional assumptions of high barriers to creative originality. A more serious challenge was to support “real users” – that is, professional composers or animators, but in a work process entailing incremental, conversational, and direct hands-on improvement. Pulfer wrote at the time:

...Up to this point, it has been assumed that the best possible way to design the computer would be to make it transparent. That is to make it look to the user as though it were not even present, so whatever idea occurred to him, it could be rapidly formed into a final creation. This is not necessarily true. [10]

Instead, Pulfer insisted, constraints are crucial to the creative process, giving examples such as conventions for perspective drawing in architecture, or scales and notational conventions in music. By computationally modeling such conventions, the user is given a more meaningful starting point than the abstract “blank slate” of total generality.

...Most computer languages now available...are unsatisfactory either because they are mathematically oriented, or because they result in cumbersome and slow programs. As a result we are usually left with the situation where an artist-programmer team is formed, the artist uses the system without having intimate control over the functions of the blocks he uses, and the programmer builds blocks without fully appreciating the needs of the artists. [10]

Pulfer and his team chose therefore to develop a system in which:

at no time [would it be] necessary for the user to learn how to program the computer, or in fact even to know how to operate it other than through making some choices from names presented to him on the screen... he can proceed to learn the ‘language’ by trial and error.[10]

Crucial to the implementation of this design was the just-published research of the first graphical user interface demonstrated in 1968 by Douglas Engelbart, as a system for “augmenting the human intellect.” [12] It is now well known that the researchers in Engelbart’s group carried the main innovations to Xerox PARC where they became important aspects of what would become the personal computer interface. [13] It is less well known that the NRC animation-music researchers were actually the first outside SRI to implement the mouse, as well as the chording keyset for the left hand; by 1970, as one researcher would later recall, the NRC’s home grown assembly was the functional equivalent

of a “1984 Apple Macintosh,” in use around the clock by professional composers and animators. [14]

The animation project came into focus when one of the researchers heard a Disney animator in Los Angeles describe how the factory-style animation studios operate, with work divided between head animators and assistants who filled in the in-betweens.

Understanding of the Disney studio was crucial here: the in-betweeners were not “low level assistants,” but they weren’t providing the creative component: rather they were restricted in what they can do, their contribution is very well defined, precisely constrained, just to do the job required... the nice thing was, it was not inventing a new way to do things, we were just going to mimic the conventional process that with which all the film animators were familiar. [15]

By 1970, the NRC had implemented for the first time a complete user-oriented system to emulate conventional cel animation, where the components are drawn on celluloid and combined into sandwich layers. The practical orientation would use the computer to simulate the drawing table and mimic the traditional tools used for drawing, inking, and in-betweening. The system was immediately used for commercial title sequences and was ready, in the researcher’s minds, to take on more challenging creative projects.

TECHNICAL INNOVATION AT THE CANADIAN NATIONAL FILM BOARD

The National Film Board of Canada, founded in 1939 as the Government Film Office, was home to a world famous tradition in documentary film and experimental animation. [16] A strong technical research department maintained a watch on the global development of motion picture technology, and this group too had a well-established tradition of technical innovation. In 1951, under the direction of the already highly acclaimed animator Norman McLaren, it had produced the first stereoscopic animated film, presented to stunned crowds at the Festival of Britain; during the mid-1960s, another team of filmmakers and technicians developed a unique multi-screen projection and camera system for the Labyrinth pavilion which was soon thereafter transformed and commercialized as IMAX wide-screen format. [17] An electrical engineer who had previously worked in the telecommunications industry on the application of the computer to digital signal switching brought a disciplined benchmarking approach to the analysis of the computer as a tool for motion pictures. This quickly produced an intensive learning program in which the NFB had received visits from and in most cases, pursued in-depth dialogues with all of the key U.S. players; it also conducted tests using borrowed equipment. [18]

McLaren had insistently taught that the animation set-up should be malleable to the individual’s creative gesture, permitting improvisation like a musical instrument; but most important was that the particular material properties of the

set-up, their limitations “when brought in touch with the theme,” should “be the growing point for visual ideas”. This was the heart of the artisanal lesson of McLaren to NFB animators, that each new film be made in a small workshop of at most a few persons, with its own unique technical approach. This insistence at the NFB on an intimate link between a film’s technique and what it had to say was described by one its later practitioners, Pierre Hébert, as in terms of an allegory of “attunement” with technical apparatus. Hébert worked closely with McLaren, and went on to direct the French Animation studio, all the while developing a unique reflective discourse on the creative process of the experimental animator. According to Hébert’s notion of allegory, the artist must approach the *dispositif* (set-up) as having its own directionality or orientation, not just as a way of producing special effects, such that the way one draws out and realizes that particular orientation becomes in itself a mode of signification. [19]

Rêné Jodoin, the head of the French animation unit, was quick to understand the way a computer technique for automatic in-betweening could enhance the already very heterogeneous range of techniques and styles pursued in his unit. Rather than considering it as a generic solution applicable across the board to all problems of production, he considered it as he would any other resource that would be applied to a creative proposal. Within the NFB, the aesthetic interest in computing had so far been articulated in terms of either increased precision in the control of the camera on the animation stand (growing out of the needs of science education), or computational modeling of image vocabularies using algorithmic logic influenced by avant-garde musical practices. Neither of these existing interests were relevant to the properties of the NRC system, which as we have seen took as its ideal user the traditional character animator accustomed to delegating the in-betweening task to highly skilled assistants. [20]

But Jodoin had just received an unusual script proposal from a free-lance European animator, Peter Foldes, which called for the extensive use of metamorphosis in the context of full hand drawn character animation. This script, entitled *Hunger*, would have required a fairly large production team including many assistants. This would have more costly than normal, and “against the grain” of the prevalent production philosophy. But Jodoin could see that Foldes’ script, demanding an unusual kind of metamorphosis between images, might just be a good fit for the early capabilities of a system designed for automatic interpolation.

Jodoin next commissioned a staff animator to write a detailed documentation of the system, and to work with the NRC designers to make a series of improvements prior even to beginning any production. These exchanges were documented in NFB memoranda, circulated to the studio collective, and a pattern of mutual accommodation developed between the NRC researchers and the NFB artists in which the system would be regarded not as a fixed tool, but as a

resource to be modified in response to particular script requirements or details. As Jodoin put it,

I think there’s a distinction between using a tool, and something able to give something beyond traditional means. Because of involvement of scientific types, Nestor and Marcelli, and the artists, in such an intimate way... there’s an understanding on their part, has to be, to satisfy Foldes and myself... It was so beautiful, because it was so hard to distinguish everyone’s contribution in there. [20]

In this pre-production phase, it was evidently important in the egalitarian work culture prevalent at the NFB to describe the new apparatus in terms that would be intelligible to the entire group, whatever their individual technical preferences. A demonstration for Foldes was arranged, and in two afternoon sessions a base of material was completed by Wein, Burtnyk, and himself that could be edited into a compelling demo film – *Metadata*. Moving quickly to share the results of this work with the international animation community, Jodoin approved the entry of *Metadata* for the main international competitive festival for animation at Annecy, France. Despite the minimal effort that went into *Metadata*’s production, it garnered significant attention and reviews in the summer of 1971. This encouraging response led Jodoin to insist that the next step should be to make a “normal” NFB film, that is one that went through the usual process of peer-based approval.

Apparently aware of special risks in displacing production from the studio to a scientific laboratory, a set of explicit criteria were prepared next to guide and justify the selection of a film proposal suitable for computer system. Jodoin assigned this bureaucratic-sounding task to Moretti, a staff member who produced a highly analytical, nuanced memorandum that was circulated at the NFB. A candidate film should be one based on a “valid cinematographic concept” – i.e., not merely a catalog of technical effects – with a scenario that would “lend itself to solution by means of computer-controlled animation”. It must also present an aspect of research concerning the generic possibilities of the system, or to improving overall methods of working with computer while still suited to the system’s quite limited capacities. It should be chosen to push the medium enough to yield ‘generalizable’ results applicable beyond the single instance; and finally, it must be presented by a producer with the background to make a coherent and structured piece.” [21]

Foldes had attended one of the international meetings on new film technologies organized at the NFB, and was already enthusiastic to experiment with electronic techniques so as to dynamize hand drawn figures. Unlike the early artist-users in the U.S., who were either modernists in their rejection of figurative drawing, or were engineers who wanted to computerize animation precisely because they could not draw, Foldes’s artistic forte was his unique draftsmanship. *Hunger (La Faim)* is an angry denunciation of human inequality, depicting a runaway consumer society eventually

devoured in a revolutionary uprising of the hungry and oppressed. The film's protagonist is the figure of civilized gluttony itself, robotically and inexorably driven to gobble up everything before him. The storyboard treatment (made before computation was proposed) used metamorphosis to dramatize the self-destructive fate of civilized man. In this way, *Hunger* fit with the public education tradition of the NFB, epitomizing a late 1960s mood of socio-cultural crisis and protest, and was sharply distinguished stylistically as well from the cutesy child-oriented mainstream Hollywood product.

It was the genius of René Jodoin that he could see from the possibilities of the NRC system, that it was precisely the style and the visual research of Peter Foldes which could directly and immediately make use of it. [19]

The artist would spend a few weeks at a time working with the system in Ottawa; in the intervening periods, improvements were made based on what had been learned in production. When *Hunger* was released in 1973, it was recognized immediately as an artistically convincing character animation; it was nominated for an Academy Award and won numerous festival prizes including best animation at Cannes.

The accomplishment of *Hunger* in matching an artist's vision to the still very intractable computer of the day can be interpreted in a number of ways. For present purposes, it will suffice to note that the technique of linear key-frame interpolation was still far too primitive and mechanical to be used for what one critics have called the "anthropomorphic" style of the big-budget feature animation studios like Disney. [22] While it promised to save costs by automating the intensive human labor of the artist drawing the intermediate frames, given its technical awkwardness, it could only be put to creative use by an artist willing to shape her vision to its mechanical constraints. Indeed, this "machinic" interpolation, which in other contexts would have been a fatal defect, gave the film its expressive signature, and the impact of the film proved to be far reaching. It demonstrated that convincing artistic films *could* be produced by computer, at a time when Hollywood was only using it, if at all, for title sequences or rudimentary special effects. As well, it had a major influence in the technical community, attracting, especially in Canada, young people to the field of computer engineering or filmmaking precisely to further the possibilities of artistic animation.

Summarizing the lesson of this early episode of productive collaboration between two studio-laboratories, both were small, under-resourced, and unable to make further progress without the contributions of the other. None of the researchers identified strongly with (nor necessarily even knew) the way things "ought to be done" in computing. From the outset, both had something of a hybrid character -- the NFB, a cultural organization with a strong technical research group, skilled at absorbing and re-purposing new

techniques; the NRC, a government research institute with an intellectual work culture friendly to artistic practice.

Foldes, whom we can consider the "lead user" of the NRC system, realized how unusual was his opportunity, when he later commented:

One could say the American computer has eyes, and the Canadian computer, a hand. The Americans have commercial pressures, a concern for profitability. The Canadians at the NRC are much more disinterested, and finance pure research. [23]

After they had made this convincing demonstration -- one that was convincing in the world of professional animation and film -- Burtnyk and Wein continued to refine the system, addressing a specific control problem that had only arisen through the production of *Hunger* and the extensive discussion the work had provoked in the technical community. Character animators found the smoothness of the system's metamorphosis problematic, as it treated shapes as global but did not allow small nuanced selection of differential rates of change in sub-components. To address this deficiency, they introduced for the first time the construct of an intermediate "skeleton" with a given number of control points which drag the outer skin closest to them as they are modified. Thus the animator was able to introduce refined variations in the rate of change within an aggregate, without needing to formalize them. The 2D skeleton concept, like the mathematics of splines, allows the artist to draw structurally in a new way, which greatly improved the refinement that each keyframe is given before the automatic inbetweening is carried out.

By now, however, their research was clearly legible in the professional terrain of the newly formed techno-scientific community that was founded during the years of production. These research results on skeleton drawing were duly presented to the ACM Siggraph conference -- and even recognized as one of seminal scientific papers in the field, 25 years later. [24] However, it was not "proven out" through production as the first system had been with *Hunger*. They did not see themselves, in fact, as "HCI" specialists (though that's what they were) because that field itself was in a pre-disciplinary formation. By producing this paper [25], Burtnyk and Wein had moved fully from general investigators seeking to understand more intuitive techniques for human-computer interaction, to builders of advanced motion dynamics programming systems.

At this point (1975-76) the NRC decided not to continue the research. The reasons are many and conflicting: management suggested they needed to look at industrial applications of graphics, such as robotics or space exploration; evidently, the notion that animation software would *itself* become an important industry was not apparent. The NRC had also, since the rising economic pressures of the mid-1970s, become uncomfortable with its association with art production, which was expressed in practical language as needing to spin-off the system to the production sector

having successfully made a convincing demonstration – the first in the world – of the viability of computer controlled character animation.

They arranged a technology transfer of the prototype production system to the NFB on the assumption that the animators there could continue to work with it once updated for faster hardware. The transaction, paid for jointly by the two agencies in a deal worth about a million dollars, was difficult and took several years just to negotiate, and another three for the work to be completed (even then, unsatisfactorily).

When finally installed at the NFB, and debugged, it became a fertile seedbed for the development of creative capacity in computer animation. Few films were produced, but intensive learning about the problems and challenges of the emerging field helped to foster the marked capability in Canada in both animation systems and production. [26]

CONCLUSION AND RELEVANCE

In a creative environment shaped by a strong auteur tradition, in which individual film-makers fashioned new technical set-ups as part and parcel of each new expressive work, the first system for figure based computer animation was introduced and proved out with a highly convincing demonstration film, *La Faim/Hunger* (1973). The techno-aesthetic frame of auteur animation conditioned the collaboration with programmer-engineers so as to sustain an already strongly embedded tradition of individual authorship. The collaborating team seamlessly distributed creative contributions between the roles of director/artist, software programmer, technical animator, and producer. The last two roles were central because they both entailed the ability of a single individual to understand both sides of the technical and artistic creative process, thereby serving as a bridge to the other two more specialized roles (artist and programmer). The collaboration in this emblematic case was a strong instance of “exact imagination”, a concept here introduced to designate a close interdependency between the technical and artistic components of a creative work. Exact imagination may be an attribute of both versatile individuals and of complex collaborations. A particularly valuable result of exact imagination when distributed amongst collaborators is the production of diverse outcomes – original contributions accepted within multiple disciplinary domains. Beyond the initial success of *Hunger* in proving the viability of computer-assisted animation in artistic terms, other outcomes included scientific papers published in the then emerging Siggraph conference; tools and systems for animation production; and, more broadly, a significant techno-economic capacity in Canada in the field of computer animation.

What may be gleaned from this detailed historical reconstruction that is relevant to creativity research in general, and in particular, to the formative research agendas for creativity and information technologies?

Configuration of Boundary Spanning Individuals

The four main innovators in this case each possessed unique personal resources that enabled a sophisticated conjuncture of vision and capabilities. They spanned boundaries in a complex configuration which helps to specify successful collaboration as a *network of finely articulated differences, rather than a simplistic binary of creative vision and technical execution*. The artist, while limited in technical capability, was an inveterate experimenter and was willing to adapt his deeply embodied skill in drawing into the numbered strokes required by the computer; Foldes called this “learning to think like the computer”, while he also was prepared to accept the unique, “non-human” transformations it produced as contributing to his aesthetic intent. The technical animator, a career NRC researcher, worked closely with the artist to digitize his natural gestures, and to progressively translate artistic requirements to the primary system developer. The producer was able to imaginatively repurpose a script in terms sufficiently exact to span the boundary from conventional to computer-interpolated animation. The role of producer in art-technology collaboration may be under-appreciated, and it is advisable to consider its meditative and imaginative potential.

Inter-Institutional Collaboration

Current and recent schemes for combining artists, scientists and engineers are typically carried out on the basis of individual match-ups, or “pairings”. [27] This case well reveals the usefulness of a higher level of support for individual innovators. The NFB’s well established tradition of technical research was able to reach out to and formalize a working relationship with the NRC, while the NRC had a significant precedent of nurturing artistic work within the lab. It is important to note that the project which brought them together was differently articulated and validated in each institution. The NRC could justify involvement because of its broader interest in supporting creative uses of computers by its scientific staff; the NFB could justify the computer within the auteur tradition of singular affordances for each film, *not* narrowly in terms of technological innovation as such. From this lesson we may take away the *advisability of matching institutional collaborators, with intersecting but non-identical research agendas or artistic policies*. An advantage of this approach, only partially realized in the case here presented, is the stability afforded for iterative project planning and management; too often art-technology experiment ends after a single, more or less convincing effort, without the opportunity for iteration in subsequent projects.

“Attunement” of Domains in Technology and Art

Exact imagination entails a process of mutual accommodation: it requires at once a precise stretching of artistic language to the limits – neither beneath nor beyond – of available technique, and progressive extension of technology to actualize the expressive requirements of artistic virtuality. In this case, the limitation of crude, machinic interpolation was not merely sufficient to achieve a pre-

conceived, technocentric task of replacing human inbetweeners. Rather it was necessary to express *Hunger's* eerily disturbing atmosphere, indeed, providing it with the aesthetic signature that makes the work more than a technical curiosity today. The attunement of art and technology in *collaborative research today will benefit from the emergent formulation of such an exact imagination*, distributed across networks of differentiated creative individuals, and buttressed by enlightened institutional policies.

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REFERENCES

1. McLaren, N., Film Animation, in *Documentary Film News* 1948.
2. Russett, R. and C. Starr, Eds. *Experimental Animation. An Illustrated Anthology*. New York, Van Nostrand Reinhold Co. 1976.
3. McLaren, N. Cameraless Animation. A technique developed at the National Film Board of Canada. Montreal, National Film Board of Canada. 1958.
4. For a recent discussion of practice based research, see Edmonds, E. A., A. Weakley, et al. The studio as laboratory: Combining creative practice and digital technology research. *International Journal of Human-Computer Studies* 63, 4-5 (2005), 452-481.
5. Edwards, P. N. *The closed world: computers and the politics of discourse in Cold War America*. Cambridge, Mass., MIT Press, 1996.
6. Wein, M. and N. Burtnyk, "Computer Animation", in *Encyclopedia of Computer Science and Technology*. Marcel Dekker: New York, 1976.
7. About the National Research Council, interviewed were Marcell Wein, Ken Pulfer, Nestor Burtnyk, as well as Bill Buxton. For the National Film Board: René Jodoin, Doris Kochanek, Pierre Hébert, Robert Forget, Daniel Langlois, Kar Liang.
8. Young, G. *Hugh Lecaine, Pioneer in Electronic Music*. Ottawa, National Museum of Science and Technology, 1989.
9. Schon, D. A. *The Reflective Practitioner: How Professionals Think in Action*. New York, Basic Books, 1983.
10. Pulfer, J.K., Man-Machine Communication in Creative Applications. *International Journal of Man-Machine Studies*, Number 3 (1971), 1-11.
11. Pulfer, K. Interview. 1997.
12. Engelbart, D. and W. English. A research centre for augmenting human intellect. in *Fall Joint Computer Conference* (1968).
13. Bardini, T., *Bootstrapping: Douglas Engelbart, Coevolution, and the Origins of Personal Computing*. Palo Alto, Stanford University Press, 2000.
14. Buxton, B. Interview. 1998
15. Burtnyk, N. Interview. 1997
16. Aldercotte, F. *The National Film Board: Animation Department (1941-55)*. Montreal, NFB: Typescript, 1979. National Film Board. Portrait d'un studio d'animation. Montréal, 1991. Jones, D. B. *Movies and Memoranda. An Interpretive History of the NFB*. Ottawa, Canadian Film Institute, 1981
17. Low, C. Interview, 1998.
18. Liang, K. Interview, 1999.
19. Hébert, P. Interview, 1999, and Hébert, P. *L'ange et l'automate. Propos sur le cinéma d'animation et autres sujets*. Laval (Québec), Les 400 coup, 1999
20. Jodoin, R., Interview, 1998
21. Moretti, P. Memoranda to René Jodoin. Montréal, National Film Board of Canada Archives: File # 73 009. 1971
22. Panofsky, E. Style and Medium in the Motion Pictures, in *Three Essays on Style*. Cambridge, MA, The MIT Press. 1948 (1995). Klein, N. M. *Seven Minutes: The Life and Death of the American Animated Cartoon*. London, Verso Books, 1993.
23. Foldes, P., Interview, in *Écran.*, January 1973. Author's translation.
24. Wolfe, R., Ed. *Seminal Graphics: Pioneering Efforts that Shaped the Field*, ACM Siggraph, 1998.
25. Burtnyk, N. and M. Wein. "Interactive Skeleton Techniques for Enhancing Motion Dynamics in Key Frame Animation." *ACM Communications* 19(10), 1976.
26. Langlois, D. Interview. 1999.
27. Harris, C., Ed. *Art and Innovation*. Cambridge, MIT Press (1999). Leach, J. "'Being in Between': Art-Science Collaboration and a Technological Culture" *Social Analysis*, 49(1): 2005