
Contributions & future work

This document began with a discussion of two disparate areas of human endeavor — contemporary choreographic practice and agent-based artificial intelligence. My work is located between these two areas, bridging them, exploiting each one for the other.

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This thesis offers a productive critique of what I believe to be the two most persistent and widespread fantasies in digital art — its fascination with “emergence” and its reliance on the metaphors and techniques of “mapping”. The first chapter of this work highlighted three axes, directions or trends in interactive art: a “conceptual” trend — moving from the hand-crafted and hand-established mapping relationship through a variety of machine-learning-based techniques; a “technical” trend — from the hardware-based pre-history of digital interactive art through fast, flexible software-based tools designed to allow a great many mapping relationships to be experimented with and tuned; and a “methodological” dimension — opposing the hand-crafted and thought-through mapping with the unexpected complexities of emergence. Beyond the termini of these axes I place AI’s agents in general, and, of course, the kinds of agents constructed in this thesis in particular. The articulation of these directions was not

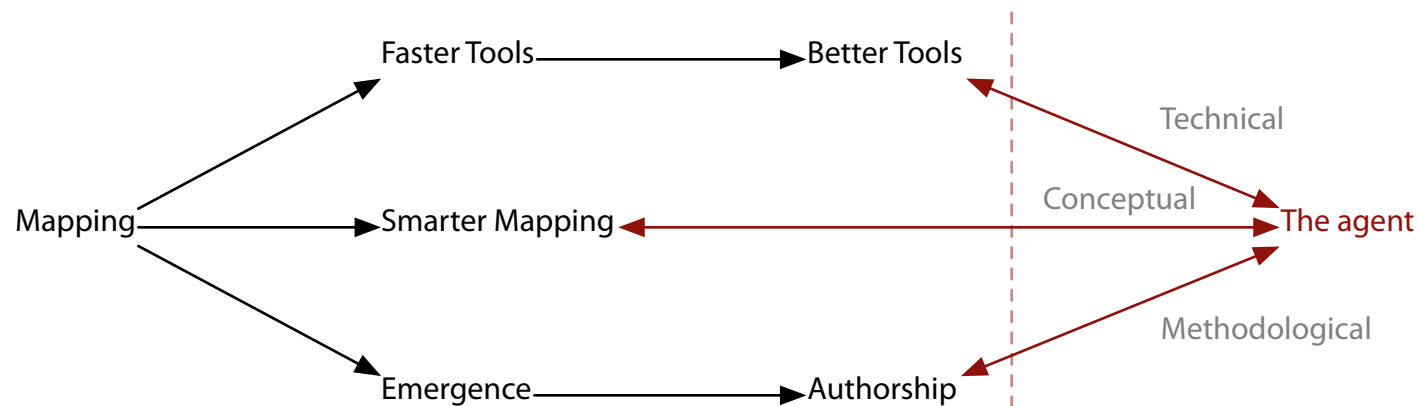


figure 151. The three axes introduced in chapter 1 (figures !![undeclared reference maxis1], !! [undeclared reference maxis2] and !![undeclared reference maxis3] on pages !![undeclared reference maxis1], !![undeclared reference maxis2], !! [undeclared reference maxis3] respectively.

intended to organize or predict the *quality* of the art produced by particular practitioners at particular positions on this illustration. Rather, it aimed to indicate the currents in the academic research and literature already present, and to create a frame through which my work could be viewed. In starting with the agent, I sought to start where I considered interactive art to be heading and move in a counter direction. This counter-move is more than just a theoretical posture; rather I place the very interactivity, relevance and success of the artwork at stake in my ability to traverse these trends backwards toward constructing apparent interactive relationships, finding tools that ameliorate the difficulties of my approach, and techniques that help navigate the complexities of the agent-based.

Along the conceptual axis, I take the agent, in all of its complexities, and look for mechanisms to absorb the recent techniques for developing relationships (i.e. “smart” mappings) and techniques to allow simple relationships, which may cut across many parts of the complex agent, to be authored. My carefully deployed learning techniques and perceptual structures can be seen in this light. Along the technical axis, I have developed tools, algorithms and frameworks that solve two classes of problems. Firstly they allow a “modular” approach to

the construction of agents to be retained during the art-making process — I have offered a variety of communicative blackboards and modifications and extensions to programming languages that share this goal. This modularity, if truly retained, escapes an otherwise perennial tension present at the heart of complex software systems between generic, broadly applicable frameworks that become hard to use because of this breadth and specific crafted solutions that are hard to *disassemble*, reuse technically or use conceptually to structure future works. Secondly, my technical contributions, my tool *Fluid* and my “glue systems”, span many such “modules” specifically so that modifications and interactive potentials that cut across the whole agents can be constructed. Finally, along the methodological axis, both my tools and interstitial contributions speak to the problems of authoring systems that have emergent (that is, both unforeseeable and copious) consequences.

Much of this counter-move from agent to interaction, of course, has something to say about the limits of the present day field and forms the basis of this thesis’s critique of the existing literature and approaches. Along each thread of this document — the development and maintenance of the potential of algorithmic systems, the envisaging and use of tools, and the deployment of “tactical formalisms” in a collaborative work — I show how an alternative metaphor, that of the agent, directly confronts what emergence and mapping ignore.

summary of technical contributions

I have offered specific implemented examples of the use of simple learning techniques to control the potential developed by complex agent-based systems — in the “stack” of emergence and authorial control of *Loops*, in the long-term learning database of *The Music Creatures* and in the agents of *how long...?*. I have been closely involved in developing an action-selection technique — the approach of the c5 agent toolkit — and have then extended it to the **diagram framework**,

which radically expands the vocabulary available to the agent author for the purposes of shaping and constraining the temporal patterns it creates. I have been closely involved in and learnt the lessons from creating complex agents in collaboration, identifying a set of problems and solutions that lie half-way between artificial intelligence and software engineering, leading to **the context tree**. I have identified two reusable design patterns for the creation of agent's perception systems and proved them in a wide range of particular instantiations — **the b-tracker framework** and **the distance mapping algorithm**. Generalizations and re-specifications abound in my work — I have created the **generic pose-graph representation** that allows the rapid creation of agents with a wide range of bodies and source material; my **generic radial-basis channels**, my **language interventions** and the **context tree** all decouple elements of the agent, allowing them to be quickly repurposed and recast. I have surrounded these complex assemblages in a set of tools and representations that allow them to not just be demonstrated but integrated into ongoing art practice; these tools are collected in **Fluid**. I have created graphical rendering techniques and intermediate body representations for agents — **the re-projection renderers** — that open the possibilities of ambiguous visual forms back out to the agent itself.

The nature of these technical contributions needs some careful consideration in two ways. Firstly, for the purposes of both a dissertation and a broader academic context it is important to consider what it is that they actually *contribute*. Secondly, for the purposes of considering how these techniques might be perpetuated in intellectual discourse outside this document, we need to consider *how* it is they are structured.

On the one hand it is my belief that they do little, if anything, to extend the *theoretical* reach of artificial intelligence as measured by the standard data-sets and conventional micro-worlds of machine learning. However, I believe each of them makes significant and original contributions to the *practical* reach of the

agent. This disconnect between the directly quantifiable and the pragmatically useful is independent of the predominant art context of my work. It is not that my decision to deploy my technical contributions in the service of making artworks somehow thwarts AI's methods for evaluating contributions. Rather, it is due to both the lack of quantification inherent in the field — particularly when close to large-scale, heterogeneous AI systems and even more so when discussing design approaches and structuring frameworks rather than specific algorithms.

My technical contributions appear as both general structure and multiple, specific instances; often the specific instances are present in, perhaps even dominant in, specific technical fields. Each contribution possesses this double nature: the b-tracker framework has in a very real sense no algorithmic core, it is a framework, a structuring template that gets populated based on the task at hand. In doing so, the resulting system may recapitulate computer music's score follower or computer vision's tracking algorithms as well as providing novel hypothesis trackers that are hybrids or just plain different. And while in these cases, my resulting "implementation" (which is nothing more than a particular specification of the variable parts of the b-tracker framework) work well in these areas, any evaluation of the technical competencies of these particular instances of the frameworks do not quite get at the heart of the quality structuring contribution itself. And despite this algorithmic displacement, the b-tracker framework refers not just to a chapter of this document but also to specific, singular implementation, a specific body of code, that is present enough to also be the site of fixed visualization tools and offer interactive surfaces and abstraction barriers up to other modules inside the agents that I create. The distance mapping algorithm generalizes and reinterprets statistical techniques such as multi-dimensional scaling — techniques that have been around for decades that I have no claim over — but recasts them in such away that they have broad use to the problems that interactive artists face. The use (e.g. of multi-dimensional

scaling approaches to a broad range of mapping problems) is novel, but it is the recasting itself (e.g. the articulation of the general problem and solution and a constructive proof that there exists an implementation that survives this generality) that I believe is lasting and significant.

Thus I am often left seeking, for the purposes of locating my contribution, mechanisms of “proof” of the technical contributions not at the level of specific implementations but at the level of the framework. Towards this end, I can see three lines of reasoning. Firstly, one argument exploits the range of artworks — installations, compositions, interactions, works for live theater — together with works with an explicit and clear biological referent — *Dobie, alphaWolf* — that have used these technical underpinnings as a step towards securing the quality of these techniques. Secondly, while the argument that many of these artworks were constructed quickly (in the case of *Loops* in particular) may appear structurally unsound, I believe that there are certain thresholds of speed and facility that, when crossed, allow new kinds of artworks to be created, and new kinds of collaborations to succeed. That the score follower for *Imagery for Jeux Deux* in the original conception of the work was thought to be unnecessary was constructed and tested in an afternoon and ultimately became fundamental to the interaction of the piece, and that the recapitulations of *triangle* were constructed during a break in rehearsal, point towards the crossing of such qualitative thresholds.

for a use of the pose-graph in robotics: C. Breazeal, D. Buchsbaum, J. Gray, D. Gatenby, B. Blumberg. *Learning from and about Others: Towards Using Imitation to Bootstrap the Social Understanding of Others by Robots*, in : L. Rocha and F. Almedia e Costa (eds.), *Artificial Life* 11(1-2). 2005.

for a use of the contex-tree in simulation theory: J. Gray, *Goal and Action Inference for Helpful Robots Using Self as Simulator*, Masters of Science thesis, Media Arts and Sciences. MIT. 2004.

Thirdly, I offer the range of researchers working *with* rather than *on* my technical ideas as an argument for the strength of their contribution. They have had widely differing concerns and agendas and many have constructed their own work around the agent-toolkit that incorporates my techniques and code. This second layer of validation offers an alternative plane of collaboration — one where I assume, as I do in my artworks, responsibility for some of the technical path, but reject responsibility for the artifactual destination. In this fashion, one might point to the use of the pose-graph motor system to control robots (hybridizing computer animation techniques with expressive robotic control); or the use of the context tree to create agents that simulate other agents (the embedding of a “virtual” agent within another by using the hierarchical context). Since I comprehensively lack the skills or opportunity to work in robotics or the background in the simulation theories of cognitive modeling, I cannot retroactively claim these tasks as motivation for the pose-graph motor system or the context tree. Since these extended uses remain within the realm of messy, large-scale AI research, there are no critical results on standard data-sets, no disprovable predictions strong beyond the number of “free-parameters” that my techniques possess, that I can borrow for the purposes conclusive proof. Instead I might claim what might be large-scale AI’s only equivalent of the scientific standard of replication — a relatively independent reuse of AI design ideas and implementation.

But in a broader context I refuse to shy away from these harder-to-evaluate approaches and framings not simply because of the practical utility that they offer me in my varied collaborations, the practical fluidity that they allow in my work or the thrill of seeing them adopted, expanded upon and reused in domains distant from my own opportunities. Rather, I believe that such frameworks, such reframings of algorithms and data-structures, are precisely the research project that both artificial intelligence and digital art require at this very time.

This opinion, in a AI context, is sufficiently well stated elsewhere — in the work of Minsky and others. In a digital art context it bears restating. Having gone beyond a simple technical facility, the speed with which well-known and well-worked-out algorithms may be either coded (in a “text-based” practice) or called-up (in a more typical “visual-programming” environment), the research vista, the methodological frontier that lies beyond the simple mining of the flexibility and speed of computers, is to find the structures and frameworks that allow the understanding, generalization and re-recognition of common algorithms in a new light of digital art. That many of my contributions are in the interstices of code-practice indicates a recapitulation of my emergence and authorship counter-tension at a different level of practice. That the central technical problems faced by digital art (and artificial intelligence) might be shifting from the finding of powerful algorithms and data-structures to figuring out how to deploy them given that they already exist.

Without the technical contributions my artworks are inconceivable, in all senses of the word: they could not be articulated, started, or finished. Without the artworks, these technical contributions would be unmotivated, unproven, unfulfilled. The techniques are neither directly present in the surface of the artworks nor vanish completely from them, no more than the style in which these frameworks are constructed is independent of the art that I have made and provoked.

The artworks presented here are more than the techniques behind them and, simultaneously, the techniques that I have developed here are not wholly consumed by the artworks that exploit them. Indeed, one crucial indication of the technical success of an artwork is tied up in this very attitude. As artistic conditions (collaborations, available materials and interactions) provoke technical contributions that are (by personal preference, and by practical necessity) flexible, generic, or modular in nature, this effort is satisfying and worthwhile when

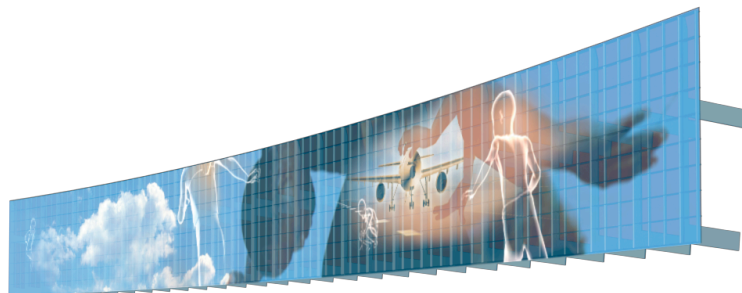


figure 152. *Horizon* installation pre-visualization.

an artwork escapes the ability to think through the potential field generated by the technique, finding the utterly unexpected deep within this field. Simultaneously the technical approaches are in themselves satisfying and worthwhile when they remain unexhausted by the pieces that they permit, pointing towards unexplored vistas after the works themselves have been “finished”.

Again, this criterion for success speaks also of the methodological importance for the modular, reusable and the generic in my work and goes some way to legitimize, at a technical level, the apparent indirection inherent in the agent-based. Rather than being a complicating and eccentric place to begin work, perhaps my agent metaphor and practice offers a vastly shortened route to this technical territory.

The future work of this thesis, my future artwork, is at the very least to continue mining the potential of the technical contributions of this thesis while using new artworks to, in turn, provoke new developments. Rather than discuss in abstract terms where my techniques might lead my art and where my art might lead my techniques, I would rather discuss two concrete, commissioned artworks that I believe illustrate and extend the two main threads of my work.

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Horizon, 2005-7

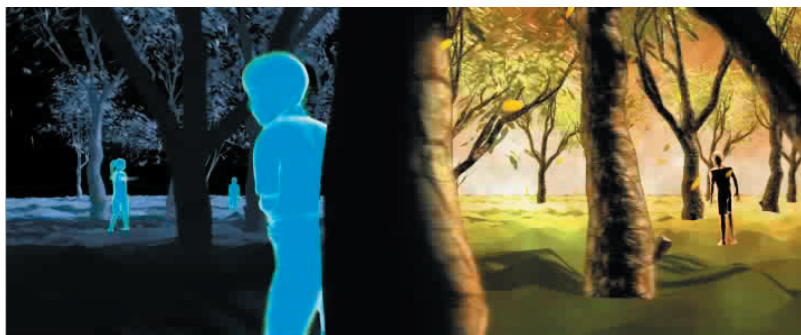


figure 153. *Horizon* sequence pre-visualization
— forest, hide and seek.

The first thread can be drawn through parts of *alphaWolf*, *Dobie* aspects of *The Music Creatures* and ultimately 22 — agents with complex bodies and large stores of animation material which require complex blending, layering and manipulation and yet have a strong, representational, figurative requirement. This thread leads to a project entitled *Horizon*, commissioned for the main hall of the forthcoming international concourse-F at Atlanta's Hartsfield-Jackson Airport.

On a 360-by-30-foot custom-made Led display, this permanent artwork will finally present the opportunity to make a piece that runs live, without repeti-



figure 154. *Horizon* pre-visualization — view from baggage claim.

tion, on an “architectural” time-scale. It will be the largest live permanent digital artwork to date.

Our imagery, which inverts the scale of child and airport, will draw on extensive motion capture libraries of children’s motion — playing hide-and-seek, manipulating the skyline of Atlanta, operating the mechanics of the airport. These game-like forms will be played out by characters assuming the figuration of children, but like 22, this figuration is not the stable affair of computer games and special effects, but rather the unstable, shifting forms of childhood dreams. To create the choreography of these multi-agent games, I expect to use and extend the Diagram framework — extending its ability to coordinate multiple action to the choreography of multiple agents — and a pose-graph motor system — extended specifically to perform well over both extremely large libraries of animations and variable bodies.

The use of the agent metaphor in structuring this work allows the imagery to be open to extension — incorporating events from the changing life of the city as the years go by — and responsive to external influences: the flux of passengers, the time of day, the weather and the season. This couples the artwork to the environment of the airport, and the time-scale of the installation setting, in a way that a finished film could not hope to achieve. The techniques developed in this thesis that allow the rapid creation, tuning and automatic “balancing” of agents will be fundamental in constructing an artwork on an display-scale setting that inherently cannot be prototyped accurately. The piece is set to open with the completion of the terminal building in 2007.

Enlightenment, 2005-6

The second thread through my work can be traced through *Loops*, *The Music Creatures*, *Loops Score* and parts of *how long...?* and *Imagery for Jeux Deux* — the



figure 155. *The Enlightenment* installation pre-visualization.

visual depiction of both generative and analytic musical processes, the notational and the enumerative. This thread leads to a project entitled *Enlightenment*, commissioned as part of the 40th season of the Lincoln Center for Performing Art's *Mostly Mozart* festival to celebrate the 250th anniversary of Mozart's birth. Ten high-resolution displays distributed down the length of the front of Avery Fisher Hall will make this work the highest-resolution live digital artwork to date, and truly allow the creation of digital imagery that can be observed at a range of distances. As in *The Music Creatures*, each screen will house a sound-producing agent communicating with its neighbors; as in *Loops Score* the "source material" for the agents will be fixed in advance; as in *how long...?* and *Imagery for Jeux Deux* the physicality of performance will brush up against an aesthetics of notation and description.

But this new artwork presents the opportunity to unite the aesthetics of effort, intention and transience with the concerns of truly "human-level" music — the central issue arguably dodged by both my musical works to date. The source material will be the last 30 measures, the dizzying display of five-part invertible counterpoint in Mozart's Symphony No. 41 "The Jupiter". And over an constant installation period of three months the agents will recompose, recast and rediscover the unities and possibilities of the material Mozart deploys in this passage, exploiting a library of video and sound captured from performances of the work. Both acoustically and visually, *Enlightenment* will be patterned on the scale of the hour, the day, the week and the month. In some senses it will be a three month long composition.

While my previous works might have used unconventional means (the agent), hardware (motion capture) and tools (Fluid), they have not yet enabled access to non-traditional audiences, scopes or venues. These new works place the artificially intelligent agent not just in new art contexts but in unexpected contexts for digital art. The "openness" of my open forms, the enticing time-scales hinted

at by *Loops* and *The Music Creatures* and the surplus potential evident in the rehearsals of my works for dance theater seem to demand a move away from the traditional gallery installation or the confines of a fixed duration performance. This move comes with considerable challenges. While I have had success, as far as my works have led, in creating pieces that are far beyond what one can *think-through* as an artist by developing techniques that allow the navigation of open interaction, can my open forms remain open while I construct pieces that are far longer than any single rehearsal, far longer than I can possibly *work-through*, even once? Both *Horizon* and *Enlightenment* stand on a new threshold for digital art.

the experience of the agent

The agent metaphor offers the opportunity to reframe the problems of algorithmic art in terms that meet the computational sensibility of contemporary choreography that I identified in my opening chapter. My most recent collaborations with choreographers have resulted in what I believe is the most sustained example to date of a dialogue centered on this computational sensibility. I have constructed networks of computational representations that are complex enough to yield surprising forms, material and relationships, and controllable enough to allow the unexpected to be assured. I have sought the technologies required to bring these forms to human movement and human movement to these agents. By careful formulation and generalization of learning, programming and visualization techniques, I offer the extensions, frameworks and tools that this agent metaphor needs in order to be more than just an organizing principle. My technical contributions alleviate the difficulties posed while exploiting the opportunities offered by the indirection inherent in the agent-based.

This indirection is the aesthetic center of my body of work; my agents are autonomous enough, intelligent enough, to maintain a dynamic disequilibrium with their environments. Because of this relationship to their setting, I believe my agents embody an aesthetics of intention, effort and transience unobtainable by more “direct” means. I offer new “open forms” that are solutions to the paradox of “scoring” an autonomous system.

A number of times throughout this thesis I have documented this aesthetics that I believe is attainable from this agent-based practice and indicated, or at least hinted at, the moments when it truly comes to the fore in my work: the musical renegotiations of *The Music Creatures* — the error-prone echos and the observable attempts by the creatures to traffic musical material, the intentionality of *network*, the broken clock-like movement of *tile*; the endless recomposing of *Loops*; the quirky, fragile rhythmic material of *Loops Score* that produces material that is unexpected yet somehow inevitable; the layered excesses and inadequacies of *how long...* — the goal of *triangle*, the fleeting shifts of *memory score*; the moments when, having drifted apart, the imagery, movement and narrative of 22 collide. All of these aspects, all of these moments, seem at their core to be both technical and aesthetic consequences of the construction of autonomous agents. But what precisely links them all and, more importantly, but perhaps even more speculatively, what accounts for my personal attraction to these phenomena? What are the experiential intentions of my work?

It remains impossible and impractical for me to find a definitive statement on these matters, yet my sense that there remains a stable and common core to these “aesthetic moments” that escapes merely the technical relationships between the works begs some attempt at explanation.

One route that offers some promise in this direction is to return to the opening chapter’s brief discussion of the status of the “formal systems” developed in both

contemporary choreography and, by influence and extension, my work. In these fields I have referred to these approaches as deploying “tactical formalisms”, that is, formal techniques that arrive methodologically prior to the discovery of their consequences, and perhaps even their natures, that are protected from interrogation during their articulation and given privileged status during the mining of the potential that they develop. These formalisms are deprived of any totalizing wider role by an equal, but opposite, tendency to question and undermine these very formal ideas between works, between explorations. I believe that in my work my set of experiential goals are actualized when these formal approaches come into oblique contact with a seemingly opposed set of concerns — that of realism.

At the simplest level the search for this tension between the formal, the autonomous, and the realist might explain my continual return to human materials — be it human motion — *Loops, how long...* — the fundamentals of human music (rhythm, timbre) — *The Music Creatures* — the human voice and language — *Loops Score*. These, often explicitly, counter-balance my agent-based formal indirections. Alternatively, perhaps it predicts my interest in developing “ambiguous” computer graphical techniques that can transit between the realist and the abstracted — most notably in 22. Perhaps it suggests a deeper reason for my sincere, but admittedly uneasy, engagement with biological referents — in *The Music Creatures* specifically and in the the c5 agent toolkit in general. But these aspects again draw us back to a more technical level than this discussion was intended to take, or at least one internal to the work rather than external, and does not explain the considerable autonomy I give to my formal approaches.

Quotes are from
P. Klee, *Paul Klee Notebooks, Volume 1 : The Thinking Eye*,
J. Spiller, (ed.) George Wittenborn, NY, 1961.

For a selection of essays by members of the Oulipo:
W.F. Motte Jr (trans., ed.), *Oulipo: a primer of potential literature*,
University of Nebraska Press, 1986.

For a more encyclopedic introduction:
H. Mathews, A. Brotchie, *The Oulipo Compendium*, Atlas Press, 1998.

from pp. 58-9, in D. Sylvester, *Interviews with
Francis Bacon*, Thames-Hudson, 1975.

There is a long tradition, however, of attempting to rehabilitate the realist project, freeing it from what, for example, Paul Klee called the “painfully precise investigation of appearances”, of transferring concern from appearance to *functioning* — from “anatomy to physiology”. Perhaps one might identify in my work, or at least in my aesthetic intentions, couched in and supported by the presence of the human, in motion and in sound, a realism that lies one further step removed from the optical than this physiology.

Perhaps this occulted presence of nature accounts for the longevity of contemporary choreography far from the “hook” of narrative, mimesis or emotion. Perhaps there is a point of contact here with the longevity of the Oulipo literary group’s “formal” or “axiomatic” investigations. Returning to my first chapter’s concerns with the interplay between figuration and abstraction, perhaps this is what Francis Bacon isolates as the tension between order and representation, between one level and another:

“One of the reasons I don’t like abstract painting, or why it doesn’t interest me, is that I think painting is a duality, and that abstract painting is an entirely aesthetic thing. It always remains on one level. It is only really interested in the beauty of its patterns or its shapes. [...] I think that great art is deeply ordered. Even if within the order there may be enormously instinctive and accidental things, nevertheless I think that they come out of a desire for ordering and for returning fact onto the nervous system in a more violent way.”

Perhaps too this is what musicologist Michel Imberty, searching for a naturalistic foundation for music, and by my extension the “temporal arts”, has encountered:

M. Imberty, *The Questions of Innate Competencies in Musical Communication*, in: N.L. Wallin, B. Merker, and S. Brown, *The Origins of Music*, MIT Press, Cambridge MA, 1999

All [music's] temporal substance is nourished by our way of being in the world; that is, in our time, our culture, our perceptions, our bodies, our emotions, and our sentiments. It is not communication but a representation of our ability to communicate, it is a stylized game for our opening to the world, it is communication without an object to communicate. In this sense, music is indeed, the symbol of our fundamental relation to time, life, and death.

To give a name to the place where the anatomical, the physiological, and the formal intersect, I propose that this at this core is an *infra-realism*, in which the audience (and the artist) recognizes not a precisely analogous or parallel mode of functioning but the very functioning-like aspect of bodies and their imbalances with the world. A captivating recognition that *Loops Score* does not resonate with the rules of language *per se* but draws its strength from a parallel recognition that language incorporates an alien mechanic current; that *The Music Creatures* point towards a formal quality possessed not just by the algorithmic machinations of western art music but even the song of birds; that in *how long...* my images point to the arbitrary yet necessary core of both choreography and human movement in general. Perhaps this is the thread that ties my technical relationship to motion-capture, through my conceptual choice to begin with the autonomous agent rather than a “more direct” interactive relationships, to my deployment of such localized formal systems, my preference for imbalance and transience, the aesthetics of my visual imagery, and finally all the way through to my experiential intentions.

To gain access to this territory within the context of interactive digital art I have had to abandon the conventional points of origin, the standard tools, and the traditional methodologies and create my method, technique and structuring concepts afresh. I have sought the collaboration of a diverse range of artists and AI researchers. Although I claim that the technical contributions are strong and the artworks successful, and I believe that I have proved this as much as it can be proven by applying these techniques to an extremely diverse range of

works, my firmest belief is that the technical contributions are of interest to digital artists who are both willing and able to interrogate their own technical practices. In general I hope that my thesis expands digital art's working practices — changing the starting points of pieces, the methods and in particular the tools used on the journey and the possibilities open to artists. I hope that my thesis, like my works, indicates and develops a field of previously unknown potential and demonstrates techniques for navigating this field.