DIGITAL NATURALISM:

DESIGNING A DIGITAL MEDIA FRAMEWORK TO SUPPORT ETHOLOGICAL EXPLORATION

Excerpt: Chapter 1

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By

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SUMMARY

This research aims to develop and evaluate a design framework for creating digital devices that support the exploration of animal behaviors in the wild. In order to carry out this work, it both studies ethology's foundational ideas through literature and also examines the contemporary principles at a rainforest field station through on-site ethnographies, workshops, design projects, and interactive performances.

Based upon these personal and practical investigations, this research then synthesizes a framework to support digital-ethological practice. Finally, this framework is utilized to design additional ethological expeditions and activities in order to assess the framework itself. The resulting framework encourages digital technology that supports four key concepts. Technological Agency pushes for devices that promote understanding of their own internal functions. The tenet of Contextual Crafting leads designers and ethologists to create devices in close proximity to their intended use. Behavioral Immersion promotes visceral interactions between the digital and organismal agents involved. Finally, Open-Endedness challenges researchers to create adaptable tools which strive to generate questions rather than answering them. Overall, this research, referred to as Digital Naturalism, explores a developing design space for computers in the wild.

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CHAPTER ONE
DIGITAL NATURALISM

ETHOLOGY AND THE BEHAVIORAL MEDIUM

1.1 Introduction

Digital Naturalism originally sprouted from my experiences working simultaneously in two conceptually different laboratories at Georgia Tech. One lab studied how to design computers that let people play and interact with their environments. The other wanted to harness the raw power of computers to extract the secrets of animal behavior from nature. Both drew me into exploring the unique challenges of working with computers, animals, and environments.

1.1.1 Digital World and Image Group

I initially came to the Digital Media graduate program to explore the avant-garde of computers as a new form of communication. There I joined Michael Nitsche's project studio, The Digital World and Image Group. Together, we aspired to craft digital-physical performances to help people engage with each other, their tools, or their environments in new ways. For instance, we created mobile apps for subverting governmental restrictions against dancing,[1] electromagnetic paintbrushes for exploring ancient water-marbling crafts,[2] and devices which mark digital territory through real-world urination.[3]

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[1] (Quitmeyer, Andrew, Ansari, and Nitsche 2013)

[2] (Nitsche, Quitmeyer, and Farina 2014)

[3] (A Quitmeyer and Nitsche 2012)

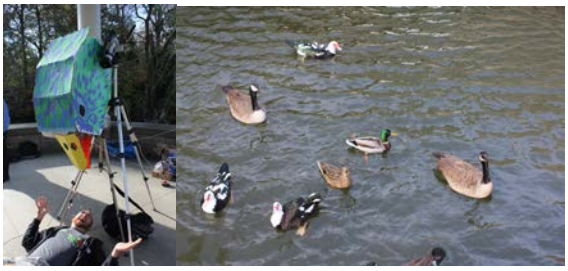

Figure 1 - Images from the *Ducks Feed People* project

In one project, *Ducks Feed People*, we built and installed a robotic duck head in a park that took commands from the actions of ducks in the lake below. Inverting the traditional power structure, wherein humans toss bits of bread to prompt reactions from the ducks, the robot spit candy to the humans above the waterline whenever the ducks gathered in a particular space. The project, with its simple concept but difficult implementation, gave a small, initial taste of the intricacy and power involved with developing these real-time situated experiences. The complex interconnections that emerged from the environment, weather, humans, and computers in our projects illuminated the potential for rich interactions through simple computation. I was captivated by the additional challenges of ducks interacting with non-human creatures in their own territory in *Ducks Feed People*.

1.1.2 Bio-tracking

Working with animals and technology enhanced opportunities for explorative, unpredictable work. This caused me to begin working in Georgia Tech's Bio-tracking lab[4]. Under the leadership of Tucker Balch, I participated in, and eventually spearheaded, research to create state-of-the-art software for the computational perception of animals. Our Bio-track Pack[5] suite of programs was designed to let scientists automatically monitor the movements and interactions of multiple creatures simultaneously in laboratory experiments. One sample goal would be to draw conclusions about ants' foraging techniques

[4] bio-tracking.org
[5] http://www.bio-tracking.org/category/software/

by video recording multiple feeder stations, automatically tracking each of the visiting ants, and then rapidly analyzing this information.

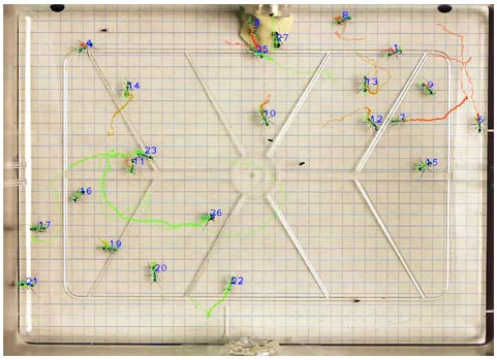

Figure 2 - Automated tracking of animals in the lab

The Bio-tracking lab also gave me my first peek into the peculiar research practices needed by of animal behavior researchers. Our group collaborated with Stephen Pratt's ant behavior research lab at Arizona State University. Most of our lab's research was completed as remote collaborations, sharing video data and testing our software. Once a year during grant meetings, however, our labs met and personally updated each other on biological and technological progress of the joint research. This was a chance for the technologists to shadow our collaborators in the field and learn the intricacies of their process first-hand.

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1.1.3 Difficulties

Unfortunately, the challenge of working with real animals replaced my initial fascination with frustration. After years of working on our tracking software, it began to feel overly-complicated and non-functional. The ants always seemed to find new complications to compromise our software's tracking algorithms, and the physical divide separating our laboratories to additionally hindered development.

In the few times our labs were able to meet, the same discussions would be repeated over and over again: The scientists pointed out difficulties or shortcomings of the software with different data, while

the engineers on our side responded with stricter limitations on how the scientists were supposed to use these tools during their experiments. As the development of this software continued, it seemed counterintuitive to force the scientists change their research processes to fit the needs of their tools.

During one of our joint meetings the scientists took the engineers into the field sites where they studied the ants, and I first saw biologists as specialized artisans of their own important scientific technologies and practices. They must wrestle with myriad difficulties both before and after the actual experiment. One guide for animal behavior research directly describes this problem:

> At first glance, studying behavior is easy, but as every budding ethologist quickly realizes, there are a host of complex, practical, methodological, and analytical problems to solve before designing and conducting the study. 'How do you choose which species or which behavior to study? What equipment will you need to observe and record behavior successfully? How do you record data in the dark, in the wet, or without missing part of the action? How do you analyse and interpret the data to yield meaningful information?[6]

As opposed to the long, abstracted development time of our software being created inside a climate-controlled laboratory, the scientists were rapidly confronting and solving the numerous different challenges presented by the unique environment directly in the field.

These field biologists often deal with uncooperative, absconding, or hidden subjects: unpredictable shifts in the weather, bodily fatigue, predation, and disease.[7] They often face many of these challenges arriving at their basic research question for the experiment. For instance, during one field trip to capture test

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[6] (Lehner 1998, 3)

[7] Martin and Bateson provide a similar description of the difficulties of field work on p. 20 - Martin, Paul, and Patrick Bateson. Measuring Behaviour: An Introductory Guide. Cambridge University Press, 2007. Web. 25 Oct. 2013.

footage, we spent the majority of our time building a large shade to counteract weather-related changes in the lighting.

Working with scientists directly in the field, I realized perhaps my frustrations creating the biological software stemmed from larger flaws in the overall *design process* of digital-behavioral tools.

1.1.4 New Research

Here I saw an opportunity to combine my research with the Digital World and Image Group to find techniques that could benefit field biologists. Basing the design of the digital tools around the scientists, animals, and their environment – instead of solely upon the targeted problems – could alleviate many of the previous difficulties. Tools would be created in parallel with the development of the scientists' questions and practices during their early research stages. Computational instruments could also be designed not just for the experiments themselves, but to counter the difficulties surrounding initial setups and observations, and provide new ways of exploring and sensing hidden factors in the environment.

From these experiences, I developed a plan to work with these scientists in order to better understand the entirety of their research process. By diving into the worlds of these animal behavior researchers, we would discover a new design process to guide the development of digital tools based on the needs of the scientists themselves.

1.2 Challenge: Ethology and Digital Media

1.2.1 Ethology

Ethologists, a name given to scientists studying the behaviors of animals in their natural environments, thus became the primary stakeholders targeted by this research. Understanding the best ways to support these scientists requires a deep analysis of ethology itself.

Studying animal actions dovetails into the development of many fields of science. As Bill Wcislo explains:

> Animal behavior is central to biology. Behavior is the interface between mechanistic and ecological studies – what Marston Bates called 'skin-in' and 'skin-out' biology. It is the means by which animals shape their environments, and determines the flow of energy and information among organisms.[8]

This field, however, has traditionally held an enigmatic position among the other scientific fields. Whereas laboratory research typically venerates efficiency, control, and reduplication, the infinite unpredictability of fieldwork pushed ethology to develop supplementary values. Biologists studying animal behavior in the field have long defended the values of open-ended exploration[9] in natural settings. Scholars like Niko Tinbergen and E.O. Wilson have endorsed such "seemingly aimless wanderings in the fields" as indispensable to later "experimental analysis."[10] Present-day ethologists continue to press for such open-ended exploration. Martin concurs: "The value of broad description arising from sheer curiosity should not be under-estimated."[11]

These principles of open-exploration derive from ethology's roots in Romantic naturalism. Joining such romanticism with techniques within scientific empiricism gives ethology a unique hybrid nature. Operating as a chimera between humanistic and scientific academic institutions, this field often suffered

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[8] ("William Wcislo - Smithsonian Tropical Research Institute" 2015)

[9] (Hölldobler and Wilson 1994)

[10] (Tinbergen 1958, 306)

[11] (Martin and Bateson 2007)

challenges in its acceptance.[12] Its special intersection of positivism and naturalism, rigid experimentation in conjunction with visceral, undirected natural engagement[13] gives ethology "an inclusive approach that provides a way out of the fruitless nature/nurture dichotomy."[14]

The unique difficulties which challenge wildlife researchers inspire a need for personalized tool-making. Few mass-produced instruments meet the specific requirements of a researcher's desired interaction with a wild animal living in a unique situation. Therefore, many field biologists find themselves crafting their own tools. Tinbergen's gull-head puppets[15] and Frisch's rotatable bee hives[16] are examples of key scientific tools built from scratch and formed by the research questions being asked.

Additional simple appendages are often improvised from the environment to extend the abilities of the ethologists. Sticks, rocks, and piles of dirt can lengthen our reach, prod at different physical scales, or modify the landscape. For instance, Hölldobler and Wilson discussed insights found when adapting parts of their own bodies to interact with animals. Hölldobler describes,

> …while waiting on the edge of a road for a car ride, Wilson succeeded in "milking" giant scale insects surrounded by ants, simply by touching them with hairs from his head … (Such are the informative pleasures that fill the idle hours of naturalists in the field.) [17]

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[12] (Tinbergen 1974)

[13] (Tinbergen 1958)

[14] (Weisfeld 2004)

[15] (Tinbergen 1960)

[16] (Frisch 1971)

[17] (Hölldobler and Wilson 1994)

Some of the most exalted experiments amongst these researchers are those that gathered enough background intuition to manage multiple environmental and animal factors in elegant ways. For instance, in one famous recent study of ant navigation over bleak shifting dunes in the Sahara, Wittlinger, Wehner, and Wolf proved how ants counted their steps by gluing tiny stilts onto the ants' legs.[18] This simple manipulation directly targeted the research question without greatly detracting from other environmental influences. Such experimental elegance is created by meshing a deep understanding of both theoretical literature as well as practical engagement with the creatures, environment, and materials.

Digital technologies, with their abilities to create interactive behaviors, stand to grant even more powerful, dynamic faculties to such open-ended exploration. However, one must always be wary of blindly introducing technology into any practice. Instead of supporting a scientific endeavor, the new devices can sometimes draw the researcher's focus upon themselves (as our ant tracking software appeared to become at times). For instance, one ethologist that I interviewed discussed the hurdles that come with a reliance on certain technological setups:

> *I feel that [our] lab has gotten into something of a rut with one (sometimes great) experimental set up. It is good, but now I think a lot of experiments are designed around the set-up rather than the questions, and it limits the type of questions that we ask.*

Thus, when incorporating a new technology, such as digital media into an existing field, it behooves the scientists and designers alike to analyze *how* these devices can serve the practice.

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[18] (Wittlinger, Wehner, and Wolf 2006)

1.2.2 Digital Media

The wildness and discovery of ethology, however, have generally contrasted with the traditional uses of computers. Digital technology offers unprecedented new abilities to extend human analytical and interactive abilities. As the ethologist Chauvin, points out, "The behavior of computers constitutes the only possible analogy with animal behavior."[19] The singular behavioral properties of digital technology allow ethologists to generate sophisticated virtual models like those of Couzin, [20] Pratt,[21] and Hrolenok.[22] Additionally, though, computers also allow ethologists to create behavioral interactions with living creatures in the real world. Ryan's "Robo-frog,"[23] for instance, can be programmed to move in realistic ways, letting scientists ask dynamic questions in their experimental setup. Due to their unparalleled advantages, computers "have become increasingly popular for collecting data in enclosure and laboratory settings."[24] However, Lehner warns scientists should "remember data loggers are only a faster and more efficient way of collecting and storing data. They will not substitute for a poorly designed study."[25]

This sentiment points to the dual-edged sword of computers' present role within ethology. As Agre notes, "computing has been constituted as a kind of imperialism; it aims to reinvent virtually every other

[19] (Chauvin 1977, 227)

[20] (Couzin and Franks 2003)

[21] (S. C. Pratt and Sumpter 2006)

[22](Hrolenok and Balch 2013)

[23] (Barrett A Klein, Stein, and Taylor 2012)

[24] (Lehner 1998, 256)

[25] (Lehner 1998, 256)

site of practice in its own image."[26] The extraordinary new abilities of digital technology can augment the biologist's abilities. At the same time, there is the danger that the computer's affordances and limitations also might force ethologists into unproductive patterns as they do not relate to their field.

Computers' propensity for abstraction and disengagement from the physical world is a key challenge for the incorporation of digital artifacts. Scholars like Suchman and Agre have argued that all research practices, "even the most analytic, [are] fundamentally concrete and embodied."[27] They encourage a basic shift from the design of large singularly powerful or intelligent artifacts to those which make use of and function with the networks of interactions constituting their target environments. Instead of designing technology strictly in the laboratory and in the manner of a disembodied brain, it becomes necessary to explore and design within the specific sites or sociological contexts the devices are used.

As Agre notes, an artifact developed in a computer science laboratory incorporates assumptions, values, and challenges from its environment, and these may be at odds with those encountered by prototyping directly in the field. This schism hinders a tool's physical and scientific efficacy. The technology might not function properly due to changes in moisture, power availability, space requirements, or the non-participation of the animals. Lehner elaborates on this necessary step forward:

> Ethologists should be more than collectors and analyzers of data; they should seek to 'understand' their animal subjects at a higher level than quantitative analysis can provide.[28]

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[26] (Agre 1997, 1)

[27] (Suchman 1987)

[28] (Lehner 1998, 5)

Thus, digital tools are challenged to not only collect experimental data but also foster exploration and reflection among the scientists. These can for be data collection and scientific gathering, but they might also be tools, like Silver describes, which aim to instead focus scientists' "attention back on nature… and how to build with it, nurture it, and form an intimate relationship with it."[29] Determining methods for creating tools appropriate for the fullness of ethological work is, however, still a developing task

1.2.3 Thesis: Designing Digital Media to Support Ethology

The hidden challenges that computers carry with them into ethology form the key research target of this dissertation. It seeks to understand ways that digital media can be designed to support ethology's core principles. In particular, it focuses on how computational abilities can be used in the early, exploration phase of n ethologist's research process.

This thesis responds to this question through the following steps. First, this research needs to explore what ethological practices and values digital media should address. On top of this, it must also examine ways in which digital tools are already being utilized in ethology. Finally, it will explore and evaluate what design guidelines can let digital media fulfill the needs of thee ethological principles. Based upon these personal and practical investigations, this research then forms a framework to support digital-ethological practice. Finally, this framework will be utilized to design ethological expeditions and activities in order to assess the framework itself.

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[29] (Silver and Rosenbaum 2010)

This is the challenge of this research hereby referred to as “Digital Naturalism.” Digital refers to the abilities of computers which this research seeks to explore and harness. Naturalism refers to ethology and its researchers’ designations as “naturalists.”

1.3 Methodology

This research necessarily assembles many different fields and practices. A research structure which can cope with these manifold theoretical and practical discussions and challenges is therefore essential. Since a standard methodology did not already exist to meet these needs, one had to be customized from the several disciplines concerning science, technology, and design.

In general, this work follows a philosophical paradigm of qualitative, Action-research. The historical and contemporary values and practices of the primary stakeholders, the ethologists, are analyzed in multiple ways. The ideas collected from this process are then developed into new practices and tools and iteratively evaluated with the scientists. Owing to the embedded-ness of ethological practice in the field, a key part of this methodology includes work on site studying various scientists, animals, and environmental conditions.

At more specific levels, this dissertation pursues techniques and strategies utilized in areas like Science and Technology Studies, Critical Making, and Performance Studies. These domains of scholarship informed emerging design framework, which, in return, shaped a range of deployed activities and tool constructions. Combined with ethology, these practices were employed while directly living and working with scientists at a major biological research station. Here, traditional ethnographic tools like interviews and questionnaires were employed along with pragmatic, exploratory tools like workshops, performances, and new digital devices.

The multi-modal data resulting from this work was then collected and organized into Digital Naturalism's final design framework. The concepts within this framework were used to develop a final series of workshops, the Hiking Hacks, which evaluated these ideas over the course of three expeditions studying animal behavior in the wilderness. This framework and ideas behind Digital Naturalism continue to develop as this research is tested in new locations.

1.4 Framework

The result of this research is the discovery of four primary concepts that can guide digital technology's design to support ethology. These are Technological Agency, Contextual Crafting, Behavioral Immersion, and Open-endedness. Making tools that foster Technological Agency within the scientists helps give them the power to shape the tools according to the requirements of their original research question. Crafting digital devices within the context of their use in the wilderness with animals, can help speed up iterative development, and ensures the devices have appropriate features for use. The design principle of Behavioral Immersion encourages the development of tools which engage with a scientist's sensory abilities and promote the researcher's abilities for intuition. Finally, targeting Open-Endedness in the functionality of ethological tools promotes adaptability and serendipitous discovery of new behavioral phenomena. Each of these key criteria is described in more detail in Chapter Eight along with a subset of techniques for working towards these components of the framework.

Digital Naturalism Framework		
Construction	Technological Agency	Promote transparency of the tools' functions.
	Contextual Crafting	Build the tools in the wild.

Functions	Behavioral Immersion	Create embodied, dynamic interactions with animals
	Open-Endedness	Design non-specific, adaptable, improvisational instruments

This research demonstrates that by targeting these concepts, one can facilitate the design of digital artifacts which uphold the values of ethology from the ground up. The process leading up to the creation of this framework, its explication, and evaluation form the basis of this dissertation.

1.5 Chapter Outline

1.5.1 Chapter One: Introduction

Chapter One introduces the subject matter and arguments of the dissertation. It quickly defines the main concepts behind Digital Naturalism while providing a background of the motivations leading up to this research. The introduction establishes the logical structure which this research will utilize.

1.5.2 Chapter Two: Foundational Ethology

Chapters Two and Three provide a background of the disciplines feeding into this dissertation. Chapter Two provides a primer of the target field, Ethology. Based on foundational literature, the history of this discipline – along with its foundational values, practices, and technologies – are presented and analyzed. This cultural and technological history provides the context for the specific set of principles guiding this research in digital studies of animal behavior in the wild.

1.5.3 Chapter Three: Behavioral Media

Next, Chapter three presents an overview of media technology and its relationship with animal behavior. First it discusses digital media's background and unique affordances for immersion and interaction. Then, it dissects and analyzes the emerging, nebulous fields of bio-art and bio-media. Finally, this chapter examines unique new forms of digital, behavioral media that blend computation with the actions of living creatures. Outlining the fields of digital, biological, and behavioral media provides the scope of

possibilities for novel forms of digital-animal interaction, which have yet to be fully explored in ethology.

1.5.4 Chapter Four: Thesis and Research Plan

This chapter lays out the key concepts of this research project. First, it explains the details and scope of the problem space between digital media and ethology. It then describes the research target of this project to create a framework for digital design through hands-on investigations of the principles and practices of contemporary ethologists. This chapter concludes with the basic proposal of the research's tasks and field location at the Smithsonian Tropical Research Institute in Panama.

1.5.5 Chapter Five: Research Structure

Digital Naturalism's interdisciplinarity and intertwined biological, technological, and cultural factors necessitate the creation of a customized research structure. This chapter explains the origins and synthesis of its hybrid approach and the methods used throughout this investigation.

Building from basic philosophies of Qualitative Research and Action Research, this project seeks to discover and analyze digital-ethological challenges through the generation of rich, experiential data which is iteratively evaluated. To tackle this research's particular technological and behavioral challenges, Digital Naturalism incorporates specific strategies from Science and Technology Studies, Critical Making, and Performance Studies. Finally this chapter discusses how the qualitative data generated is analyzed through the technique of "thick description."

1.5.6 Chapter Six: Contemporary Ethology: Principles, practices, and digital utilization in present-day ethological work.

Chapter Six details experiences spent investigating the values, working styles, and technologies of present-day researchers. It starts with an ethnography of the broader community of scientists at the Smithsonian Tropical Research Institute (STRI) in Panama. Questionnaires work to elicit information from the broader ethological community. These are followed by an analysis of detailed case studies with individuals and groups studying multiple types of organisms in their own specific ways. The chapter

concludes by compiling the important common features found in the sections concerning the scientist's principles and practices.

1.5.7 Chapter Seven: Technological Probes

Building from the previous ethnographic work, in Chapter Seven, technological projects are created to probe even deeper into digital media's potential impact on ethological practice. Workshops, projects, and performances are created to pragmatically investigate how digital media can support specific principles of ethological work. The probes are once again conducted in the jungle with the researchers at the STRI. These inquiries also illustrate useful attributes of digital media design to be incorporated into the final framework. The chapter finishes with an analysis and summary of the important features discovered.

1.5.8 Chapter Eight: Framework Synthesis

The eighth chapter of this dissertation synthesizes the findings of the ethnographic and technological analyses and field testing of the preceding chapters. The result is an overall framework for designing digital media to support ethological practice.

First, it consolidates the ethological values and digital features unpacked in previous chapters. These key principles are then categorized into the four components of the final framework: Technological Agency, Contextual Crafting, Behavioral Immersion, and Open-endedness. The framework's elements are described, along with specific guidelines for creating digital technology in accord with these concepts.

1.5.9 Chapter Nine: Evaluation

Chapter Nine describes a practical evaluation of the framework generated in the previous chapter. A final series of participatory, mobile workshops were designed to test the utility and effectiveness of the concept in Digital Naturalism's design framework. The designs of these "Hiking Hacks" are described along with their instantiations as expeditions in Panama, Madagascar, and the United States. The specific components of the framework are analyzed and discussed through the responses of the

workshops' participants. This final test assesses the design framework as a useful tool for designing digital media for ethological exploration.

1.5.10 Chapter Ten: Conclusion

The final chapter of this manuscript presents the findings of this research. It reviews the development, discoveries, and important takeaways from this project. The chapter additionally identifies targets for this research's continued progression. Further areas of interest are presented which will promote Digital Naturalism's progression into its own topic of study.

1.5.11 Chapter 11: Appendix

The Appendix chapter includes additional items referenced throughout this dissertation. Examples include copies of the questionnaires issued to the participants and handouts delivered in workshops.

1.6 Contributions

Little groundwork has been previously laid for this research's specific intersection between digital media and ethology. For this reason, many other contributions to these parent fields had to be developed along the way. In addition to an iteratively evaluated design framework for digital-ethological tools, this dissertation presents several other useful artifacts.

First it provides a techno-historical analysis of the field of ethology along with an evaluated model of the scientific process of ethological researchers. It also provides an additional means of analysing and categorizing emerging areas in the study of biological media and arts in their relation to digital media. As mentioned earlier, it also became necessary to outline and utilize a pragmatic hybrid research structure for studying inter-mixed technological, cultural, and scientific factors utilizing real-world performance and construction.

The hands-on work with scientists also led to the design, analysis, and documentation of several new digital media tools for studying and interacting with animals some of which have already been taken up

by ethological researchers themselves.[30] Next, and most importantly, this work provides a structural design framework for designing digital media to meet the needs of ethological exploration.

Finally, in order to evaluate the framework, this research also contributes the documentation for hosting a new form of mobile, participatory design workshop, the Hiking Hack. These new theoretical models, analyses, designs, and pedagogical forms can become useful other research conducted at the intersections of biology, media, engineering, and design.

1.7 Conclusion

Digital Naturalism studies how to design a framework from important features of ethology and digital media for exploring behaviors of animals in their natural environment. This structure develops and exemplifies a novel means of creating, evaluating, and sharing new media forms which connect digital and biotic behaviors. By helping ethologists design and build their own computational tools, this research strives to extend the ethologist's tool-making traditions into the digital realm. In order to carry out this work, this research will join with and study the practices and tools of scientists embedded in the wilderness. This dissertation in Digital Naturalism thus serves as a foundation for deeper collaborations between the human, digital, and biological worlds.

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[30] (P. Marting 2012)