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Works in Progress Session: Dissertation Proposal

Dear SIGCIS Workshop participants,
Thank you for reading my dissertation proposal! I look forward to any and all feedback and suggestions you can provide about framing my argument, proposed sites, historiography or anything else. Looking forward to meeting and learning from you at the workshop! -- Alana

Working Title: A Body in Motion: A History of Human Modeling for Computer Graphics and Animation, 1960s-1980s

Abstract

My dissertation examines the history of human modeling for computer graphics and animation in the United States from the mid-1960s through the 1980s. I investigate the circumstances in which engineers, animators, technicians, and human models used electronic digital and analog technologies to render 3-dimensional humanoid forms for design engineering and commercial media. This study will pay particular attention to the role of the live human model in this process, and how he or she interacted with an array of instruments to capture, make discrete, and animate computer-generated humanoid figures. Through archival research, oral histories, and material culture studies, I aim to demystify part of this creative process, which aided in the co-development of seemingly disparate institutions since at least as early as the 1960s.

My project's periodization extends from the early 1960s, an era that marks the beginning of experimentation in human modeling for 3-D computer animation and human factors applications, through the 1980s, when computer-generated imagery and simulation proliferate in many parts of the world. The history of human modeling and motion studies speaks to an extensive legacy rooted in scientific inquiries into physiology

and kinematics of living things, the use of photographic and cinematic techniques for these and other studies, and the need to design machines and workspaces with laboring bodies in mind. Within the last third of the twentieth century, these practices coalesce around both analog and digital computing phenomena, which pervasively extend to the present day. I aim to situate these phenomena in historical context, taking into account their social and material constellations. To that end, this work will contribute to literature where histories of technology and computing, design history, and body studies intersect.

Project description and background

Digitally-rendered and realistically-animated figures captivate the attention of spectators; however, we often take their existence for granted. Less than a half-century ago, the ascendancy and proliferation of digital electronic computing technologies, let alone digitally rendered humanoid forms, was not at all obvious (Edwards 1996; Small 2001). While scholars of visual culture, film, and media studies address the *representational* characteristics of digital images, and digital bodies in particular, historians of technology have paid little attention to the origins of this phenomenon, including how to approach the problem of digitally rendering humanoid forms, and the extent to which a diverse set of objects and stakeholders participated in these practices. Furthermore, while historians of technology have developed robust investigations of the social and political dimensions of computing phenomena, they have not fully examined the *labor-intensive role of the human model* in computer graphics and animation, particularly in relation to the array of instruments used to discretize, digitize, and animate the human body. To that end, this study will bring a fresh perspective to an under-studied realm in history of technology and STS literature pertaining to the imbrication of bodies and technologies in computer graphics, design engineering, and commercial media environments.

A central concern of this project involves the phenomenon of capturing, making legible, and representing motion and movement in human beings at a time when animators started to make use of computerized formats. I am especially interested in instances where specialists recruited living subjects or models for motion study and motion capture. Human subjects enacted any number of physical and aural movements and gestures, in the interest of creating "believable" and realistically animated figures for whatever purposes the engineers and animators saw fit. These subjects were asked to wear and interact with a range of technologies, including photogrammetric and scanning equipment, audio-visual recording devices, and analog and digital apparatuses for measuring their bodies and body parts, both in motion and at rest.

Alternatively, live human subjects were not always recruited for human modeling and simulations; in fact, in industrial or design engineering applications, experts often relied on anthropometric data to carry out their work.[1] Investigating those instances in which specialists did *not* recruit live human subjects will be just as important to this study, because they likely indicate what constitutes and qualifies a "standard body" in practices of human modeling. While it is often necessary to establish standards in

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[1] In design engineering and ergonomics applications, the work of ergonomist and anthropometrist Henry Dreyfuss was very influential. Dreyfuss was active from the 1930s to the 1970s. His 1959 book, *The Measure of Man*, which was later re-printed as *The Measure of Man and Woman*, served as a conceptual bedrock for applied design and ergonomics for several decades. Specialists continue to reference Dreyfuss's landmark contributions to anthropometry and ergonomics, as the industrial design firm, Dreyfuss Associates, continues to issue subsequent editions of the book. See Henry Dreyfuss, *The Measure of Man*, New York: Whitney Publications, 1959; Alvin R. Tilley and Henry Dreyfuss Associates, *The Measure of Man and Woman: Human Factors in Design*, Revised Edition, New York: Wiley, 2002.

industrial practices that require large-scale coordination, attending to the circumstances in which a population generates and adopts standards can reveal taken-for-granted norms and values embedded within those standards (Bowker and Star 2000; Lampland and Star 2009). In human modeling for industrial and commercial applications in particular, tensions arise between the desire to customize computerized bodies for aesthetic and stylistic purposes and the economic need to standardize and streamline the process. Investigating the instances in which design engineers, computer graphics researchers, and animators sought to customize and/or standardize human models (or their various components) will reveal certain norms, values, and assumptions embedded in these practices.

This project seeks to extend the literature in three thematic areas, including histories of models and modeling, the dialectical relationship between standardization and customization, and materiality and embodiment. Based on these thematic orientations, my dissertation will attempt to answer three main questions about the history of human modeling for computer animation, and in turn, elucidate on the critical stakes of this investigation and what bearing they have on the fields of STS and history of technology.

> **Research Question 1:** From the perspectives of the actors who will be studied in this project, what were the social and material circumstances in which the creation of 3-dimensional computer animated humans took place, at a time when electronic digital and analog computer animation began to proliferate in the United States?

> **Research Question 2:** What is the role of the human model in the overall process of creating 3-dimensional computer animated humans? How does this vary across the realms of theoretical and applied research in computer graphics and animation and in design engineering? What characteristics (physiological, aural, affective, or otherwise) did engineers, animators, and artists seek in the recruitment of live human models for creating 3-dimensional computer animated humanoid figures

when animation began to shift to electronic computerized formats in the 1960s? At what points did engineers, animators, and artists *not* recruit human subjects for computerized human modeling, and why was this the case?

Research Question 3: What happens to human modeling, and the human models themselves, when animation shifts to digital formats beginning in the 1960s? What bodies, human or otherwise, are worth modeling and animating?

Intellectual contributions

Histories of models and modeling

This project will highlight the important role that models – both human and algorithmic[2] – play in computer animation. Working with the understanding that broadly speaking, models serve as analogies for real-world phenomena (Hesse 1966; Morrison and Morgan 1999; Sismondo 1999), I aim to probe what it means *to model* and what it means to *be* a model, as well as the nature of the relationship between human models and their digitized "counterpart." These considerations necessitate understanding the experiences of the human models who participated in rendering computer animated figures as well as the social relations involved in carrying out this work. In order to gain this understanding, I will conduct oral histories of individuals who served as subjects in motion studies for computer animation as well as those recruited for commercial applications from the 1960s through 1980s. The above considerations furthermore require an understanding of the computational models employed to render the 3-dimensional humanoid figure, as well as the relationship between the human model or models and the diverse set of practices used to render and animate the figure. With that in mind, I aim to

[2] "Algorithmic" in this context refers to a set of objects, practices, and discourses that comprise computing culture in general. Although a computer algorithm specifically means a set of instructions, usually in the form of a mathematical function, it also represents one of many components of computer software, which Nathan Ensmenger labels "a material artifact; … a technology embedded in systems of practice and networks of exchange" (Ensmenger (2012): 8).

situate in conversation literature on both human and algorithmic models. This approach will provide a unique perspective from which to address questions about *what it took* to be a human model for computer graphics, when researchers and animators were just beginning to implement electronic digital and analog technologies to model and simulate human movement for a variety of applications, including design engineering and commercial media.

Literature on the social and historical dimensions of modeling within an STS framework emphasize that models serve as analogues of complex, real-world systems. It is worth noting, however, that models-as-systems manifest in several different forms, including as mathematical equations for theoretical physics and economics; as algorithmic functions; as biological organisms in laboratory experiments; as computer simulations; and even as "exemplary" practices that stand in for complex social situations studied, for instance, by sociologists and anthropologists (Creager et al. 2007). Evelyn Fox Keller notes that models blur the boundaries "between theory and practice, between pure and applied, and between representing and intervening" (Keller 2000: S72). They serve as manipulable entities that are "simultaneously material and conceptual," (S84) and "can themselves function as tools for material intervention" (S77). In what ways have human models served as tools for, in Keller's words, "material intervention?" In what ways have computerized human models similarly served these means and ends?

Echoing the above notion with respect to mathematical models and simulations, Sergio Sismondo points out, "As analogues [models] are tools for understanding, describing, and exploring [physical] systems. They should *behave* in the same way as the things they represent behave" (Sismondo (1999): 249). In the context of human modeling for computer animation, simulating human movement *realistically* and *accurately* is one of the most difficult problems to reconcile; it remains a rigorous area of study for computer graphics researchers in the present day. If, according to Sismondo, models should "*behave* in the same way as the things they represent behave," then analyzing the relationship between the human model or models and their computerized "counterparts" comprise a necessary undertaking, and one that will reveal certain taken-for-granted norms and assumptions about *what it takes* to be a model and *what bodies* certain stakeholders consider worthy of animating.

In many ways, we might consider the work of the human model a form of "hidden labor," characterized by behind-the-scenes activities that not only go largely unnoticed by front-end users and spectators, but also *unacknowledged* in their contributions – namely that of providing "body data" – to the computerized human model (Downey 2001; Shapin 1989; Light 1999). Of course, exceptions to this under-acknowledgement exist, especially in commercial applications where publicizing the identity of the human model or models might prove profitable. Recent work on the sociology of fashion models in Western Europe and the United States reveals the extent to which modeling in commercial contexts center on the active cultivation of bodily habits and techniques. In her sociological study of the global fashion model industry, Ashley Mears points out that becoming a fashion model requires the cultivation of learned bodily habits and techniques, and that the work undertaken by fashion models constitutes forms of both aesthetic and affective labor (Mears 2011). Sociologist Elizabeth Wissinger elaborates on the affective work of fashion models, especially those more elevated in the "fashion hierarchy," who find themselves in situations where they are asked to embody different moods in any given moment (Wissinger (2007): 260), much in the way an actor needs to elicit affective behavior not only through the role she plays on the stage, but also through the process of being recruited and cast in that very role (Dean 2005 and 2008). To that end, one question that this project addresses involves whether or not engineers, computer scientists, and animators instituted recruitment processes for the human models they employed. If so, did they seek out certain bodily "characteristics" in these individuals? How, if at all, did the recruitment criteria implicate decision-making processes in the laboratory spaces, offices, and studios of the sites in this study?

Dialectics of standardization and customization

Through investigating histories of models and modeling, a central theme that warrants attention involves the dialectical relationship between standardization and customization.[3] With respect to human modeling for industrial and commercial applications in particular, tensions arise between the desire to customize computerized bodies for aesthetic and stylistic purposes and the economic need to standardize and streamline the process. While it is often necessary to establish standards in industrial practices that require large-scale coordination, attending to the circumstances in which a population generates and adopts standards can reveal taken-for-granted norms and values embedded within those standards (Bowker and Star 2000; Lampland and Star 2009). For instance, visual culture scholar Lisa Cartwright has examined the construction of

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[3] For a sweeping history of large-scale practices of industrial and bureaucratic standardization in Modern Western Europe, see David S. Landes, *The Unbound Prometheus: Technological Change and Industrial Development in Western Europe from 1750 to the Present*, 2nd Edition, Cambridge: Cambridge University Press, 2003. For a history of standardization, mass-production, and customization in industrial practice in late-nineteenth to early-twentieth-century United States, see Philip Scranton, *Endless Novelty: Specialty Production and American Industrialization, 1865-1925*, Princeton: Princeton University Press, 1997.

“standard bodies” in biomedical imaging practices, where the white male body often serves as the “biomedical norm” in anatomy education and other applications for anatomical visualizations. In the case of the Visible Human Project, an online human anatomical cross-section database administered by the U.S. National Library of Medicine, Cartwright analyzes the discourses surrounding the Visible Man and Visible Woman, as well as the differences in conventional applications of each model. While the Virtual Man usually serves as “a gender-neutral model of human anatomical form and function,” and furthermore one in which racial categories are wholly absent, the Virtual Woman is more often used only for “gender-specific projects” (Cartwright 1997 and 1998).

Live human models in commercial arenas occupy a complicated space where tensions might arise between the aesthetically oriented desire to customize and the economic need to standardize. In the global fashion industry, for instance, the demand for adequate fitting clothing necessitates the widespread manufacture of mass-produced, uniform clothing with *approximate* fit (Aldrich 2007; NIST 2003). Caroline Evans’s work on the history of fashion modeling in early twentieth-century U.S. and France elucidates on this tension, which materialized in several ways, including through the bodies of fashion models. Evans contextualizes the origins of fashion shows and fashion models in their greater cultural thicket, which comprised discourses and practices that sought to “rationalize” and “streamline” the modern body in terms of work, leisure, and art (Evans (2014): 3). With respect to human modeling for computer animation, the tension between customization and standardization may frequently pose an implicit dilemma, wherein the desire to customize, or personalize, a computerized humanoid figure may prove exceedingly time-consuming and cost-prohibitive.

Additionally, I seek to analyze the circumstances in which engineers and computer animators benefitted from standardizing computer-animated bodies and body parts for both design engineering and commercial media applications. And lastly, I wonder whether a discernible relationship exists between implementing customizing or standardizing practices and the likelihood that the model will be publicly acknowledged and/or credited. In other words, what would it look like if we brought to bear practices of standardization and customization on aspects of hidden labor in computerized human modeling?

Materiality and embodiment

Much of the extant literature on the history of computer graphics and animation largely comprises participant histories that focus on the pioneers of the field. While these contributions prove exceedingly informative about key actors, instruments, and software, there is little in the way of historical interpretation, analysis, or theoretical grounding. An important part of my project will involve situating the history of human modeling for computer animation within a material culture studies framework. Media theorist Jacob Gaboury is among the few scholars studying the material culture of computer graphics and animation. His intellectual interests center on the hermeneutic move to treat digital images as material objects (Gaboury 2015). Gaboury's dissertation focuses on early computer graphics research at the University of Utah from 1965 to 1979, and reveals the history behind the creation of certain computer graphic "object standards" that proved formative for subsequent developments in that field (Gaboury 2014).

The importance of materiality to this project aligns with a rigorous body of literature in STS that emphasizes the importance of the imbricated nature of objects, people, discourses, and networks in biomedical and technoscientific practices (Law 2007; Mol 2002; Prentice 2013; Haraway 1997; Latour 1986). This study will draw upon object and ephemera studies and oral historical interviews to attempt to understand the history of human modeling for computer animation, highlighting an array of people, places, and things that helped shape the practices of computerized human modeling, at a time when engineers and animators were beginning to implement both electronic analog and digital inscription devices and formats.

The body of work in film studies that pertains to materiality and phenomenology in photographic, cinematic, and more recently electronic digital technologies attends to both the *technical* and *visceral* elements of film in general (Sobchack 1992 and 2004), and animation in particular (Hansen 1999 and 2004; Barker 2009). While filmic technologies are not made of skin and bones, the *corporeal* nature of the filmic apparatus in itself, as well as the visceral sensations experienced by spectators, constitute what film scholar Vivian Sobchack calls a *filmic body* (Sobchack 1992). Sobchack adopts a phenomenological lens to elaborate on the film's body, which as a means of "instrumental mediation" not only "[enables] the filmmaker's and spectator's perception and expression," it is also "a direct means of having and expressing a world [for itself]" (Sobchack 1992, 168). With that in mind, I aim to apply the concept of the film's body to this investigation, although rather than a filmic body, I propose the use of a term along a similar vein, the *algorithmic body*. What we might gain from thinking in terms of an algorithmic body, much in the same way certain film scholars appropriate the idea of a filmic body?

Lastly, I aim to underscore the importance of embodiment in practices of human modeling for computer animation. Through oral historical interviews, I will attempt to understand the perceptual and sensory experiences of subjects who served as human models for computer animation. The framework set forth by anthropologist Thomas Csordas will be useful in this regard, as Csordas considers embodiment a methodological schema in itself, namely by treating the body as the primary node of perceptual and sensory experience (Csordas 1990; 1993). I am also interested in investigating how engineers and animators inscribe, record, and interpret the embodied actions of human models in motion studies and motion capture projects. Through documentary behind-the-scenes footage of both traditional and digital animation, as well as in exploratory interviews with two character developers for computer animation, I have learned that many animators work through problems with animating the bodies of humanoid figures by referring to their own movements and gestures in a mirror. This self-referential activity implies that in some cases, the animators themselves serve as their own model for studying how, for instance, an elbow joint bends or a head turns. In a similar register, Natasha Myers' investigation of the embodied actions of modelers for protein crystallography reveals the "body work" that takes place in computer-mediated visualizations of modeling complex molecules (Myers 2008). Although these molecules look nothing like human bodies, model builders rely on their own bodies to help think through and visualize complex molecular structures, leading Myers to assert that "the crystallographer is an essential component of [the crystallographic modeling] technology" (Myers 2008, 185). As visualization technologies and their applications change over time, the animator remains an important part of the modeling process.

Methodology

This project will primarily draw on archival and oral historical research, as well as object studies. Criteria for selecting sites include those that employed human models; those that used electronic analog and/or digital computers to animate figures; and those that were concerned with human movement.

Main research sites and participants

- Boeing and the Joint Army Navy Aircraft Instrumentation Research (JANAIR) Program (mid-1960s-early 1970s)
- University of Utah (late 1960s-mid 1970s)
- Animac and Scanimate (1969-early 1980s) (Dave Sieg, Ed Tajchman, Debbie Macomber, Ed Kramer and others from Computer Image and Image West)
- University of Pennsylvania (Norman Badler, mid 1970s-1980s)
- New York Institute of Technology (Ed Catmull, Alvy Ray Smith, Rebecca Allen, Lance Williams; mid 1970s-mid 1980s)

Boeing and the Joint Army Navy Aircraft Instrumentation Research (JANAIR) Program (mid-1960s-early 1970s)

Computer graphics designer William Fetter (1928-2002) is credited with developing the first 3D computer animated wireframe human model, called Boeman-I, while working under the partnership of Boeing and the Joint Army Navy Aircraft Instrumentation Research (JANAIR) Program from the mid-1960s to the early 1970s. I am interested in researching the institutional dynamics of one study in particular, called "Cockpit Geometry Evaluation," which applied the Boeman-I simulated model to cockpit design in military aircraft and presented a simplified computer model for human motion based on a "23-pin-joint articulated stick-man (Boeman-I)."[4] Some documents from this six-phase study are available electronically through the Defense Technical Information Center (DTIC) website, and I suspect that more documents reside in the National Archives (specific location TBD), which houses the records of the Office of Naval Research, the Naval Air Systems Command, and the Army Electronics Command – offices whose personnel comprised the Working Group for this project. With respect to Boeing, the study was conducted under the auspices of the Military Aircraft Product Development and Support Systems Engineering divisions.

University of Utah (late 1960s-mid 1970s)

The University of Utah was an important site for research in computer animation and 3-D computer generated human modeling since the late 1960s. A number of key figures in the history of computer graphics completed their dissertation work in the Department of Computer Science at the University of Utah, where David C. Evans and Ivan Sutherland founded the pioneering computer graphics company, Evans & Sutherland Computer Corporation, in 1968. The David C. Evans papers and the David C. Evans audio-visual collection, housed at the J. Willard Marriott Library, contain several correspondences, papers, audio-visual recordings, photographs, and other ephemera related to Evans & Sutherland, as well as computer graphics research conducted by graduate students and faculty at the University of Utah. Some notable people who

[4] "Cockpit Geometry Evaluation, Phase I, Final Report." Joint Army-Navy Aircraft Instrumentation Research Program, Office of Naval Research, Department of the Navy, (January 1969): v.

completed their graduate degrees at the University of Utah include Frederic I. Parke, Edwin Catmull, Henri Gouraud, and Phong Bui Tuong. These and other individuals interested in problems of human modeling focused on developing algorithms and other coding techniques for a variety of factors related to realistically rendering and animating humanoid forms. ARPA funded much of the computer graphics research at the University of Utah, where computer scientists developed flight simulators for pilot training, space simulations for NASA, and techniques for 3D modeling of microorganisms, among other applications. In many instances, the popular Evans & Sutherland computer graphics hardware/software platform, Picture System 1 and 2, served as the interface for visualizing computerized models and simulations at several research hubs, including at the University of Utah.

Animac and Scanimate (1969-early 1980s) – bulk of story will be late 1960s

The Animac and Scanimate were electronic analog computer animation machines invented in the late 1960s by Lee Harrison III. I will focus my discussion on the Animac, the proof-of-concept machine that preceded the Scanimate, because it contained a harness that a model could wear to capture his or her movements in real time. I plan to contextualize the history of Animac and Scanimate technology in relation to the way animators sought to understand and animate a computerized body by way of simplified models of joints and skeletons. Dave Sieg is a self-proclaimed curator and historian of all things Scanimate. He was the Chief Engineer of Image West, a Los Angeles-based company that used the Scanimate through the 1970s and into the early 1980s. Sieg is the owner of the few remaining Scanimate in the world, and his rich in documents, photographs, and ephemera broadly related to Scanimate and Animac technology. Sieg connected me with Marilou Harrison, widow of Lee Harrison III, and Edwin J. Tajchman, former Chief Engineer of Computer Image Corp., the company that developed the Animac in the mid 1960s and made and distributed the Scanimate beginning in 1970. I have already interviewed and consulted the private collections of Sieg and Tajchman, and have been in touch with Marilou Harrison.

University of Pennsylvania (mid 1970s-1980s)

Norman Badler is Professor of Computer and Information Science at the University of Pennsylvania, and has served as a faculty member in that department since 1974. In the late 1970s, Badler and his colleagues developed a set of algorithms based on Labanotation, an early twentieth-century form of dance notation, to program movement of a computerized figure for design engineering simulations (Badler et al. 1979, Badler and Smoliar 1979). This technique does not require a human model to collect information about body movements – it is a completely digital input-output form of representing human movement. Computer scientists still use Labanotation for simulating human movement, but I don’t know whether this technique is used in commercial computer animation applications.

New York Institute of Technology (mid 1970s-mid 1980s)

The research in computer graphics and animation that came out of the Computer Graphics Laboratory (CGL) at NYIT from the mid 1970s-mid 1980s was very influential in the field and primarily geared toward commercial applications, including television cartoons and animated shorts and motion pictures. In Tom Sito's history of computer animation for the motion picture industry entitled, *Moving Innovation* (2013), he devotes a chapter to computer animation at NYIT. Sito emphasizes the tensions inherent in combining the skills of traditional animators with younger computer animators, including Ed Catmull and Alvy Ray Smith, who were enticed to the university on Long Island by the state-of-the-art equipment and generous operating budget provided by founder Alexander Schure. I would like to interview Rebecca Allen, Professor in the department of Design and Media Arts at UCLA, because she is a computer animator and video artist and was involved in research in human movement at CGL. I would also like to interview Lance Williams, a computer animator at CGL who also worked on human movement projects.

Organization

Chapter 1: Understanding the Modern Body in Motion

This chapter will contextualize the idea of "modern" human movement for a variety of applications, beginning in the mid-nineteenth century, when physiologists implemented experimental photogrammetric inscription devices on humans and animals to track and measure motion and movement (Cartwright 1995; Braun 1992). Modern motion studies derive from research into human movement and fatigue studies in the workplace (Rabinach 1990; Brown 2005), experimental research in physiology and kinesiology (Braun 1992), and studies in early twentieth-century modern dance (Schwartz 1992; Laemmli forthcoming). I will explicitly relate these practices to those that emerge later on in human modeling for computer animation, making the important connection between the need to understand the human body in motion and the sorts of questions that researchers and technicians asked about this topic, alongside the array of technologies that they implemented to aid in practices of measuring, recording, and inscribing moving bodies.

Beginning in the early 1960s, human factors specialists including engineers, ergonomicists, and biomechanists implemented standardized computer-animated bodies and body parts in their research. They used anthropometric and biomechanical data to simulate the movement of "standard" operators of, for instance, airplanes and automobiles. William Fetter developed the first 3-dimensional computer-generated wireframe human model, called Boeman-I, while working under the partnership of Boeing and the Joint Army Navy Aircraft Instrumentation Research (JANAIR) Program in the mid-1960s and early 1970s. An important study that came out of this collaboration, called "Cockpit Geometry Evaluation," applied the Boeman-I simulated model to cockpit design in military aircraft. It presented a simplified computer model for human motion based on a "23-pin-joint articulated stick-man (Boeman-I)."[5] Fetter designed Boeman-I based on Air Force anthropometric data for a 50th percentile figure; that is, a (male) figure whose measurements and upper-body joint articulations correlated with about 50 percent of Air Force pilots.[6] Standardizing and approximating body measurements constituted a necessary step in design engineering practices, which required careful consideration of human factors variables for designing machines and spaces for a range

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5 "Cockpit Geometry Evaluation, Phase I, Final Report." Joint Army-Navy Aircraft Instrumentation Research Program, Office of Naval Research, Department of the Navy, (January 1969): v.

6 William Fetter, "Computer Graphics: A Graphic Form of Visual Communication," Presentation to the American Society for Engineering Educators Annual Meeting, 20-24 June 1966, Washington State University, Pullman, WA, Courtesy of The Boeing Company Archives.

of body shapes and sizes. Although Fetter's creation was initially used for cockpit design engineering, the wireframe Boeing Man (or Boeman-I) was quickly appropriated for commercial purposes, as it appeared in a television commercial for Norelco in 1970. The Boeing Man's body measurements and movements came from averaging anthropometric data, probably derived from manual measurements of bodies using tape measurers, goniometers, and other instruments.

Proposed themes: standardization, embodiment, history of the model and modeling

Chapter 2: Capturing and animating human movement: Motion tests, rotoscoping, keyframing, and sensing equipment

In this chapter, I will discuss several techniques pertaining to studying bodies in motion from the perspective of the animator and his or her interactions with human models, and how this relationship has changed over time. While recording equipment may vary, the overall technique for graphically capturing human movement relies on first filming or videoing the model performing a series of movements, and then transcribing (and perhaps digitizing) that information to animate it using a computer. The computer, whether analog or digital or hybrid, would implement algorithms to make the figure move, a topic I will address more closely in Chapters 3 and 4. The animator might then manipulate the footage through rotoscoping, the process of tracing the image frame-by-frame from the film footage. This technique is labor-intensive, whether rotoscoping applies to traditional or computer animation, because it's a frame-by-frame transcription of an image (Fox 1984, Cartwright 2012). Early digital computer animation from the 1970s often involved tracing gridlines on a live model (or a non-living object) and plotting those points on the computer using a contact probe, another labor-intensive approach. I aim to highlight the point that the animator often acts as artist, technician and even biomechanist, as he needs to know how bodies move, how to operate machinery associated with sensing and capturing movement, and how to graphically represent it, whether via film or computer.

Proposed themes: standardization/customization, embodiment, history of the model, expertise, hidden labor

Chapter 3: Bones, Skins, and the Language of analog-digital Computerized Motion

My preliminary research shows thought-provoking connections between the way that early computer animators thought about making computer-generated figures move on the screen and how they went about actually mapping out and implementing those computerized functions. The work of Lee Harrison III, a pioneer of electronic analog computer animation, reveals explicit relationships between bone joints and metaphors of skin to map out the process of analog computer animation, first through the experimental analog machine, Animac and then the more marketable version, Scanimate. I interviewed Dave Sieg, Ed Tajchman, and I hope to interview Debbie Macomber, a professional dancer who wore the Animac body harness in 1969 for a promotional opportunity.

Beginning in the mid-1970s, Norman Badler's research in electronic digital computer animation at the University of Pennsylvania also reveals an emphasis on articulating bones and joints in algorithmic form for digitally animating figures, but without the use of a live human model as reference.

Proposed themes: standardization/customization, embodiment, history of the model, expertise, hidden labor

Chapter 5: Photorealism and digital computer animation: NYIT Computer Graphics Laboratory as a Case Study

In this chapter, I will discuss photorealism by way of the Computer Graphics Laboratory (CGL) at NYIT. As I mentioned in the description of NYIT, this site was an important research hub in computer graphics and animation from the mid 1970s to mid 1980s. The work that came out of CGL was primarily geared toward commercial applications, including television cartoons and animated shorts and motion pictures. CGL founder Alexander Schure hired both traditional and computer animators because he recognized the need for artistically- and mathematically-minded people to work together in computer animation. According to Tom Sito's account in *Moving Innovation*, this combination of skills generated tension between the "old guard" animators and the younger animators trained in computer science (Sito (2013): 133-34) . Focusing the discussion on photorealism will provide context for the widespread interest by this point in attaining ever-more-realistic imaging through digital computer graphics and animation. I suspect that SIGGRAPH conference proceedings and journal articles from the late 1970s through the 1980s exemplify a growing interest among computer scientists and animators for photorealistic rendering, although I will need to verify this.

Proposed themes: standardization/customization, embodiment, history of the model, expertise, hidden labor, digital 'optimism'

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