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GAME INFRASTRUCTURE

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by

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Abstract

Game Infrastructure

Christopher Kerich

The tools and paradigms used to create video games have long been understudied. These infrastructural technologies of games have powerful social and cultural impacts on players and the world but rarely see proper analysis. This dissertation takes these objects as the main object of inquiry and through historical research, close readings, and artistic production, seeks to pursue an anti-racist, anti-sexist, and anti-colonial understanding of these tools. In doing so, this dissertation shows that these tools are not politically neutral and carry with them a powerful influence that shapes and structures the world of video game play, pushing users in the direction of white entitlement.

Acknowledgements

This document would not exist if not for the influence and guidance of many others. I'd first like to thank my advisor Warren Sack for his diligent oversight and his many notes over the course of the writing of this dissertation. Similarly, my thesis committee, Soraya Murray, Neda Atanasoski, and micha cárdenas have each contributed valuable insight to the various chapters. Each chapter has its own lineage and the influence of many along the way. The seed of chapter one was sown in one of my very first seminars at UCSC, and I want to thank Anna Friz for cultivating the space in that class where I could generate the art piece that would later become *Piles*. I would later finish *Piles* at Stochastic Labs in Berkeley, California under the care of Vero Bollow and Alex Reben. The very first iteration of chapter two began in a different critique class at UCSC run by Larry Andrews and comprised of only myself, Erick Msumanje, and Zia Mannah, all of whose feedback was essential in the first drafting of the chapter. The *GamePyg* project which accompanies chapter two took the longest of the three, and as such passed through many different iterations and eyes. The first videos were seen in micha cárdenas' DANM 201 course, and I was later encouraged by her to develop it into a more diegetic piece. Later, Patrick LeMieux and Stephanie Boluk expressed interest in seeing the piece more as an ARG or narrative, and this ultimately transformed it into the version that exists today. Commensurate with COVID, the writing of chapter three was a more solitary affair, but I am very grateful for all the support that made getting it done possible. Thank

you to my FDM buds, Yasheng She and Rosy Hearts, whose companionship and big brains I couldn't have finished without. Thanks also to Brian Brown, Adrian Hagerty, and Gigs, the Game Boys, without whom my Thursdays and Saturdays wouldn't burn nearly as bright as they consistently do. The art project for the third chapter was also done mostly alone, though I appreciate Cat Bluemke, Jonathan Carroll, and the Ender Gallery for finally making me put it onto paper. Finally, nothing I've done here would be anything like it is without the support of Kara Stone, whose nonstop edits, advice, and encouragement are the bedrock on which this dissertation is built. If this dissertation is worth anything, it's because I learned from the best. And by the best, in this specific case, I mean Kara.

Introduction

Imagine a 3D character. How does it look, what is the shape of its body, and what do you first see when you look at it? In most 3D games, this is governed by a polygonal modeling paradigm: a game infrastructure. Now imagine the world around that character, stretching out into an infinite horizon. What does this world look like and how was it constructed? In many video games, this terrain is generated programmatically through a process known as procedural generation, another game infrastructure. Now, imagine that world coming apart and a vast chasm opening underneath the character who begins to fall, twisting and turning, limbs flailing and waving. How would you describe the frantic, erratic choreography of this bodily movement? In many games, such falling behavior is governed by a physics system, which attempts to roughly replicate Newtonian physics and is also a game infrastructure. These infrastructures have a profound effect on the ways that games work and how they are processed and received by players, but are not often directly studied. This dissertation is an attempt to develop a theory of game infrastructures, and more broadly understand how the unseen elements of games affect play, players, society, and culture. What I argue is that often the uncritical use of these infrastructures affords many negative elements of game design and culture including entitlement to the bodies of others and colonial expansionist game design. I hope to ultimately set a groundwork for building up new games making practices that are

resistant to these negative elements by providing the ability to critique the infrastructures that are instrumental in their deployment.

In this case it is best to start with what makes this sort of a study difficult. In the introduction to their book *Gamer Trouble*, scholar Amanda Phillips lays out some of the difficulties in a nuanced, critical study of games and the section is worth quoting at length,

> Many academics write about AAA games even while harboring a deep fear that they are not worth writing about at all, either because coming to their defense looks very bad and is probably bad for society or because the bad things about them are such low-hanging fruit for critique that it is difficult to sustain a nuanced conversation about them. As a result, we have a lot of theoretical work that avoids engaging with games that most people play, a lot of critical work that glosses over the politics of representation, a lot of descriptive work that looks over but not into the structures of racism and sexism in gaming culture and the industry, and a lot of hit pieces that resonate with our academic and politically minded peers. However, these never quite square with the phenomenological experience many of us have while playing a racist, sexist, homophobic, violent game.[1]

Instead of being a reason to abandon the study of games, and perhaps retreat to a less tumultuous discipline (if any truly exist), Phillips instead resolves to forge on into this trouble. I, too, plan to focus my critique on big budget or otherwise extremely profitable and popular games, and am facing all the same challenges that Phillips describes. I myself am writing from the position of a white, cis, male, settler scholar and I have the attendant limitations of such a perspective in addition to raw

[1] Phillips, Amanda. *Gamer Trouble: Feminist Confrontations in Digital Culture*. New York: New York University Press, 2020. p. 4

human clumsiness. Instead of scrubbing the whole project, I too will forge on into my own trouble for risk of losing the valuable critical potential that Phillips describes in the quote above. Still, I plan to remain critically and dramatically open to reworking and revisiting the ideas I will put forward in the coming pages with full appreciation of my own positionality.

With that in mind, I have decided to focus my analysis specifically on some of the more technical, esoteric and subtle elements of games, what I am calling "game infrastructures." While these will receive a more detailed description later in this chapter, in short they are structuring software paradigms that are used to both build and then execute games. In the opening paragraph, there were three examples of game infrastructures. The main project of this dissertation is to explore the work that these infrastructures do in shaping, conveying, and allowing different feelings and ideas in games, especially those surrounding entitlement and control. I also intend to approach this from an anti-racist, anti-sexist, anti-colonial lens and invest in trying to imagine ways that these infrastructures could be brought more in line with those projects. This, however, is getting slightly ahead, as I would first like to establish what I mean by infrastructure and how we can tie it to games. This will be followed by an examination of various other theoretical frameworks which will be useful in pursuing this topic.

What is Infrastructure and What is Games

A significant claim implicit in the phrase "game infrastructure" is that my objects of study are actually infrastructure in some theoretical sense. Scholar Paul Edwards contends that most commonly the term "infrastructure" has become expanded and genericized, and is "...often used to mean essentially any important, widely shared, human-constructed resource."[2] Notions of infrastructure in a more academic context have become more specific, especially in the broad academic discipline of Infrastructure Studies. This collection of scholars has developed a multiplicity of ways to both define and study "infrastructure." This multiplicity is actually core to Infrastructure Studies, as it is often understood that all infrastructure is domain-specific.[3] It is very intuitive that this is the case, as various kinds of infrastructure do not cleanly map onto each other. For example, you can't drive on telephone wires. As such, all Infrastructure Studies splinters into various domains, civic infrastructure, media infrastructure, software infrastructure, and so on. Despite

[2] Edwards, Paul N. "Infrastructure and Modernity: Force, Time, and Social Organization in the History of Sociotechnical Systems." In Modernity and Technology, edited by Thomas J. Misa, Philip Brey, and Andrew Feenberg, 185–225. Cambridge, MA: MIT Press, 2003. p.187

[3] One example of this sentiment in writing on infrastructure, is the beginning of Liu, Alan. "Toward Critical Infrastructure Studies," February 23, 2017.

this splintering, there are some concerns and commitments shared across most if not all of these sub-areas that should be discussed before getting into any individual area.

The foremost of these concerns and commitments is perhaps articulated best as "substrate becomes substance."[4] Infrastructure studies understands that infrastructure is invisible, unnoticed, and transparent. The lived world, whether it be transportation, engaging with media, or using software, relies on acting through the "substrate" of infrastructure. This is a sentiment found time and time again in modern infrastructure studies: that "infrastructures are defined by their invisibility."[5] The key transformation of infrastructure studies is to turn the analytical gaze to the substrate itself. It is this invisible yet pervasive nature of infrastructure that motivates much of the scholarship devoted to it. It is, however, important to note, as Edwards does, that "This notion of infrastructure as an invisible, smooth-functioning background 'works' only in the developed world."[6] Infrastructure is often said to become "visible" when it

[4] Star, Susan Leigh, and Karen Ruhleder. "Steps Toward an Ecology of Infrastructure: Design and Access for Large Information Spaces." *Information Systems Research* 7, no. 1 (March 1996): 111–34. p. 113

[5] Parks, Lisa, and Nicole Starosielski, eds. *Signal Traffic: Critical Studies of Media Infrastructures*. The Geopolitics of Information. Urbana: University of Illinois Press, 2015. p. 6

[6] Edwards, Paul N. "Infrastructure and Modernity: Force, Time, and Social Organization in the History of Sociotechnical Systems." In *Modernity and*

breaks down, but this becoming visible does rely on breakdown not being the norm. While this dissertation will focus on infrastructure from a primarily Western perspective, the productive work of breakdown will remain present throughout.

An additional key belief of modern infrastructure studies is the entanglement of the social and technical in infrastructure. For example, Lisa Parks and Nicole Starosielski define "media infrastructures" as "...situated sociotechnical systems that are designed and configured to support the distribution of audiovisual signal traffic."[7] In their understanding, media infrastructures are not only data centers, cell phone towers, and undersea cables but, as Paul Edwards writes, things like "...organizations, socially communicated background knowledge, general acceptance and reliance, and near-ubiquitous accessibility…"[8] all collaborate in the construction of infrastructure as a subject.

Technology, edited by Thomas J. Misa, Philip Brey, and Andrew Feenberg, 185–225. Cambridge, MA: MIT Press, 2003. p.188

[7] Parks, Lisa, and Nicole Starosielski, eds. *Signal Traffic: Critical Studies of Media Infrastructures*. The Geopolitics of Information. Urbana: University of Illinois Press, 2015. p. 4

[8] Edwards, Paul N. "Infrastructure and Modernity: Force, Time, and Social Organization in the History of Sociotechnical Systems." In *Modernity and Technology*, edited by Thomas J. Misa, Philip Brey, and Andrew Feenberg, 185–225. Cambridge, MA: MIT Press, 2003. p.188

These key beliefs about the nature of infrastructure are articulated well in a 1996 article by Susan Leigh Star and Karen Ruhleder, "Steps Toward an Ecology of Infrastructure"[9]. Their definition of infrastructure comes with the understanding that infrastructure emerges in use, and in relation to its use. For example, a squirrel climbing a telephone pole does not receive it as infrastructure, or at least, not in the same way that a suburbanite does. This acknowledgement further complicates how an infrastructure is defined, as Star and Ruhleder note, because one must ask not only *what* is infrastructure, but *when.*[10] As a way of helping to categorize and navigate this idea of "infrastructure," Star and Ruhleder offer eight different dimensions that infrastructure is involved in: it is embedded in other structures, it is transparent, it has spatial or temporal reach or scope, it is learned as a part of membership in a community of practice, it has links with conventions of practice, it embodies established standards, it is built on an already installed base, and it becomes visible on breakdown.[11]

I seek to extend this definition of infrastructure to what I'm deeming "game infrastructures," and I will use these dimensions as a guide in my description and justification for why they should be considered thus. I define "game infrastructures"

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[9] Star, Susan Leigh, and Karen Ruhleder. "Steps Toward an Ecology of Infrastructure: Design and Access for Large Information Spaces." *Information Systems Research* 7, no. 1 (March 1996): 111–34.

[10] Ibid., p. 112

[11] Ibid., p. 113

as the tools, processes, and paradigms that structure digital game worlds. Like many kinds of digital artifacts, they are both object and process, a set of paradigms and codes as well as specific algorithmic implementations. For example, the first chapter of this dissertation focuses on physics systems, the systems in games which can govern the movement of objects and characters according to basic Newtonian physics and gravity. These systems exist with a theoretical and conventional basis, there are set ideas about how physics in games "works," but there are also specific physics engines, such as Havok,[12] which have unique implementations of physics systems which can be directly used in game development.

Game infrastructures largely fit the eight dimensions that Star and Ruhleder dictate. They are "sunk" into larger software structures which we call video games (i.e. they are components of the construction of video games), and are part of a convention of practice around games: game development, which has warped over time around these infrastructures. This also helps illustrate why they are learned as a part of membership: learning them is often a part of becoming a "game developer." While game infrastructures may be visible to a developer, to a player they are by design transparent, meant to facilitate the world without calling attention to themselves. The same infrastructure, or even the same implementation in the case of something like a physics engine, can be used over and over again across many different games, and are instantiated again and again whenever that game is run which gives them both a "spatial" and temporal reach. Game infrastructures are

[12] See https://www.havok.com/

required to work with other elements of games, including other game infrastructures, and so they are required to be standardized and themselves represent certain standards. Game infrastructure is also installed on computers, on hardware, and so it is subject to those constraints (for example, there is not enough processing power in a computer for physics to be modeled at a molecular level). Finally, game infrastructures do become visible on breakdown. Much of games reporting on "broken" or "glitched"[13] games is focussed specifically on malfunctioning game infrastructure.

Games infrastructures are not neutral objects. They are built with certain values and ideologies in mind, and create game worlds that afford some constructions and interactions more than others. The politics of objects has been a central part of science and technology studies for many years, dating back to Langdon Winner's 1980 "Do Artifacts Have Politics?"[14] where Winner argues that while inanimate objects do not actively hold beliefs, they still carry politics with them. For Winner, this comes in the way that artifacts can embody power and authority while still remaining non-agential in themselves. The rise of digital platforms in the 2010s

[13] For example, see this GamesRadar article detailing bugs and glitches in *Assassin's Creed: Unity* (2014) https://www.gamesradar.com/assassins-creed-unitys-glitches-are-awful-also-kind-amazing/. The article covers both physics and polygonal modeling bugs, both of which are game infrastructures later covered in this dissertation.

[14] Winner, Langdon. "Do Artifacts Have Politics?" *Daedalus*, 1980, 121–36.

brought with it a rise in scholarship dubbed Critical Algorithm Studies which, while not the first scholarship of this type, was still a major extension of the politics of artifacts to digital artifacts like software. For example, Safiya Noble's *Algorithms of Oppression*[15] focuses on the racial and sexual biases of search engines, specifically Google. Similarly, Virginia Eubanks' *Automating Inequality*[16] performs similar analyses on automated decision-making and eligibility tools. Both these pieces of research contend that these software systems do not create new social ills and issues, but rather exacerbate existing ones, or make their effects on those they harm more efficient and direct.

One way to understand how exactly software, or game infrastructures, function to enact ideological or political actions is through the concept of the "affordance." In an article titled "Encoding and Decoding Affordances," Adrienne Shaw defines the affordance as "action possibilities"[17] of an object, and that affordances are "...highly interpretive, as deciphering the use of objects and

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[15] Noble, Safiya Umoja. *Algorithms of Oppression: How Search Engines Reinforce Racism*. New York: New York University Press, 2018.

[16] Eubanks, Virginia. *Automating Inequality: How High-Tech Tools Profile, Police, and Punish the Poor.* S.l.: Picador, 2019.

[17] Shaw, Adrienne. "Encoding and Decoding Affordances: Stuart Hall and Interactive Media Technologies." *Media, Culture & Society* 39, no. 4 (May 2017): 592–602. https://doi.org/10.1177/0163443717692741. p. 594

environments is related directly to the subject position of the organism."[18] In other words, affordances are a contextual property of objects, and one that makes certain actions or tasks easier or more desirable. Shaw later goes on to combine the concept of affordance with the sociologist Stuart Hall's concept of "encoding and decoding" as a way of extending Hall's concept originally designed to address television and broadcast media to games and new media. Encoding and decoding is the idea that the intention that is given to the construction of a piece of media, encoding, may be different than what different audiences receive from it, decoding. Shaw's extension of this to affordances is to ask the questions, "What types of uses do they lend themselves to? What types of interaction do they encourage?"[19] about a piece of software as it is designed and encoded and also as it is received and decoded in play. This results in affordances being extremely contextual and inextricably tied up in the agency and desires of the user. To further theorize this messy entanglement of the infrastructure and the user, I will turn to classic feminist science and technology studies. I do this because of feminist STS's strong history of engaging with subjective knowledge and the entanglements of humans and technology.

In the 1988 essay "Situated Knowledges," Donna Haraway presents the issue of objectivity to feminist science. The issue is presented thusly,

> ...how to have simultaneously an account of radical historical contingency for all knowledge claims and knowing subjects, a critical practice for recognizing our own "semiotic technologies" for making meanings, and a no-nonsense commitment to faithful accounts of a "real" world, one that can

[18] Ibid. p.594

[19] Ibid. p.597

be partially shared and that is friendly to earthwide projects of finite freedom, adequate material abundance, modest meaning in suffering,and limited happiness.[20]

This issue might be succinctly phrased as: How do we square social construction with scientific fact? How can we honor the contextual and contingent while also pursuing the practical benefits of there being a 'real' and objective world? Bruno Latour would later return to this same tension in 2004 in his essay "Why has Critique Run out of Steam?" without citing or recognizing Haraway and other feminist science's many years of grappling with it.[21] In general, there are problems with committing to either extreme: there is either the loss of any concrete motivation to make change, since context and contingency can shift at any moment, or there is the loss of the respect and acknowledgment for a variety of experiences and understandings of the world.

[20] Haraway, Donna. "Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective." *Feminist Studies* 14, no. 3 (1988): 575-99. https://doi.org/10.2307/3178066. p. 579

[21] Latour, Bruno. "Why Has Critique Run out of Steam? From Matters of Fact to Matters of Concern." *Critical Inquiry* 30, no. 2 (January 2004): 225–48. https://doi.org/10.1086/421123.

Haraway's solution is what she calls "partial perspective"[22] and it is a way of holding both sides at once. The idea is that applying either view, total relativism or positivist objectivity, to the whole world will inevitably not be able to account for all of it. Instead, slices need to be taken of it, intentional partiality, inside of which definitive statements can be made. This partiality is relative; statements made about and in these partial perspectives are not meant to extend to everything, but the statements made about a given partial perspective are definitive with respect to itself. Subjects of these statements are also constructed as a part of this taking partial perspective and therefore exist only as a part of them. Haraway is navigating this epistemological space in order to make room for the experiences and knowledges of marginalized people, especially people marginalized along the axis of race and gender, who have important knowledge but that don't have the ability to often speak through global knowledge and science. This system is quite elegant and practical, and allows for a deep engagement with the world without losing the ability to make real claims. This dissertation will rely more on a different piece of feminist science literature, but one that shares much in common with Haraway's partial perspective.

Karen Barad's *Meeting the Universe Halfway* can be best understood by first beginning with the dual-slit experiment, something that the text itself does across

[22] Haraway, Donna. "Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective." *Feminist Studies* 14, no. 3 (1988): 575–99. https://doi.org/10.2307/3178066. p. 583

chapters two and three.[23] The dual slit experiment, as it is widely known, was a Gedanken experiment (or thought experiment) discussed by Niels Bohr and Albert Einstein regarding the nature of electrons. The dual-slit experiment was designed to determine if electrons exhibit wave or particle behavior by measuring their impacts on a screen after having been fired through two slits. One pattern on the screen would mean particle behavior, and another wave behavior. The result of this experiment (and as was later proven in an actual construction of the thought experiment in the 1990s) is that if the apparatus is constructed in such a way that the path of each individual electron is measured (in essence, measuring the electrons as if they are particles) then the resulting pattern on the screen reflects particle behavior. If the apparatus does not measure the electrons in that way, then they exhibit wave behavior on the screen. In short, depending on how the electrons are observed, they exhibit different behavior.

It should already be clear how this aligns with Haraway's partial perspective: depending on the perspective you take in observing the electrons, you are able to make different, consistent, grounded reports about them. However, Barad takes this notion even further and establishes a notion of "agential realism" based on a concept called "intra-action." Barad writes, "In other words, relata do not preexist relations; rather, relata-within-phenomena emerge through specific intra-actions. Crucially, then, intra-actions enact agential separability-the condition of

[23] Barad, Karen Michelle. *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning*. Durham: Duke University Press, 2007.

exteriority-within-phenomena."[24] In other, other words, things, people, plants, animals, any subject or object only come into being through phenomena, meaning specific arrangements and relations between them (these relations are called "intra-actions"). I and the chair only come into being through our relations to each other and the rest of the world in the phenomena of sitting. It is at first a disorienting reworking of what Barad calls the "Cartesian cut" which determines subjects and objects prior to phenomena, but one that ultimately reaffirms radical contextuality and the power of Haraway's partial perspective. This reworking of agency, where objects and subjects do not act on each other but rather bring each other into being through intra-actions inside of phenomena is what Barad calls "agential realism."

Infrastructure, usually understood to be sitting "behind" or "beneath" the existing structure of the world, does not hold that position with respect to intra-action. Instead, it's an active constitutive part of the intra-action alongside all other components of phenomena. Returning to game infrastructure, incorporating agential realism makes some of the confusing relationship between player, creator, and infrastructure a little more clear. Isolating the phenomena of play, the game infrastructure comes into being in its relationship to the player, and in fact the player and game infrastructure mutually configure and construct each other and the rest of the game space at the moment of play. This means that to study game infrastructure, they cannot be fully evaluated outside the actual moments of play where they come into what Barad would call "mattering", when they have a real intra-actional impact.

[24] Ibid. p. 140

As such, while the chapters of this dissertation will explore historical and cultural elements of various game infrastructures, special attention will be specifically given to their use in the context of play. Partially, this will be accomplished through the use of various artworks created specifically for this dissertation, which can provide material insights into various phenomena where these infrastructures are used that would be inaccessible through other means.

A Review of Relevant Literature in One Act

The overall project of this dissertation is one that bears in common many similarities with other academic projects surrounding software and games. Using software objects and code to illuminate underlying biases and politics is a powerful idea, as is using agential realism to help pursue those goals. It is worth reviewing some of these prior works in order to help contextualize the project of game infrastructure in the ecosystem of these many others. In this section we will look at work engaging with critical analyses of systems as well as prior attempts to integrate Barad's work into game studies.

A recent example of work in this area is Noah Wardrip-Fruin's *How Pac-Man Eats*, a project that breaks down the operations of video games into cultural units which can then be analyzed. Wardrip-Fruin defines these as "operational logics" and "playable models"[25], with the latter being composed of the former. He defines

[25] Wardrip-Fruin, Noah. *How Pac-Man Eats*, 2020. http://mitpress.mit.edu/9780262044653. p. 23

"operational logics" as "...foundational combinations of *abstract processes* with their *communicative roles* in the game, connected through an ongoing *game state presentation* and supporting a *gameplay experience.* Operational logics are essential building blocks of playable models, through which games represent everything from physical space to economic systems, social relations, character development, and combat."[26] These have great overlap with the notion of game infrastructure, as they both describe software objects and paradigms used to create and operate a game. Whereas game infrastructure casts them as infrastructural elements, operational logics cast them as logics of communication that happen in games. Game infrastructures also do communicative work, so even this distinction is only slight. The biggest distinction between them comes not from anything definitionally, but rather how they're intended to be used. Operational logics allow an insight into games for the purpose of understanding how abstract concepts are concretized and communicated in games. My notion of "game infrastructure," on the other hand, provides insight for the purpose of understanding what is possible inside the framework of games and importantly the effects and biases these bring to the spaces created in play. It is the very intentional inclusion of an inherent critical property of game infrastructure that encourages me to stick with the term.

A somewhat infamous framework for finding the inherent political or ideological elements of games comes from games scholar Ian Bogost, and is called

[26] Ibid. p. 24

"procedural rhetoric." Laid out in Bogost's 2007 *Persuasive Games,*[27] procedural rhetoric is an application of the ancient Grecian tradition of oral rhetoric to modern video games and the procedures therein. Procedural rhetoric is the idea that game processes can do rhetorical acts,[28] in a similar-but-uniquely different way to speech acts of rhetorical persuasion or written acts of rhetorical persuasion. Procedural rhetoric has since become a very popular way of understanding the persuasive power of games and is well cited both in and out of academia. Game infrastructure, however, is positioned to address a key area that procedural rhetoric cannot. While procedural rhetoric focuses on gameplay processes, like how crime functions in a game like *Sim City* might influence how people consider crime statistics in the real world, it does not cover how non-gameplay elements of games also structure and influence players. It also does not cover the ways that elements of games more subtly create spaces for players to enact ideological experiments for themselves, it is fittingly only concerned with direct persuasion. This in itself is no critique of procedural rhetoric. It is only to simply say that procedural rhetoric and my stated goal for game infrastructures, while on the surface both engaging with how games influence people, are actually intentionally operating in different domains from each other.

Similarly, Mary Flanagan's *Critical Play* advocates for what Flanagan calls "radical game design" that exists not merely for profit or entertainment, but because

[27] Bogost, Ian. *Persuasive Games: The Expressive Power of Videogames*. 1. MIT Press paperback ed. Cambridge, Mass.: MIT Press, 2007.

[28] Ibid, p. 2-3.

the artists who make them have "something to say."[29] Instead of developing tools to understand the persuasion of different elements of games abstractly, *Critical Play* takes a broader approach in examining different individual game artifacts and analyzing the unique ways that they achieve radical game design in different kinds of environments and contexts. Thus, engaging with some of these games can therefore cause a player to be in the titular state of "critical play." Critical play is an amorphous term, but is generally a positive one, and involves the player doing something subversive or disruptive, either to the game itself or to the culture in which they're playing. For example, playing a game of *The Sims* which intentionally upends traditional gender roles could be considered critical play. For this to happen, however, players often have to work against much of the game infrastructure: the clothes available to certain Sims or the composition of a Sims household, which all push them in certain directions and encourage certain play situations. It is for this reason that game infrastructure is an essential component to understanding the effects of play, both critical and not.

This dissertation is by no means the first to attempt to apply Barad's agential realism to video games. One example comes from C. McKeown, who in a 2018 article applies agential realism to code-injection in *Super Mario World* (1990).[30]

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[29] Flanagan, Mary. *Critical Play: Radical Game Design*. Cambridge, Mass.: MIT Press, 2013. p. 3

[30] McKeown, C. "Playing with Materiality: An Agential-Realist Reading of SethBling's Super Mario World Code-Injection." *Information, Communication &*

Code-injection describes the process of inserting foreign code into an existing software object, in this case the SNES game *Super Mario World*. Their conclusion results in a kind of "performative account of the matter."[31] To reach this point, they engage in a direct analysis of the actual electrical mechanisms that make video games operate and extend those conclusions to the operation of all matter. They write, "Rather, intellectually engaged players should embrace the possibility that although they are engaged in a process of moving voltages from one 'place' to another, those voltages are, in themselves, composed of trillions of electrons, which, in turn, have only a loose 'location' in existence (super-position). Rather, the mutability of software speaks to the constant dance of matter that constitutes things such as video games, but also – potentially – all things."[32] While this conclusion does reaffirm Barad's agential realism from the perspective of the raw materiality of games, it does not extend to higher-order functions of software such as the ones covered by game infrastructure.

This work is also not the first to consider the production of digital artwork to be an essential part of reflecting on cultural and social issues. One such example of this type of work is D. Fox Harrell's work at MIT in his Imagination, Computation, and Expression (ICE) Lab. This lab regularly produces games and other media as well

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Society 21, no. 9 (September 2, 2018): 1234–45. https://doi.org/10.1080/1369118X.2018.1476572.

[31] Ibid. p. 1242

[32] Ibid. p. 1243

as scholarship that engages with important issues of identity, representation, and discrimination. One such example is 2018's *Chimeria:Grayscale*,[33] an interactive narrative piece which focuses on sexism in the workplace. This project places you in the fictional shoes of an HR manager and, through an interface designed to look like a corporate email client, you are faced with a toxic, melancholy workplace. This project is one of only a relative few that attempt to engender real reflection on significant issues like sexism in the workplace in the form of games. The work in this dissertation seeks to join it.

The Next Bits (of the Dissertation)

This dissertation is broken up into three chapters followed by a conclusion. Each chapter focuses on a different element of game infrastructure and reflects on a corresponding art piece which has been developed specifically for that chapter to help formulate its argument.

Chapter 1 examines the game infrastructure of physics, the mechanisms that cause bodies and objects to behave "realistically" in a physical sense, meaning they roughly follow Newtonian physical properties like gravity and friction. The chapter specifically looks at how physics modeling is engaged with how players perceive death in games, and how it relates to issues of agency and control. The art piece for this chapter is titled *Piles*, a set of videos of the piling of dead bodies in different

[33] ICE Lab. 2018. *Chimeria:Grayscale*. Browser. http://groups.csail.mit.edu/icelab/content/chimeriagrayscale.

video games, a practice which relies on physics infrastructure. In looking at *Piles*, the chapter builds an argument that physics systems are intimately associated with death and afford an entitlement to the bodies of the other.

Chapter 2 is focused on polygonal modeling, the game infrastructure which is the foundational paradigm for the 3D rendering of characters and other objects. The idiosyncrasies of this infrastructure have profound effects on the way that visual forms of representation occur in games, and how players interact with them. The art piece for this chapter is *GamePyg's Face and Body Overhaul*, a small alternate reality game, or ARG, which depicts a near-future science fiction premise: what if a video game modification became sentient? The chapter again looks at entitlement to bodies, this time through the lens of race and gender, and how polygonal modeling systems often allow for a commodification of bodies in game spaces.

Chapter 3's main infrastructure is procedural generation, the practice of generating game assets through programmatic methods rather than by hand. The chapter revolves around the idea that procedural production lends itself to an imaginary of infinite production and consumption, and the inherent times to imperialism and colonialism that this imaginary brings with it. The art piece for this chapter is *Three Impossible Worlds*, an exploration of the limits of *Minecraft*'s procedural terrain generation system which includes modifications to radically change and alter it. In this chapter, *Three Impossible Worlds* serves as a concrete example of the imperial game design trends that procedural generation is often engaged in.

Finally, there is a short coda which wraps up the different infrastructures covered thus far and looks forward to how studies of game infrastructure may develop in the future, and briefly covers a collection of infrastructures not covered in individual chapters. It reflects on the value of this work and looks towards a future where it is pursued further.

The goals of this dissertation are to explore elements of games not often studied, and approach them in a variety of ways. Game infrastructures inevitably have a cultural and political character, and to ignore that in scholarship is to the detriment of all work in the field. By putting forth the three examples in the following chapters, I hope to start to build a space where game infrastructures can be discussed with precision and depth. In addition, I hope to show that these technologies are not neutral and can have serious cultural and social consequences in their uncritical application and adoption. In particular, enabling entitlement and exacerbating racism and sexism.

Chapter One: Physics

Figure 1: A pile of bodies in *Dishonored: Death of the Outsider* (2017)

A jiggle and a twitch; leg twists over an arm and the pile fluidly begins to slip across the floor. Spreading evenly across the surface, the bodies seem to move of their own accord. After a moment, the creator of the pile, who had been silently watching, walks over and begins to reconstruct the pile once again.

This scene, one of many from my project *Piles*, showcases some of the peculiarities of the ways that bodies behave in video game spaces. The chief force that regulates the behavior of dead or unconscious bodies in many video games is the game infrastructure called physics. Video game physics are the processes and structures by which the laws of physics of the real world are translated into video

game spaces. Of course, the physics of our world involve interactions at the atomic and subatomic level, as well as physical forces that extend across the universe, and there is not the will nor the processing power to simulate that in games. Instead, we can consider video game physics as the approximation of real world physics in 3D worlds. In practice, this area has primarily been concerned with the realistic interaction of physical bodies with relation to forces like gravity, friction, and momentum as well as interactions (collisions) between bodies.

Because video game physics are an approximation of real-life physics, human decisions need to be made in how to translate them into digital spaces. Thus, the ways that physics systems are implemented in games are political and rooted in varying human conceptions of what physics 'should be like.' As I will later show, physics' close association with death in games situates it as participating in what Amanda Phillips terms "mechropolitics,"[34] the "virtual, often whimsical, politics of death and dying with complicated resonances in the real world." Therefore, the decisions that physics designers are making, intentionally or not, are not only how physics 'should be' but in fact how death 'should look.' The way the physics systems participate in representing death and violence create a space where players entering play with feelings of entitlement to the bodies of others will find those feelings eagerly and easily reinforced. In many games with physics systems, players are not only imbued

[34] Phillips, Amanda. "Shooting to Kill: Headshots, Twitch Reflexes, and the Mechropolitics of Video Games." *Games and Culture* 13, no. 2 (March 2018): 136–52. https://doi.org/10.1177/1555412015612611. p. 138.

with the sovereign right to choose how and when other characters die, but also what to do with their remains. In examining how physics systems, and other related systems, construct the physical representations of bodies in games, an underlying politics of access and control becomes readily visible.

Amanda Phillips' 2018 essay "Shooting to Kill: Headshots, Twitch Reflexes, and the Mechropolitics of Video Games" explores the representation and mechanics of death in video games. To do this, Phillips coins the term "mechropolitics," a transformation of Achille Mbembe's "necropolitics". While necropolitics is focused on the political power of being able to determine who lives and who must die, mechropolitics is focused on the power inherent in virtually representing death and the resonances it has in the real world. Mbembe's work on necropolitics has significant racial dimension, in that it is primarily focused on the power to determine how Black people live or die, and Phillips extends that same racial dimension into their discussion of mechropolitics. While Phillips does touch on ragdoll physics (a common type of video game physics) briefly in the essay, it is primarily focused on the mechropolitical device of the headshot, and how it can be used to frame the ongoing epidemic of police violence against people of color. Phillips tracks the history of the headshot from media spectacle (the assassination of JFK), to cinematic spectacle, to finally video game device, where it came to represent technical virtuosity and a twitch reflex skill. Where once shooting for the head might be discouraged as a dangerous wartime tactic, Phillips argues we now have entered a world where video game players now desire the headshot as a part of their real life

firearms training and hold twitch reflexes as a key component of firearm use.[35] Phillips argues that both these things have a direct influence on policing, as some of those video game players are recruited to the police force. The essay ends with a call to action for other scholars to deploy "...intersectional paradigms that can cut across identity categories, technological processes, and human actions without losing sight of the complicated relationship between play and reality."[36] One key goal with introducing game infrastructure as a term in this dissertation is to do just that.

This chapter is broken down into three key sections. The first section will briefly describe different types of physics systems in games and analyze their mechropolitics. The following section will then look at some of the history of game physics to understand where the fundamental assumptions of game physics arise from and to trace some of the legacy of the development of game physics. Finally, the third section and the bulk of the chapter will combine these historical and technical insights with *Piles*, an art piece created by me focused on the different ways that games approach physics implementation. With *Piles*, I will ground the mechropolitics of game physics in concrete artistic examples. To conclude, I will look forward to the development of new physics paradigms and how that may affect the political groundwork set in the chapter.

[35] Ibid, p. 147

[36] Ibid, p. 148

Physics, in Detail

There are many different kinds of physics in games which vary based on their applications. Collision detection is used to prevent objects from occupying the same space, causing them to bounce off each other when they would do so. Another type of game physics is particle physics which dictates how particles move in space, often used for effects like fire or sparks. However, the main type of physics that I will be focusing on is rigid-body, or ragdoll physics, which is most often applied to the motion and behavior of lifeless bodies.

The most straightforward principle in rigid-body or ragdoll physics is the rigid-body assumption; that is, to ignore the fact that in real life when forces are applied to objects they deform around the force. In many cases this is mostly imperceptible but sometimes it is very noticeable, like in the case of poking skin or a cloth. The rigid-body assumption is to assume that objects are not deformed by forces, and in fact never lose their shape when being acted on by force. Because the "soft body" effects are often very subtle, this is thought to well approximate physical interactions while cutting down on the complex calculations that might come with a soft body approach.[37] The result is a fundamental turgor, or stiffness, in the objects and bodies in a rigid-body system. There are some ways to make rigid bodies more

[37] Özkaya, Nihat, and Margareta Nordin. "Introduction to Deformable Body Mechanics." In *Fundamentals of Biomechanics*, by Nihat Özkaya and Margareta Nordin. New York, NY: Springer New York, 1999. https://doi.org/10.1007/978-1-4757-3067-8_6. p. 117–24.

bendy, however. In those cases, they can be made to behave in more flexible ways by combining and connecting rigid segments. Still, each individual component, at its irreducible level, is a rigid object. The effect can be masked, but never removed. In many games it is still noticeable despite attempts to downplay it; a slight weight, a heaviness, a disjunction between it and the rest of the world. When applied to bodies, it is as if there is an instantaneous rigor mortis; bodies tumble like stacks of blocks knocked over because that is exactly what they are behind the scenes. Phillips refers to this as "literally objectifying"[38] a body; it becomes decomposed from fluid, living animation states to a chunky collection of solid masses.

This decomposition of a body into a set of connected rigid-bodies (often called a 'skeleton' or 'rig') is also a very important aspect of ragdoll physics. This data object maps onto the represented body and allows physics to operate over it as a set of connected objects as opposed to a single one, giving it the ability to bend at joints and otherwise move in a 'realistic' way. This skeleton system is a universalizing tool to help all bodies function not only realistically, but similarly across similarly shaped characters. All humanoid figures will have roughly the same skeleton, with minor variations for size and limb length. Each of the physics regions that composes the body is likely a rigid-body, giving the overall effect that of a wooden puppet. While the overall body is moveable and poseable, individual regions

[38] Phillips, Amanda. "Shooting to Kill: Headshots, Twitch Reflexes, and the Mechropolitics of Video Games." *Games and Culture* 13, no. 2 (March 2018): 136–52. https://doi.org/10.1177/1555412015612611. p. 139.

are hard and uniform. This doll-like behavior is very evident when these bodies collapse, when they die or are killed in a game, hence the term “ragdoll” for this kind of physics system

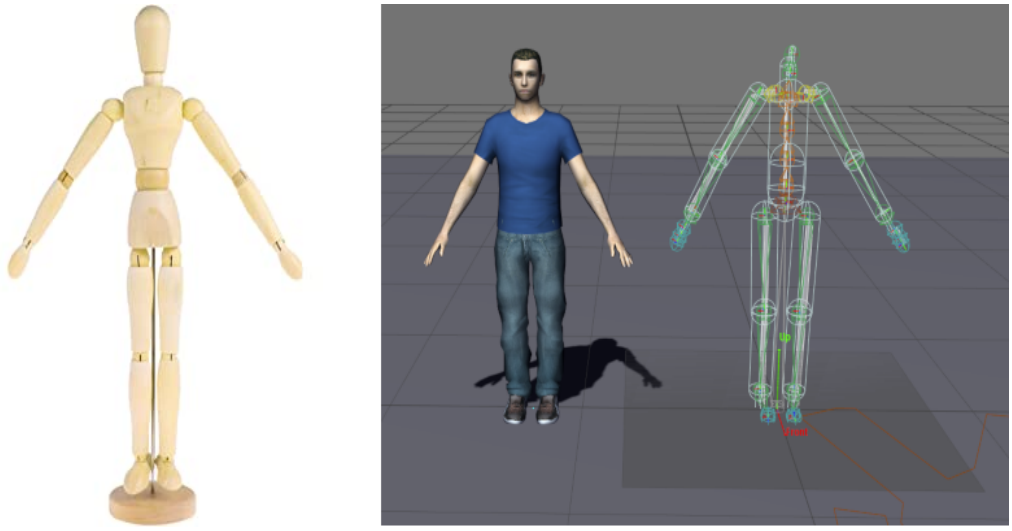

Figure 2: A comparison of a drawing doll and a modeled skeleton[39]

These two assumptions together produce a physical subject of violence that is puppetlike to the extent that the moment of death and the transition to the physics system is like having their strings cut. However, the mechropolitics of the ragdoll cannot be expressed solely using the technical structure of the infrastructure itself. To do that, we have to look at this physics system in dialogue with cultural ideas around death and dying as well as how this infrastructure is deployed in various different game circumstances. The mechropolitical work that physics systems do, in line with

39 https://golaem.com/content/doc/golaem-crowd-documentation/setting-your-character-physics

agential realism, happens in the phenomena of play, where they participate in constructing the possibilities of what can happen. Before moving on to more modern examples, let us review some of the history of physics in games.

The History of Physics and Death

When Mario jumps up into the air, Mario comes back down to earth. In a sense, "physics" has been incorporated into games as early as the falling blocks in *Tetris* or the bouncing ball of *Pong*. One fundamental grounding principle that allows us, as humans on Earth, to understand what is happening in games is a shared sense of physical reality. The primary physical force we see in early video games is gravity; a constant downward pull. Another very common one is collision; two objects cannot occupy the same place at the same time. This principle governs a large number of game interactions: the *Tetris* blocks stack on each other, Mario bumps into a Goomba and takes damage, etc. Early physics systems like gravity and collision were limited not just by the technical limitations of the hardware they were running on, but the visual fidelity of the games they were being implemented for in the first place. Accordingly in 2D sprite-based environments[40] simple gravity and collision are relatively straightforward to implement.

During the advent of the polygonal 3D game in the 90s, there came a desire to develop new kinds of physics for those new 3D spaces. One of the earliest games in

[40] A sprite is a 2-dimensional image, and in sprite based games many of these sprites are combined to create larger, more complex scenes.

doing this was *Trespasser*, a 1998 PC game licensed by Dreamworks in the *Jurassic Park* universe. In it, you play a hapless traveler named Anne (voiced by the actress Minnie Driver) who becomes stranded on an island full of dinosaurs and must fight her way out. *Trespasser* was poised to be a huge hit, and not just because of the attachment to a popular film. It also boasted a large number of technical innovations including a dynamic texture caching system, a "real-time" audio generation system, advanced "dinosaur AI" and most significantly, a fully simulated rigid-body physics system, a move away from the emulated physics of other 2D and 3D games.[41] However, *Trespasser's* ambition led to its ultimate critical failure, as it was widely panned for exceeding the technical limitations of most of the consumer-grade computers of the time and causing the game to be unplayable on those systems.[42]

[41] Wyckoff, Richard. "Postmortem: DreamWorks Interactive's Trespasser." Gamasutra, May 14, 1999. https://www.gamasutra.com/view/feature/131746/postmortem_dreamworks_.php, p. 1-2.

[42] Ibid, p. 3.

Now, it exists more as an oddity and footnote in the history of games.

Figure 3: A screenshot from *Trespasser* (1998)[43]

[43] https://www.imdb.com/title/tt0304846/mediaviewer/rm2722698497/?ref_=tt_md_1

In the history of game physics[44], however, *Trespasser* has a huge significance, as mentioned before, by its implementation of rigid-body simulated physics as opposed to emulated ones. Emulated physics are the kind we see in 2D sidescroller style games, where physics is not acting as a universal system applying to all objects but rather a system that applies only to certain objects at certain times. A character might only have "gravity" when they are jumping or falling, but once they land, the game is no longer applying a physical force to them. In a simulated physics system, physics is a semi-universal system that applies to most objects (those designed as "physics objects") at all times, regardless of their state. In *Trespasser*, the physics system was used in two major areas. The first is for objects: many areas in the game contained physics-enabled objects of various sizes and shapes that could be manipulated by the player. These were things like boxes, benches, and other elements of the environment. There were physics-centric puzzles in the game which used these objects, and it is worth noting that these were always "destructive" puzzles; the physics system was good at letting objects get knocked down, but much worse at

[44] To date, there exists no written history of video game physics. The history covered in this dissertation is a small contribution towards compiling it. This compilation is essential as any real accounting of game physics history needs to collect information which is spread across many different computer science lectures, game postmortems, and Youtube videos.

allowing objects to be stacked up (they would slide or bounce off of each other).[45] The second area that physics is applied in *Trespasser* is for the dinosaurs. The dinosaurs were not physics-enabled when they were alive (instead executing animation routines), but their bodies became physics-enabled after they were killed by the player. This could arguably be lumped into the first "objects" category; however, the dinosaur bodies function differently than all the other physics objects in the game. They are alive and moving (without physics) when you first encounter them, and then post-combat are transformed into dead, physical objects.

Just two years later, the release of *Hitman*: *Codename 47* in 2000 by IO Interactive would mark one of the first real commercial successes of so-called "ragdoll" physics in the world of games. *Hitman: Codename 47* is a stealth action game that has you playing as the eponymous hitman assassinating targets in locations around the globe. It also uses ragdoll physics, but implements a different method for computing the physical forces than *Trespasser*. *Trespasser* used a more basic physics system rooted in what are called "collision penalties."[46] When a moving object

[45]Wyckoff, Richard. "Postmortem: DreamWorks Interactive's Trespasser." Gamasutra, May 14, 1999. https://www.gamasutra.com/view/feature/131746/postmortem_dreamworks_.php, p. 2.

[46] While *Tresspasser'*s physics engine was developed in-house and as such has no public documentation, it can be assumed it was similar to the penalty force model discussed in real-time physics literature, such as here: Drumwright, E. 2008. "A Fast

collided with a surface, in order to simulate that collision, an inverse force was applied to the object. In essence, it is as if the moving object was "pushed" in the opposite direction. This system has many issues, the primary one being that the application of inverse force as a simulation of a collision is a very rough approximation of the complexity of the interaction, and could cause some truly exaggerated movements — especially in cases where the two objects accidentally overlapped, where the inverse force would be extremely strong.

Hitman, on the other hand, uses Verlet Integration, a different algorithm that instead acts on particles as "velocity-less."[47] As opposed to many systems where the velocity determines particle position, Verlet Integration works in reverse, where objects' positions are set first and the integrator determines the velocity using the difference in position.[48] This affords a lot more control over the positions of objects in

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and Stable Penalty Method for Rigid Body Simulation." *IEEE Transactions on Visualization and Computer Graphics* 14 (1): 231–40. https://doi.org/10.1109/TVCG.2007.70416.

[47] Jakobsen, Thomas. "Advanced Character Physics." Accessed October 22, 2020. https://www.gamasutra.com/view/feature/131313/advanced_character_physics.php, p. 1.

[48] For a more detailed technical explanation of Verlet Integration in a geometric setting, see Hairer, Ernst, Christian Lubich, and Gerhard Wanner. 2003.

the world and can avoid many of the extreme cases that arise in the collision penalty model. In a presentation from the 2001 Game Developers Conference, Thomas Jakobsen, the head of research and development at IO Interactive at the time, explains, "With the Verlet integrator it is easy to control the motion of objects by bombs, bullet hits etc. – simply move the particle positions proportionally to the force inflicted on them and the velocities will be adjusted automatically."[49] This quote also indicates that in the world of *Hitman: Codename 47* the imperative was also to simulate the physics of bodies—specifically violence done to bodies. While Verlet Integration results in more "believable behavior"[50] than the penalty system of *Trespasser*, it is also more counterintuitive. Instead of velocity determining position (as it does in Newtonian mechanics[51]), the difference in positions determines velocity,

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"Geometric Numerical Integration Illustrated by the Störmer–Verlet Method." *Acta Numerica* 12 (May): 399–450. https://doi.org/10.1017/S0962492902000144.

[49] Jakobsen, Thomas. "Advanced Character Physics – the Fysix Engine." Powerpoint Presentation presented at the Game Developers Conference, San Jose, March 20, 2001. Slide 20.

[50] Ibid. Slide 31.

[51] As given by the equation $p = p_0 + vt$, where p is position, p_0 is initial position, v is velocity, and t is time.

which in turn determines future position.[52] In other words, the physics system works backwards from positions to velocity, favoring "believable behavior" and results over a faithful recreation of real-life physics. What "believable behavior" means in the context of *Hitman* is not only that bodies fall in the "right" way, but also that they can be manipulated after death by the player. The edge of what is believable lines up with the edge of player control, and physics systems are entirely oriented around the purpose of aligning control and believability.

[52] Which can be modeled $v = (p_2 - p_1)/t$, where v is velocity, p_1 and p_2 are two positions of the object, and t is the time elapsed between the object being at p_1 and being at p_2.

Figure 4: A screenshot from *Hitman: Codename 47* (2000)[53]

As we can see in both the *Trespasser* and *Hitman: Codename 47* examples, in the world of simulated, rigid-body physics, from the very beginning it has always been all about the bodies—specifically corpses. In many games including *Trespasser* and *Hitman: Codename 47*, physics systems are not responsible for the enactment of killing or the creation of the death state but always swoop in at the moment of death and then take control. Death and dying have been important to games long before

[53] https://oldpcgaming.net/hitman-codename-47-review/

rigid-body physics. As Amanda Phillips puts it, “Death, as the ending of life, is a rather effective mechanism.”[54] Death and dying are mechanisms that “... structure the activity of gaming: for fun, frustration, or fairness.”[55] Physics for bodies is a necessary corollary for this—if the act of killing in a game is meant to be pleasurable, then the results of that action likely need to be pleasurable to see. This was the demand that rigid-body physics has grown to fill.

In early 2D sprite-based games where characters are represented by 2D images, a technique often used to represent death was simply to replace the living sprite with a dead one. This was especially common in the days of early first-person shooters such as *Doom* (1993) and *Wolfenstein 3D* (1992). As the first person shooter genre moved to polygonal 3D, this system became displaced by the rise of rigid-body physics. Even contemporarily, there are other methods for representing death in games. One such method that is still popular is through animation; instead of surrendering the body to the physics system, the body will execute an animation of dying, clutching at their body, wailing, or some other action before crumpling to the ground. This system is not mutually exclusive with physics; sometimes games will execute dying animations and then switch over to physics to simulate the body

[54] Phillips, Amanda. “Shooting to Kill: Headshots, Twitch Reflexes, and the Mechropolitics of Video Games.” *Games and Culture* 13, no. 2 (March 2018): 136–52. https://doi.org/10.1177/1555412015612611. p. 137.

[55] Ibid, p. 137.

afterwards. Death may have hooks into many different infrastructural technologies of games, but rigid-body physics is an infrastructure almost solely devoted to death.

Necro and Mechro Politics

While Phillips' paper on mechropolitics is devoted largely to the headshot, there is a brief section on ragdoll physics. Phillips concludes that ragdolls, "...offer a playground of cruelty that operates firmly within the logics of necropolitics—and yet, it is still just a game."[56] This "playground of cruelty" is related to a core aspect of mechropolitics that is based on Mbembe's description of "death worlds," the idea that there exist cultural understandings of necropolitics, of who may live and who must die, that extend through "real" power and politics down to the digital.[57] While Mbembe doesn't directly write about video games, there is an understanding that playfulness can be a part of necropolitical death worlds. In writing about the introduction of the guillotine to France, Mbembe writes, "...a new cultural sensibility emerges in which killing the enemy of the state is an extension of play."[58] The relative ease and democratization of death that the guillotine brought to France, and the performative nature of public beheadings, made finding and executing "enemies of the state" a public game. Mechropolitics can thus be the link between the fictional

[56] Ibid., p. 140.

[57] Mbembe, Achille. "Necropolitics." *Public Culture* 15, no. 1 (January 1, 2003): 11–40. https://doi.org/10.1215/08992363-15-1-11. p.40.

[58] Ibid., p. 19.

death and dying of games and the real playfulness in death that exist in necropolitical death worlds.

In many games, the construction of the player character and the enemy who they fight is very similar to Mbembe's description of the sovereign state and the construction of the enemy for whom they have the right to kill. He writes, "...the state of exception and the relation of enmity have become the normative basis of the right to kill."[59] In other words, the state constructs and maintains its right to kill through a state of emergency, the exception, and "a fictionalized notion of the enemy,"[60] the enmity. Here, Mbembe is writing specifically about how the state constructs and manages Black people in plantation slavery systems. In games, the construction of the player as a virtual sovereign behaves very similarly to Mbembe's description of a sovereign, most directly in the fictionalized notion of the enemy, as all opposition in (non-multiplayer) games is composed of fictionalized enemies. The enemy in games can always be depicted as being as evil or cruel or heartless as desired by game creators, and the player can always be positioned in whatever way that provides the most justified killing of those enemies. Similarly, the emergency can always be constructed as the most compelling, most urgent justification for the death that the player is often the sole arbiter of. The player is the central nexus around which a collection of forces conspire to construct the most justified right to kill.

[59] Ibid., p. 16.

[60] Ibid., p. 16.

This sovereign right to kill in games is apparent not only in the killing of characters in games, but also in a wide range of practices and patterns that surround the core activity of killing. Phillips mentions a few of these in their article: teabagging[61] and physics fling games such as *Stair Dismount* (Lauha, 2002)[62] are two examples where ragdoll physics in particular constructs a relationship of the sovereign control of a player over the bodies of others.[63] One particularly interesting behavior is the piling of bodies in games. This practice involves the collection of bodies from around the area of a game into a single location, piling the bodies on top of each other. Sometimes this can be done for comedic effect[64] and sometimes for sheer visual spectacle;[65] either case relying on the fact that the bodies can be

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[61] Teabagging is a gloating behavior in multiplayer games where after one player kills another, the living player with repeatedly squat over the face of the now lifeless player.

[62] A game where you fling a ragdoll physics body down a set of stairs

[63] Phillips, Amanda. "Shooting to Kill: Headshots, Twitch Reflexes, and the Mechropolitics of Video Games." *Games and Culture* 13, no. 2 (March 2018): 136–52. https://doi.org/10.1177/1555412015612611. p. 140.

[64] See "There's a Problem With the Toilet" by Roger Chin, https://www.youtube.com/watch?v=n9Czc3aKUDk.

[65] Purdom, Clayton. "Someone Keeps Blowing up Piles of Video Game Corpses." AV Club. Accessed December 11, 2020.

manipulated, moved, and most importantly, that they have ragdoll physics applied to them.

These piles call to mind real life scenes of mass death and torture, including instances like Abu Ghraib, where the United States army and CIA generated visuals of similar kinds of piles of bodies as the result of torture practices in Iraq. What's more significant than the visual similarity, however, is that the logics of power and control work in a similar way in both cases. In *Terrorist Assemblages*, Jasbir Puar examines Abu Ghraib through the lens of *homonationalism*, specifically in how the torture at Abu Ghraib reinforces an Orientalist distinction by which the simulated oral sex and other acts that the Iraqi prisoners were subjected to, the physical manipulation of their bodies, was perceived to be especially damaging because of their "cultural" objection to homosexuality, and conversely that the torturers from the United States, in their "civilized" culture, were not opposed to such things and were able to weaponize it against the Iraqi prisoners.[66] In doing so, despite the grotesque act of torture, the cultural superiority of the United States was able to be maintained. Though the torturers were most likely not thinking of how their pursuit of the erotic pleasures of their torture could support their country, they nevertheless enacted reinforcement of it through that torture.

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https://news.avclub.com/someone-keeps-blowing-up-piles-of-video-game-corpses-1798254842.

[66] Puar, Jasbir K. *Terrorist Assemblages: Homonationalism in Queer Times*. Duke University Press, 2007.

The piling of bodies in video games, on the other hand, is probably best described as a performance of torture, but one that still relies on perceived and assumed ideas about the relationship of the piler and the other bodies in the game world. Specifically, ideas about the piler's entitlement to the manipulation of other bodies and the role of the pile in the game world—usually as a transgression of some kind. Whether knowing or not, the pursuit of the creation of these piles reinforces the sovereign authority and power over life and death in games, the mechro/necro politics, imbued in the players who create them. This is of course deeply tied to physics, as the creation of these piles is functionally impossible in games without physics, specifically ragdoll physics. This behavior of piling bodies allows us to connect the game infrastructure of physics to the cultural questions of necropolitics.

Piles of Talking (about Piles)

To bring these questions out of abstraction and into the material, it is helpful to consider my 2019 art piece, *Piles*, which involves videos of the creation of seven different body piles in seven different video games. The videos play indefinitely on a loop and are dynamically juxtaposed with one another. *Piles* was originally streamed on Twitch.tv, a video game streaming website, and is now accessible in recorded form on my website[67]. *Piles* is a useful object for analysis here as it will aid in bringing out the nuances of the relationship of physics and necropolitics by showing the variations

[67] www.ckerich.com

in how this relationship is constructed in different games. The games used in *Piles* are *Dishonored: Death of the Outsider* (2017), *Skyrim* (2011), *Hitman* (2016), *Metal Gear Solid V* (2015), *Viscera Cleanup Detail* (2015), *Slime Rancher* (2017), and *Tabletop Simulator* (2015). Inside these seven, there's a distinction between the first four which are all AAA (big budget, mainstream) titles, and the remaining three which are all independent titles. There is no single approach to physics and mechropolitics that equally extends to all AAA or indie games, but the ones selected for the project are meant to serve as a representative selection.

Figure 5: An image in *Piles* from *Hitman (2016)*

In much the same way that the project is organized as a series of juxtapositions, the best way to approach its examination is through looking at the

differences that exist between the games. Let us first consider the AAA games. Both *Dishonored* and *Skyrim* use Havok physics (a third-party physics system), albeit in different game engines. *Metal Gear Solid V* uses the proprietary Fox Engine's physics, and *Hitman* uses the also proprietary Glacier Engine's physics. These systems all are meant to accomplish roughly the same goal: realistic movement of physical bodies. However, different physics systems change how ragdoll physics operate in various ways, but beyond that, even games using the same physics infrastructure can tweak it in ways that make the way physics functions in games very different. For instance, in *Dishonored*, which uses Havok, bodies are quite slippery and in the *Piles* video of *Dishonored,* the body pile regularly starts to slowly spread out on the floor where it is piled. Conversely, in *Skyrim*, which also uses Havok, bodies are very heavy and have high friction, and thus in the *Piles* video bodies barely slide or move at all once piled—the pile itself is rock solid throughout the piling process. These games share a physics engine but behave in very different ways.

This difference in part is due to the role of dead bodies in the rest of the game; the physics are tuned to suit this purpose. This is true in all games; the way the material properties of bodies operate follows from the needs of the game itself, whether it be in the selection of a physics system or in the configuration of that system. In the case of *Dishonored* and *Skyrim*, in *Dishonored* bodies are meant to be a nuisance for the player to manage—if bodies are laying in open space, a patrolling guard might spot them and raise the alarm, endangering the player. Keeping them slippery and loose aids in moving them—they put up no resistance to being picked up

or slid around. In *Skyrim*, on the other hand, disguising the presence of bodies is much less of a concern. Instead, what's important about a dead body in *Skyrim* is the fact that it may contain a valuable item. In this game, bodies are programmatically containers, like a box or urn, and can contain items, gold, equipment, etc. The slippery physics of *Dishonored* would simply not function for a body in *Skyrim*, as a body that contained some valuable or important item might slide away, off of a cliff or into an ocean. The intensely rigid and high friction physics implementation in *Skyrim* ensures that bodies will mostly stay put upon death, ensuring that the player never misses their opportunity to get the valuables contained within. These choices, to see bodies as obstacles or containers of value are choices rooted in what the value of a body is, and in that way are political choices. These choices then inform how the bodies are materially represented in these games. We can thus begin to see the flow from political investment to material representation.

In both *Hitman* and *Metal Gear Solid V* the player has access to methods of so-called "non-lethal" force. In *Hitman* this primarily takes the form of blunt objects like wrenches and in *Metal Gear Solid V* primarily through pellet and tranquilizer guns. Despite this similarity, there is a distinct difference in the way that non-lethal force is applied to bodies through the games' respective physics engines. In *Hitman*, unconscious bodies are indistinguishable from dead bodies. They are subject to the same ragdoll physics forces as dead bodies, and you can drag, hide, and otherwise manipulate them in the same way you can with dead bodies. There are only two distinguishing features that separate these kinds of bodies from dead ones: a spinning

icon above the body which indicates its unconsciousness, and the fact that while they will never "wake up" on their own, they can be revived by another character. Dead bodies behave in a somewhat traditional way in *Metal Gear*. They collapse according to ragdoll physics, and can be moved and manipulated like in many of the other games in *Piles*. Unconscious bodies, on the other hand, actually exist outside the physics system in some significant ways. Namely, they do not collide with other bodies, so "piling" them vertically is actually an impossible task. Instead, they are firmly maintained by the animation system which animates the slow breathing of the unconscious character.

What accounts for this difference? Why should one game allow unconscious bodies a weighty materiality and another keep them ethereal and ghostly? I would argue the main factor here is once again political and even philosophical—the difference is how distinct from each other these two games view unconsciousness and death. In *Hitman*, the two are closer together, and in *Metal Gear*, they are farther apart. This is further corroborated by how easily unconscious characters can rejoin the "living" world. In *Hitman* unconscious characters waking up is fairly infrequent and requires the bodies to be discovered. In *Metal Gear*, though, unconscious characters are simply on a timer and after it expires they will wake back up. Therefore, the state of an unconscious body in *Hitman*, uninterrupted, is to stay in that state forever, and in *Metal Gear* it is to eventually wake up. The relative permanence of the unconsciousness in *Hitman* is why the bodies are handed over to the physics system, which is associated with death and perpetuating deathlike behaviors, while

the fleetingness of unconsciousness in *Metal Gear* is why bodies only have physics applied when they die. Another way of framing this distinction is how these different games consider the severity of unconsciousness—is it a temporary or permanent affliction?

While these differences certainly help establish some of the necropolitical nuances of the different ways these games model violence and death, their physics systems are more similar than different. Ragdoll behavior always follows death, and the bodies can be manipulated in very similar ways. In physics systems, in the moment of violence or death in a game, they participate in constructing a player who is a sovereign, who controls who lives and dies, and do their part in aligning such death with the political and mechanical structure of the game, the death world in question. This selection of four games, while representing a contemporary selection of AAA action titles, does not cover the full range of games that employ ragdoll physics, especially not on bodies in particular. The *Piles* project therefore includes three independent titles, *Viscera Cleanup Detail*, *Slime Rancher*, and *Tabletop Simulator*, all of which also use ragdoll physics, as further comparison points that further clarify the general mechropolitical orientation of the AAA games in the project. Each of these indie titles brings a unique twist to the physics implementations I have demonstrated thus far.

Viscera Cleanup Detail is a satirical game where you play as a janitor who must clean up the aftermath of some kind of sci-fi shootout or industrial accident. There are many differences between *Viscera Cleanup Detail* and these other games

but the one I'd like to focus on here is that unlike *Dishonored* or *Hitman* is that you do not "produce" bodies yourself through violence; they all already exist inside the level for you to clean up. The way these bodies are represented is very gory and bloody, much more so than in any of the four AAA games, and in fact mopping up the blood is a major mechanic of *Viscera Cleanup Detail*. The player is still empowered to manipulate bodies, in order to clean them by putting them into an incinerator, but does not have even the opportunity to perform violence. Nevertheless, *Viscera Cleanup Detail* is a game that is about violence; specifically, satirizing the over-the-top gore and guts of pulpy science fiction media by making you clean each individual splatter, emphasizing just how much of it there is. Its gory depiction of the aftermath of violence is attempting to focus more on violence than the AAA games in *Piles* do. This game lets us appreciate that in many AAA games violence is a tool that the game deploys to achieve other goals like storytelling or puzzle solving but not as a point of interest in itself. Violence and death is a means to an end, and the player, constructed as sovereign, is oriented away from considering death in itself. On the other hand, in *Viscera Cleanup Detail*, violence is a subject, and the mechanics and aesthetic of the game work to emphasize it.

Slime Rancher is another science fiction game, this one about raising small alien slime creatures on a farm. These creatures are small orbs that very notably have physics enabled. In the context of considering physics and its interactions with necropolitics this is notable because despite having physics, these slimes are alive! They bounce, move and interact with the world in simple ways. Not only are they

alive, but they need to be nurtured and cared for; managed, fed, and cleaned up after. Every other game in the project shows physics only applied to dead or lifeless bodies, but *Slime Rancher* shows physics and liveliness intertwined. Despite their aliveness, the slimes are still quite hapless creatures and have a very limited ability to act under their own agency. They often listlessly bounce around, searching for food sources or away from predators, drives that the player can easily address in seconds. This provides a slightly different lens to understand physics; instead of a way of representing death, it is a way to underscore helplessness, and emphasize the need to care for these creatures. While death is often the ultimate form of control in games, *Slime Rancher*'s deployment of ragdoll physics shows that perhaps a more accurate association of the technology is with control, rather than strictly with death.

The third independent game in the project is *Tabletop Simulator* which is a simulation space designed for playing board games. While it has the capacity for custom components for the various games you can play in it, it also comes with a set of pre-loaded pieces. In the video, the pile is created from those prefabricated pieces. Each piece is a rigid-body object with physics, and as they spawn they fall and bounce down the pile. As it grows to a certain size, they start to fall off the sides of the table, only to respawn at the sides. There is a strange kind of symmetry with *Tabletop Simulator* to the rest of the games in the project; *Tabletop Simulator* provides simple game pieces which are intended to represent larger and often abstract concepts, while the other games provide very detailed bodies that ultimately serve as simple game pieces. In most of the games in the project, dead bodies have a very

limited inherent range of potential significance: they are often a nuisance, they may contain valuables, they are a material marker of the violence perpetrated in the game. On the other hand, the game objects of *Tabletop Simulator* do not have a predetermined significance, the player is intended to interpret and use them as they wish. A single piece could be the most important object in a game, or it could be an insignificant prop. This is reflected in how these games handle the 'physicality' of these bodies and objects. In *Tabletop Simulator* there are several methods for recovering a displaced game object, they will respawn if they fall over the edge, and the entire system has a simulation rewind button to undo mistakes. Even the prefabricated objects are given a deep respect, or at the very least a value placed on their continued presence and placement. However, in the other AAA games, bodies are disposable and the physics often treats them as such, rendering them slippery and easy to slide or allowing them to be moved and placed. They are obstacles to be dealt

with and after that point and it really ceases to matter how they behave.

Figure 6: An image in *Piles* from *Tabletop Simulator (2015)*

To recap, in the AAA games in *Piles* we have observed a very functional application of physics: beyond mere aesthetics, physics is intrinsically tied to the way that bodies function in larger game structures. There is a connection between physics and death; bodies that were "still alive", or perhaps more accurately, "still held the potential to become agential", were tied to animation systems but bodies that are dead are governed by physics systems. In the independent games, the connection to ragdoll physics is revealed to be more about control and power than specifically death, and violence is often just a means to achieve power and control through depersonalization, the transformation of a game character into a game piece. In these

games, the way physics is implemented is a way of concretizing and applying control in game spaces. In the moment of play, when the physics system becomes engaged, there is a constricting of the potential relations between the player and the character to which physics is being applied—they are redefined as an object, a body.

Conclusion

The era of ragdoll physics as the predominant game physics is drawing to a close. With the growth of computing power and resources, especially on consoles, the potential time allotted to physics calculation and simulations has increased. This has enabled a host of other physics paradigms, one of which is procedural animation. Often there is an immediate handoff from animation systems to physics systems as soon as the character is deemed dead or unconscious. Immediately, the "living" body is supplanted by the dead one. Among other changes, procedural animation instead extends this middle area. Instead of having a quick and immediate transition, the transition from living to dying itself is simulated. Instead of immediately turning into a rubbery mess and tipping over, the dying impulses of the character can be simulated. This goes a bit beyond traditional scripted animation: these actions are not *explicitly* scripted, but the intentions are set and the body contorts itself to best fulfill them. Perhaps in their dying moments a character would wish to reach for their gun, or up to their head, or even to a location on their body where they were wounded. These intentions are set and the muscle groups procedurally contract or expand to attempt to achieve this goal.

In 2005, NaturalMotion, the company who produces the *Euphoria* procedural animation technology used in games such as *Red Dead Redemption* and *Grand Theft Auto V*, released a whitepaper on "Dynamic Motion Synthesis," their branding of procedural animation. In it, they describe Dynamic Motion Synthesis as "accurately simulating the 3D character's motor nervous system and physical body. When a character moves, rather than using a rudimentary technology such as inverse kinematics[68], Dynamic Motion Synthesis simulates the actual nervous impulses that move the muscle fibers that in turn move the skeleton."[69] Of course, this simulation of "muscle fibers" is not significantly different from the way a ragdoll physics system might model regions of the body using static rigid-body objects. Instead of a solid rigid-body region, Dynamic Motion Synthesis uses springs which incidentally are also sometimes used in ragdoll physics. The "nervous impulses," as well, are programmatic settings of intended poses, which are a far cry from modeling any kind of realistic nervous system. While this whitepaper does heavily misrepresent procedural animation as an extremely granular and complex mapping of things like electrical signals in the brain, it does clearly represent the imaginary of procedural

[68] Inverse kinematics is the use of mathematical equations to calculate what motions a system might need to take in order to end up in a desired end position. For instance, if a character is meant to move their arm to a 90 degree bend, inverse kinematics would develop a set of equations to determine what joints needed to move in what way in order to achieve that result.

[69] NaturalMotion LTD. "Dynamic Motion Synthesis," March 2005. p. 2-3.

animation. This imagination of the technology is nothing less than the full simulation and reproduction of the body in 3D space via code. Its goal is a full reproduction of life, all the way down to muscle fibers and nervous impulses.

Procedural animation marks a transition point for physics, a transition away from objects and dead bodies to life and liveliness. Prior to this, as we have seen, physics has been a mechanism for control, coinciding with death and unconsciousness, a rendering into passivity of lively characters who would otherwise be impediments to the player's progress. In the phenomena of game violence, physics emerge as a marker of the player's dominion over the game, over the body of another character. The agential, uncontrollable actor becomes a static and passive object. We might call this relationship mechropolitical, as the violence and death in games is not real, but has resonances with real occurrences of violence and death, and importantly the power function of violence and death: what violence is meant for, and what violence does. In light of the violences committed against marginalized people that Mbembe, Puar, and other scholars are addressing in this chapter, this is especially troubling. In addition, games which engage this relationship of death and physics also are mechropolitical in terms of the pleasures of violence and death, the pleasures of controlling a problematic or feared other by reducing them to inactive physics objects. Historically, we have seen, these have been the uses of physics in games, but does this new rising paradigm stand to alter these historically entrenched relationships?

No matter how much of the mechanics of life become physically simulated, and no matter how detailed the modeling is of the physical world, I suspect that physics and death will always be intertwined. Maybe their connection will become muddied over time, but once a character is killed, there seems to be very little room for any other systems to operate besides physics. In that sense, physics is forever the game system of death.

Chapter Two: Polygonal Modeling

When a user logs into the modding website “Nexus Mods" and browses the collection of newly uploaded mods, they might find one titled “GamePyg’s Face & Body Overhaul,” click through to the page, and download it. The mod’s listing on Nexus Mods would look similar to listings for mods this user has installed in the past, perhaps used for updating textures and models. However, they would find the wording of the listing particularly curious: “There has never been a mod which has delivered on the promise of a perfect character in a game—until now!” Inside the download, the mod they find hardly delivers on this promise. In addition, there is a curious .pdf, containing a letter from a fictional company claiming to have enlisted them in a beta test of an web-based archival service. If they click the link, they would see a page that looks very like the mod page they were just on but dated several months in the future. As they browse the page and the connected snapshots, a story starts to emerge about modding, control, pleasure, skins, and textures.

Described above is the experience of stumbling upon *GamePyg's Face and Body Overhaul*, an alternate reality game (ARG) that takes place on a modding website. It is an exploration of some of the ramifications of the systems of texture and model that we use in most 3D video games today, a paradigm known as polygonal modeling. In this chapter, I will demonstrate how this technology of visual representation carries with it embedded assumptions about identity and affords a transformation of the digital body into an aestheticized commodity.

In the broadest sense, polygonal modeling is the paradigm that governs the representation of 3D characters or objects in films and video games. Almost any digital representation of a 3D thing uses polygonal modeling as a structuring system. This is not an authorial choice for the most part—while there are many kinds of software that aid in creating 3D models like Blender, Maya, ZBrush, and so on, all of them rely on polygonal modeling. At a basic level, there are two components to any 3D model made using this technology: the mesh, and the texture.[70] The mesh is the shape of the character, composed of triangular planes called polygons. A mesh has no associated outward visual appearance, it is just a collection of triangles (which in turn are collections of three points each in 3D space) that compose the shape of whatever thing the model represents. In many of the modeling programs I mentioned earlier, the mesh is represented with a default smooth, gray look similar to modeling clay to emphasize that it is incomplete and needs to be "painted on" (see Figure 1).

[70] Russo, Mario. *Polygonal Modeling: Basic and Advanced Techniques*. Wordware Game and Graphics Library. Plano, TX: Wordware Pub, 2006.

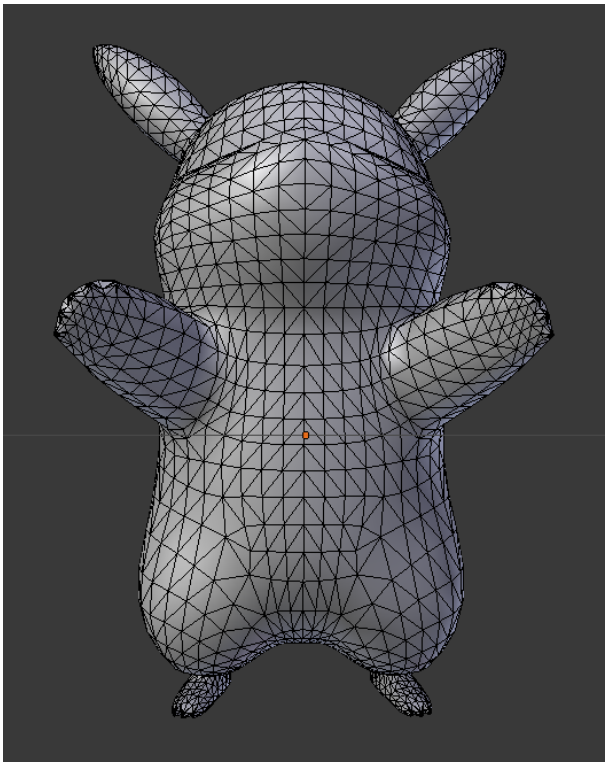

Figure 7: The mesh of Pikachu from *Pokémon X/Y* (2013)[71]

This thing that meshes are "waiting for" is the texture. The texture is a 2D image, or multiple 2D images. They represent everything visual about the 3D character or object in question (see Figures 2 & 3). This is their skin, but also clothes, hair, and other visual features. A texture determines the outward appearance of *everything* visual, except shape, which is determined by the mesh. In the key process of polygonal modeling, these textures become "mapped" to the mesh, essentially wrapping themselves around it so that the final product looks like a 3D character with skin and clothes. The result looks like a single cohesive character or object, but is

[71] This model sourced from a decompilation of *Pokémon X/Y* available on models website https://www.models-resource.com/

really a mesh wrapped in textures. This process is called “texture mapping”, colloquially “skinning.” In contemporary polygonal modeling there are many other kinds of 2D images mapped onto the meshes (bump maps, UV maps, etc.) that determine other aspects of rendering.

Figures 8 & 9: Some of Pikachu’s skins from *Pokémon X/Y* (2013)[72]

The notion that physical elements of the body, like skin and flesh, hold deeper significance than pure aesthetic is something that has been heavily discussed in critical race scholarship. One such text that engages with this topic is Alexander G.

[72] Sourced from the same decompilation on https://www.models-resource.com/

Weheliye's *Habeas Viscus*, which specifically focuses on the idea of "flesh" as a "...pivotal area for the politics emanating from different traditions of the oppressed."[73] For Weheliye, the flesh is a key nexus for the racialization of the body as well as representing possibilities for liberation and other worlds. While it has a physical and aesthetic component, the flesh itself is engaging in powerful symbolic work that goes far beyond the surface level. Weheliye quotes Maurice Merleau-Ponty in describing flesh as "...'not matter, is not mind, is not substance'; rather, in his phenomenological theorization, the flesh functions as an integral component of being, which is 'not a fact or a sum of facts, and yet adherent to location and to the now.'"[74] For Merleau-Ponty, the flesh is not separable from being, and that inseparability is something I will return to later in the chapter.

In addition, the idea of a digital "skin" has been very powerful and has been extensively reflected on by new media scholars. The 2006 essay collection *Re:skin* edited by Mary Flanagan and Austin Booth is one such work. It collects many essays on the subject of skinning. In her essay for the collection, artist, architect, and scholar Alicia Imperiale writes:

> The skin is not a straightforward simple surface that covers our interiority. Rather, the skin is an organ, divided internally into differentiated and interpenetrating strata. The skin or the surface of the body is a surface of maximum interface and

[73] Weheliye, Alexander G. 2014. *Habeas Viscus: Racializing Assemblages, Biopolitics, and Black Feminist Theories of the Human*. Durham: Duke University Press. p. 2

[74] Ibid. p. 44

> intensity, a space of flux, of oscillating conditions. The 'surface' is more slippery than it might first appear.[75]

Imperiale suggests that we cannot take the skin at its face value and we cannot simply take it as an aesthetic condition of the body. It is porous, not flat. It is alive, not dead; not a coat of paint. As we will see later, polygonal modeling's treatment of the skin is as McKenzie Wark describes in *Gamer Theory*, "...arbitrary, a difference without distinction, mere decoration."[76] The fact that these skins are disjointed costumes that are just "worn over" the body, and that can easily be exchanged with one another, is one of its most problematic aspects. It unintentionally distills a complicated notion of the self and identity into a simple division between external and internal. As artist, writer, and curator Melinda Rackham explores in a different essay:

> Usually we think of ourselves as being like a peach—having a soft and squishy skin on the outside and a solid kernel-like core. There is something about ourselves that we see as intrinsically fixed, central, immovable. It's not our mushy and vulnerable brain, and it's not our intangible and ethereal soul. Perhaps this fixed point could be the pineal gland, a small lobe in the forebrain that, according to the Eastern perspective of the chakra system, governs the experience of self and reality, integrating the entire physical, emotional, mental, and spiritual human experience. Or is this hardness more centrally located . . . lying beneath the rib cage in our heart, that strong muscle that

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[75] Imperiale, Alicia. "Seminal Space: Getting under the Digital Skin" in *Re:Skin*, ed. Mary Flanagan and Austin Booth. Cambridge, Mass: MIT Press, 2006. p. 265

[76] Wark, McKenzie. *Gamer Theory*. Cambridge, Mass: Harvard University Press, 2007. p. 39

> pumps the animating fluid of blood through our vascular systems, bringing life and nourishment to the flesh?[77]

One might stereotypically assume that one's identity lies on the surface of their own body, alongside their own skin, but Rackham playfully complicates this. For her, taking the skin seriously means rejecting it as the sole source of identity, and refusing to let identity be reduced to a mere quality of the skin. If this reduction happens, and identity becomes aestheticized as a visual property of the skin, it facilitates a very superficial, dehumanizing dismissal and erasure of the important, and inconvenient, social and historical components of skin and identity.

It may be hard, at first, to see the digital technology of polygonal modeling as having anything to do with any metaphysical questions about identity and selfhood. It may just seem like an anodyne tool with no particular values or ideology. As Mary Flanagan notes in her chapter of *Re:skin*, "Once we are faced with a paradigm, however, the underlying assumptions on which it is built become invisible."[78] Accordingly, the paradigm of polygonal modeling has rendered assumptions about identity and representation invisible. In order to make them more visible, we need to start examining, in more detail, the history of how polygonal modeling came to be the dominant paradigm in digital 3D rendering.

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[77] Rackham, Melinda. "Safety of Skin" in *Re:Skin*, ed. Mary Flanagan and Austin Booth. Cambridge, Mass: MIT Press, 2006. p. 51

[78] Flanagan, Mary. "Reskinning the Everyday" in *Re:Skin*, ed. Mary Flanagan and Austin Booth. Cambridge, Mass: MIT Press, 2006. p. 307

The History of Polygonal Modeling

Before examining polygonal modeling directly, I want to first focus on the ancestor to all kinds of 3D graphics: computer rendering in general. One of the earliest forays into using a computer as a visual tool was Ivan Sutherland's 1963 *Sketchpad,* a program that could programmatically display shapes and drawings on a screen. While artistic applications were considered for the program, Sutherland phrases it this way: "Sketchpad need not be applied *exclusively* to engineering drawings"[79] (emphasis mine), implying that the dominant or expected use of the program was for engineering drawings. This is perhaps to be expected as the program was developed at MIT and mirrors the development of much other computing technology which originally had military or engineering applications. Despite the eventual turn to more artistic use, the legacy of engineering persists in the values that drive the development of computer graphics, specifically that of reusability and interchangeable parts. This, for example, appears in Sketchpad as the ability to reuse different shapes without needing to draw each one from scratch, and it appears in polygonal modeling in the relationship between texture and mesh. A single mesh can be reused with different textures applied to it to create new characters, or a texture

[79] Sutherland, Ivan E. "Sketchpad: A Man-Machine Graphical Communication System." In *Proceedings of the May 21-23, 1963, Spring Joint Computer Conference on - AFIPS '63 (Spring)*, 329. Detroit, Michigan: ACM Press, 1963. https://doi.org/10.1145/1461551.1461591. p. 343

can be swapped on an existing mesh to simulate a change of state such as putting on different clothes. These values are more or less functional in a purely engineering context, but once these tools start to be used in new, "non-engineering" ways, their limitations become very clear.

As an example of the "non-engineering" functionality of Sketchpad, Sutherland provides a drawing of a woman's head (who can be animated to wink) made in Sketchpad. He names it "Nefertite" which is a slight corruption of the name 'Nefertiti', the "Queen consort" of Akhenaten, an Egyptian pharaoh (see Figure 4). A group of white MIT scientists creating and animating a winking Egyptian woman is a great illustration of another kind of capture being attempted with computer graphics: to take the existing world, or at least imaginations and images of the world, and make them manipulable by the computer. Just a year later, Sutherland would publish another essay titled "The Ultimate Display," a vision for what the future of computer displays could accomplish which further entrenches this idea of capture and control. Computer graphics historian Jacob Gaboury describes it as, "...a rallying cry for the industry's development over the subsequent fifty years. Its vision of total simulation has since been taken up by science fiction writers and virtual reality CEOs alike to sell a vision of the future in which the material world might be fully simulated, customized, and controlled."[80]

[80] Gaboury, Jacob. *Image Objects: An Archaeology of Computer Graphics*, 2021. http://mitpress.mit.edu/9780262045032. p. 46

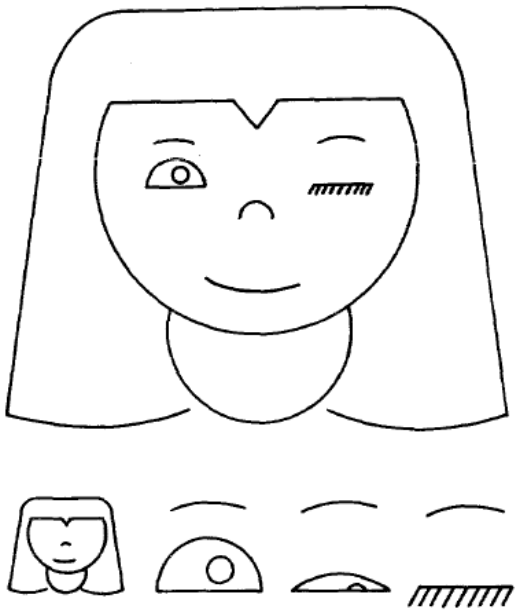

Figure 10: "Nefertite"

Following this vision, nine years later under the supervision of Ivan Sutherland and others at the University of Utah, Edwin Catmull (who would later go on to co-found Pixar) submitted his PhD dissertation on texture mapping onto curved surfaces. Texture mapping is the process in polygonal modeling where a skin is "wrapped" around the polygonal mesh and is the fundamental technology that makes polygonal modeling possible. What is interesting about Catmull's dissertation, and something that is common amongst computer science scholarship of this era, is that there is almost no problem area justification. The entirety of Catmull's justification is in the first line of his dissertation: "A motivation for the method is that we wish to produce high quality computer-generated images of surfaces and curved solid objects

on a raster screen output device".[81] There is seemingly no room in the fast-paced world of computer science development to conjure justifications for research that extend beyond the fact that the research had not yet been done. This is an issue which extends to research in mathematics and the sciences even today. Catmull's dissertation does not explain how it solves any problems beyond the fact that it solves the issue of not being able to do texture mapping. There is an implicit ultimate deferral of the responsibility of the technology to future users. The pursuit of the simulation of reality is also evident in this dissertation, especially in the example images of Catmull's texture mapping technique which involve very many examples of "real life" objects being mapped onto different shapes.[82] These include things like bottles, glasses, bricks, and photos of Catmulll's family applied to various objects. These symbols of mundane and daily life being integrated with Catmull's new technique illustrate the way that this technology was being imagined to remediate and capture life.

Something that becomes apparent when viewing both Sutherland and Catmull's work is that the theoretical full simulation of reality does not come with a corresponding attentiveness to the many other aspects of reality that are not purely visual. For instance, Catmull's texture mapping does not consider what texture is being mapped onto what; it simply maps it. The goal of these researchers was only to

[81] Catmull, Edwin Earl. 1974. "A Subdivision Algorithm for Computer Display of Curved Surfaces." Ph.D. Thesis, Utah, USA: University of Utah. p. 1

[82] Ibid. p. 69

provide tools for rendering and simulation—and not to be responsible for the simulation after it has been made. This culture of tools before applications and context has had serious ramifications on the development and deployment of 3D graphics, especially in how they can represent identity and how they have been commodified. This is very apparent when we look at the history of polygonal modeling in video games.

While 3D graphics have existed in video games since *I, Robot* (Atari) in 1984, the first real success of 3D graphics in games came 12 years later in 1996's *Quake* (id Software). *Quake* is a first person shooter and was also notable for being one of the very first multiplayer shooters. While polygonal modeling techniques are used for the environments and weapons, the most significant use is for the characters themselves, especially in the multiplayer setting. Players had the option of choosing from a selection of pre-loaded skins which were applied to a default mesh. Players who wanted to not use the default characters in multiplayer would either develop or download modifications to the game (called "mods") to change them.

A big issue with mods in multiplayer environments is that due to the structure and safety concerns of online games, mods by default only affect the local player's experience. Game developers do not want to be liable for one of their players uploading some malicious code to a game server or even to other player's computers, so the ability to apply mods to multiplayer games is extremely limited or even denied entirely. Two Valve games, *Counter-Strike Source*, released in 2004, and *Team Fortress 2*, released in 2007, allowed players to upload custom "sprays", but these

were restricted to fairly small, safe[83] image files. When *Quake* was released in 1996 there were even fewer affordances for this kind of mod dissemination in the game client. Players would instead download communal mods, called "skin packs", that would not only change your character's appearance, but also enable you to see the "skins" the other players had installed (if they were using the same skin pack).[84] This still requires some action by game developers, but it requires almost no server or bandwidth use on their part, making it a simple inclusion.

Modern Modeling, or, Contemporary Polygonal Modeling in Games

As time went on, skin packs like those that arose with *Quake* became less and less common. Instead, game companies quickly realized that they could easily enact a monopoly over aesthetic representation on their servers and began to sell the ability to customize it to their players. *Team Fortress 2* began to lock cosmetic items behind payment systems, actually locking them in fictional "crates" which could be unlocked with purchased "keys." These were known as "microtransactions" and became a way to monetize a game beyond its initial purchase, turning those games into platforms which could continually generate revenue instead of a retail product which only made

[83] "Safe" in this case purely in a technical sense, as they were often offensive and pornographic

[84] See *The Skin Factory* website for more info: https://web.archive.org/web/20160316122851/http://quakewiki.net/archives/factory/usingqw.html

money at the point of sale. In a particularly emblematic case, *Counter Strike: Global Offensive* (Valve 2012) did not initially include custom "sprays" as previous games in the series had. Later, they introduced a paid version (with a restricted set of images selected by the company) with a finite number of uses before requiring a paid refill.[85] More recent games, such as 2018's *Fortnite*, have stuck with microtransactions but have done away with the "loot box" model used by *Team Fortress 2*, *Overwatch*, and others. Instead, *Fortnite* has a marketplace that sells skins directly to players. This has actually gained them so much revenue[86] that they are able to offer *Fornite* itself for free (a practice called "free to play"), completely removing any retail aspect from it as a media property. It now purely exists as a microtransaction platform. This marks the entrance to what Tanner Higgin describes as "...the seductive video game logics of identity-as-commodity which procedurally replicate the ideologies of neoliberal

[85] Alexandra, Heather. "Valve's Decision To Charge For Limited-Use Sprays In Counter-Strike: Global Offensive Infuriates Fans." Kotaku. Accessed March 30, 2022. https://kotaku.com/valves-decision-to-charge-for-limited-use-sprays-in-cou-1787529229.

[86] This is hard to state in a definitive sense, but *Fortnite* regularly grosses billions while selling the game itself for free. Some data on *Fortnite*'s profit is located here: https://www.theverge.com/2021/5/3/22417447/fortnite-revenue-9-billion-epic-games-apple-antitrust-case

multiculturalism."[87] In other words, in games like *Fortnite*, many different kinds of characters with different identities are available to play as… so long as you can afford to buy them.

The establishment of these skin commodities and marketplaces has brought with it all of the complications and financial problems with real life economies. Valve's open marketplace in particular has been subject to scams, theft, and notoriously with respect to *Counter-Strike: Global Offensive*, various kinds of gambling that particularly target the young demographic that plays CS:GO.[88] The fact that various skins in CS:GO have a scarcity, some "drop" more often than others, combined with the fact that there is an open marketplace allows them to be assigned a monetary value. The marketplace also allows for the easy trading of these skins and so when they are used as monetarily significant bets on external sites, the transactions can then be conducted inside Valve's economy. A player might "put up" skins of a certain rarity as a bet on the outcome of a professional CS:GO game and collect their winnings or pay out their losses through Valve's preexisting market systems. Similarly, players who did not know the value of the skins they own might be approached by a friendly stranger offering a highly disadvantageous trade and be

[87] Higgin, Tanner. "Gamic Race: Logics of Difference in Videogame Culture." Ph.D. Thesis, UC Riverside, 2012. p. 8

[88] Hardenstein, Taylor Stanton. "'Skins' in the Game: Counter-Strike, Esports, and the Shady World of Online Gambling." *UNLV Gaming Law Journal* 7, no. 2 (2017).

taken advantage of. In some cases, players have also had their accounts hacked and been directly stolen from. In essence, as Thorhauge and Nielsen discuss in their analysis of both Valve and Epic's various storefronts, skins have become a "(semi) currency,"[89] a commodity currency tied to the various platforms that they exist on.

These skins can only be commodified because of the intrinsic structure of polygonal modeling. The fact that skins are separable from the mesh means they can easily be bought, sold, and interchanged. This is also what foundationally animates current discussions of NFT's (non-fungible tokens) for game assets.[90] This is the idea that, say, in a racing game, a player might be able to buy a motorcycle with associated statistics and cosmetics, be the sole person able to use it for the time that they own it, and then later on sell it. While discussions of game NFTs include many more things than purely aesthetic skins, they follow a pattern of commercialization that skins have had a large part in pioneering. To take a game, atomize its components into individual units (like the skins of characters, or weapons used, or vehicles owned) and then sell them back to the user. "Gold farming," or gathering resources in a game and then

[89] Thorhauge, Anne Mette, and Rune K. L. Nielsen. "Epic, Steam, and the Role of Skin-Betting in Game (Platform) Economies." Journal of Consumer Culture 21, no. 1 (February 2021): 52–67. https://doi.org/10.1177/1469540521993929.

[90] Binance Blog. "Crypto Gamification: How NFTs Disrupt The Gaming Industry." Accessed February 26, 2022. https://www.binance.com/en/blog/nft/crypto-gamification-how-nfts-disrupt-the-gaming-industry-421499824684903037.

selling them, is another fundamental historical example of the development of this pattern.[91] It is worth noting that the interchangeability of skins does not easily extend across games, so there is a ceiling on how far the market of NFT skins can expand as skins are restricted to their single games of origin. However, as games become larger and more and more platforms unto themselves, the market still has plenty of room to grow.

Another way that this commercialization of skins operates is in the offloading of asset creation to fan production. In 2006, Seth Giddings and Helen Kennedy wrote a chapter for the anthology *Understanding Digital Games* where they said the following of fan production: "A particularly adept skinner may eventually see their skins being included in the range of characters on offer to other players through online communities and may receive prizes and acclaim for their art."[92] This view saw eventual hiring into the industry as the goal, and free asset production more of a way of advertising their skills in order to secure a job. This, unfortunately, has proven too optimistic of a view. Now fan communities create models and skins for games

[91] For a discussion of gold farming, and its position as racialized labor, see Nakamura, Lisa. 2009. "Don't Hate the Player, Hate the Game: The Racialization of Labor in World of Warcraft." *Critical Studies in Media Communication* 26 (2): 128–44. https://doi.org/10.1080/15295030902860252.

[92] Kennedy, Helen, and Seth Giddings. "Digital Games as New Media." In *Understanding Digital Games*, edited by Jason Rutter and Jo Bryce. London: Sage Publications, 2006.

that are then bought, generally below market rate, by the companies which own the games and are then incorporated into them. Companies can then keep fewer polygonal modeling employees on staff (and save on health care and benefits), while still "producing" new content. Artists are put in precarious positions as the game companies they sell their skins to can change their policies at a whim. For example, in 2017 Valve cut the percentage of royalties given to *DOTA 2* skin creators from 25% to 12.5%.[93] The skin market that polygonal modeling creates facilitates this working precarity for digital artists.

By and large, this commercialization is successful because it relies on another aspect of skins: their expressive ability. Skins are the predominant visual element in a polygonally 3D world, and so having the ability to change that is the most direct way of visually expressing oneself. Hanna Wirman, in her 2011 PhD dissertation, explores this idea in the context of the game *The Sims 2* (2004). She postulates that skinning should be understood as expression, and in her case specifically resistant self-expression: "In addition to feminist studies on game modifying, also in the broader context of Game Studies skinning is generally understood as the player's way

[93] Gies, Arthur. "Valve Has Cut Dota 2 Royalties, and Workshop Creators Are Crying Foul." *Polygon* (blog), April 1, 2017. https://www.polygon.com/2017/4/1/15129600/valve-has-cut-dota-2-royalties-and-workshop-creators-are-crying-foul.

to subvert the game artifact and therefore as a way of being resistant."[94] This can be seen as an almost physical (or digital) version of Stuart Hall's oppositional reading. In Hall's case, oppositional reading was viewers of media interpreting those media in ways counter to the intentions of the creators, in this case it is if players do not like the way a game is representing their character, or any character, through player skinning they can literally change the way the game presents itself on screen. However, this positive outlook is a reading that is only somewhat corroborated by Wirman's research. There are players who Wirman interviewed who do take pleasure in, and purposefully do, subvert the traditional functioning of *The Sims 2*: "One of the participants, for example, is very proud of an acne face she has created. She mentions that it is interesting to fight back the 'perfect' game characters with such skins."[95] However, there are also many player skinners who just seek to produce "quality" skins, without an attempt to subvert the game itself: "Most of the players I researched do not create skins that would break the consumerist, suburban settings and ideology of the game, but clothes with different patterns and items with everyday looks instead."[96] There exists a potential for resistance, but the reality is that through player skinning games are often reified and their ideology strengthened rather than resisted.

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[94] Wirman, Hanna. 2011. "Playing The Sims 2: Constructing and Negotiating Woman Computer Game Player Identities through the Practice of Skinning." Ph.D. Thesis, Bristol, UK: University of the West of England. p. 111

[95] Ibid. p. 178

[96] Ibid. p. 176

A more recent project working on what might be called "resistant modeling" is the *Open Source Afro Hair Library*[97] being developed by artist and scholar A.M. Darke. This library is a collection of meticulously modeled Black ethnic hair styles, hair styles which are highly underrepresented in modern character design and often highly stereotyped. Companies like EA find themselves also scrambling to make hair and skin tone changes, but do so in a proprietary way that only applies to a single game like *the Sims 4* (EA 2014).[98] The *Open Source Afro Hair Library* instead aims to create a common repository of hair styles that can be used in many different games. It relies on the fact that with 3D modeling, hair can be easily moved from one model to another because it has its own mesh. When multiple meshes are combined to create a character, they are often linked in what is called an animation rig to help animate that character. Much like meshes and textures, animation rigs are somewhat agnostic to what meshes they are connecting, so swapping out one set of hair for another allows the same rig to be used. As we can see, the philosophy of interchangeable parts in fact extends to many different levels of the 3D modeling process and

[97] Darke, A.M. "Open Source Afro Hair Library," April 24, 2020. https://prettydarke.cool/portfolio/open-source-afro-hair-library/.

[98] Electronic Arts. "A Note From Our Team: How We're Addressing Skin Tone Improvements." Electronic Arts Inc., September 23, 2020. https://www.ea.com/en-gb/games/the-sims/the-sims-4/news/october-skin-tones-update.

sometimes even in a way that advocates for a wider, more accurate, representation.

Figure 11: Example of locs from the Open Source Afro Hair Library created by artist Keneisha Perry

The ease of skinning enables not just potentially resistant or reifying behavior, but also the regressive. One of the more understudied aspects of player skinning are the skins that undo racial, gender, or body diversity in games by replacing those diverse skins with homogenous, thin, white, hypersexualized ones. There are people who have inserted neo-Nazi skins in *Counter Strike* (2000), letting you play as white

supremacist figures or change your enemies to ethnic minorities (Khosravi 2017). There are also mods that involve, in the modders' own words, "cleaning" women's faces in games like *Skyrim* or *Fallout 4* (2015).[99] This "cleaning" usually involves whitening and modifying characters to fit exaggerated Western ideals of feminine beauty.[100] The fact that skins are easy to replace enables, and to an extent, encourages, this kind of far right, sexist, behavior. When a skin is easy to change, when identity and visual representation are seen just as an aesthetic, it is not surprising that players would feel entitled to change them in accordance with their own beliefs about how people "should" look.

This has two root causes. The first is that if the way that characters are represented in games is constructed as being purely cosmetic, there is less of a reason to keep them as they are. If nothing will "meaningfully" change when the skin is changed in a game, why not change it? The other reason is the invitation of the possibility itself. If some capability intentionally exists in any kind of technology it, to some extent, invites its own use. The polygonal modeling paradigm explicitly

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[99] One such example (of many) can be found here: https://www.nexusmods.com/skyrimspecialedition/mods/18067

[100] Feldman, Brian. 2015. "Weirdo Fallout Players Are Obsessed With Cleaning Women." Intelligencer. November 20, 2015. http://nymag.com/intelligencer/2015/11/fallout-players-are-obsessed-with-cleaning-women.html.

allows for this kind of bifurcation between skin and mesh, and this invites users to engage with it and makes them feel entitled to do so.

Because modern multiplayer games' skin marketplaces are largely mediated by their controlling companies, this kind of modding is restricted to single player and local games instead. This means the changes that these mods make are for just one person's game—even in a multiplayer setting, only one player is seeing the changes. This privatization is perhaps an encouragement to these modders to truly try to mold their games to some exact vision without the interference of any outside entities. While many of the large modding sites allow adult content and these mods are distributed there, there are also underground communities with less regulation where even more extreme adult mods are circulated. One such website is *Lovers Lab*, which has many subcategories for various "hardcore" sex practices like torture and BDSM, but presented as a nonconsensual action that the player can enact on NPCs in the game[101] without the rigorous engagement with consent and agency that contemporary BDSM sex practice calls for.

In terms of modern polygonal modeling, skins as a commodified resource, an expressive tool, and a technical feature all at once. This makes them an extraordinarily complex subject to understand and examine. In order to better do so, it is always helpful to have material examples. To that end, let us now turn our attention to the art project mentioned at the start of the chapter, *GamePyg's Face and Body*

[101] The integrated tag "rape" on *Lovers Lab* is emblematic of this: https://www.loverslab.com/tags/rape/

Overhaul, which is specifically interested in interrogating what we might deem "regressive" modding.

GamePyg's Face and Body Overhaul

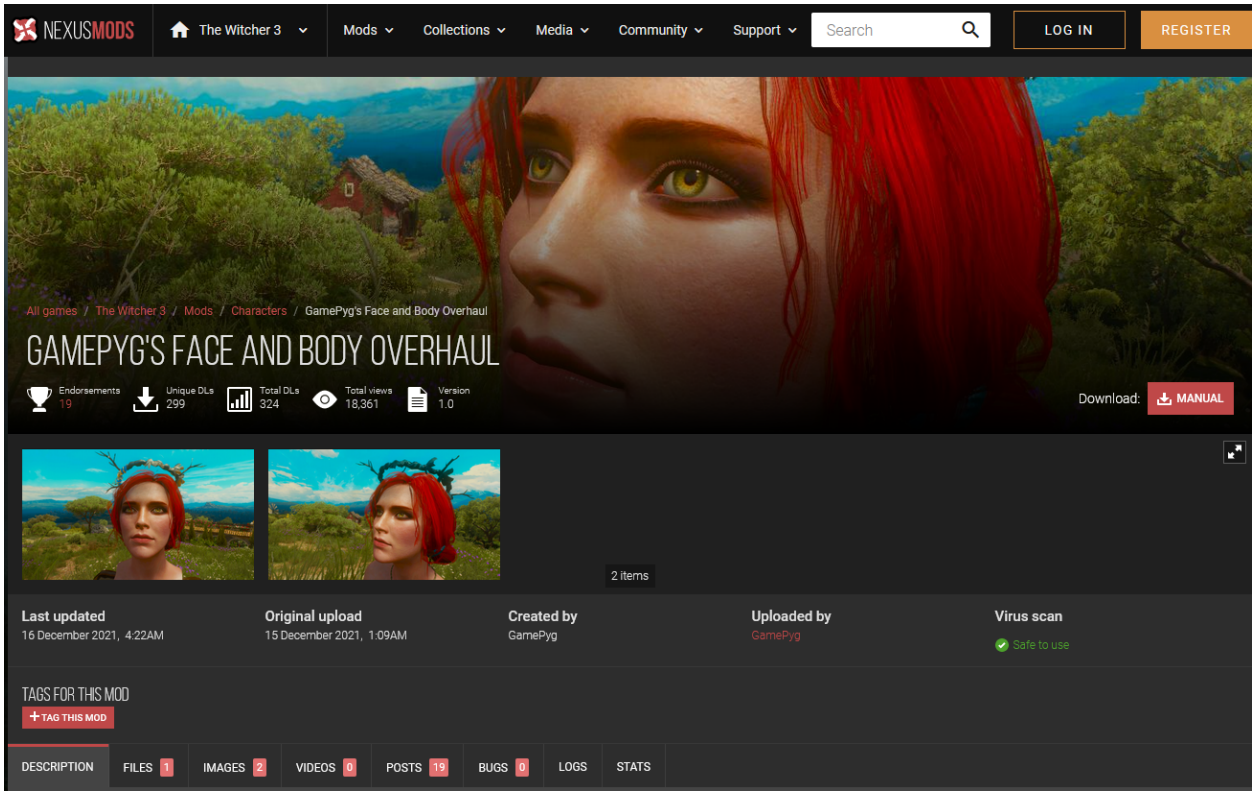

Figure 12: The landing page on *Nexus Mods* for "GamePyg's Face and Body Overhaul"

In a survey of adult mod listings I conducted on popular modding website *Nexus Mods* I found that the justifications for creating any kind of mod, but especially adult mods, are often implicit in their construction: the right to make a mod stems from the ability to do so. This is an echo of the lack of justification in tech development also seen in the dissertation of the inventor of polygonal modeling, Edwin Catmull. Very rarely is there included or evident any kind of reflection on

what exactly they are bringing into being or why. *GamePyg's Face and Body Overhaul* is an art piece that, in part, is interrogating this unreflective entitlement to mod creation and the entitlement to bodies that comes with it.

The project takes the form of several webpages, each with multiple subpages, which are designed to look like they come from the *Nexus Mods* website. In addition, there is a "starting" page that was actually posted on *Nexus Mods* itself which leads to the others. The pages are linked together with the framing device that the pages are all "snapshots" of an archived webpage in a fictional database similar to the Internet Archive (in this case called the "Archives O'Net"). The snapshots all show the same mod listing on *Nexus Mods*, several months apart from each other. Over the course of the snapshots, the mod that is listed, "GamePyg's Face and Body Overhaul," becomes sentient, and the webpages show both that and the creator and various users grappling with this new reality. Each of the pages has screenshots and video that further illustrate the ongoing story.

One major inspiration for this piece was the large number of adult mods that I found when researching polygonal modeling, and especially the large number on *Nexus Mods*. In fact, the project actually launched as if it were a "real" mod on *Nexus Mods* with links to the rest of the project hosted on my own server. Many commenters were rightfully confused as to why there was a mod that supposedly was from the future and that did not do what it claimed that it did. Others, though, could see that the project was "going for" something, and while they did not seem to get the overall storyline, they instead decided to offer suggestions as to how to make a better adult

mod. It was interesting to see that the core conceit of the project (a mod that claims to be a “total overhaul” and to create “the perfect woman”) was not so far-fetched as to be totally divorced from reality, as some commenters actually interpreted it as a genuinely feasible concept that could be improved upon

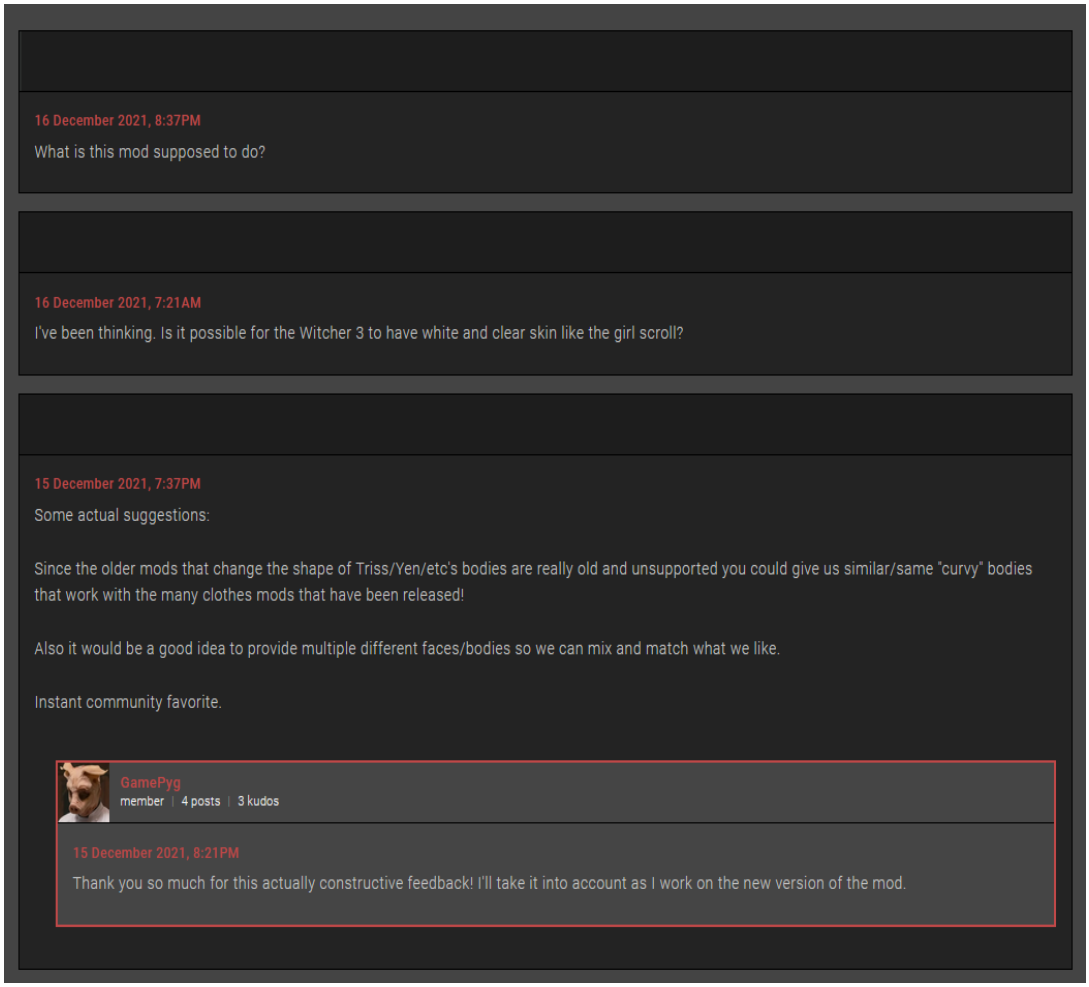

Figure 13: Anonymized comments on the real *Nexus Mods* listing for the mod containing questions and suggestions

The images and videos in the project were captured from the video game *The Witcher 3* (CD Projekt Red 2015), a game with a fairly active modding community. Because in the piece I wanted the mod to aggressively not conform to human

expectations as a way of frustrating the user's entitlement, the images and video produced are intended to show the mod bumping up against the constraints that have been placed upon it. To do this, there were a variety of production methods employed: images were captured from the unmodified game and also from a modded version (both created by real modders and by me), and then some of those images were run through a machine learning art engine called *Artbreeder*.[102] The images all depict the growth and evolution of the mod as it experiments with the different layers of polygonal modeling technology and ways of building the self: the textures are changed on a single model, the model is changed with the same texture, and different non-human elements are merged into the humanoid ones. This all has the result of creating some very abnormal looking figures. The videos, also captured in *The Witcher 3*, show an animated version of these same processes, rapidly repeating the same sections of gameplay over and over while changing the "identity" of the mod

[102] *Artbreeder* uses Generative Adversarial Networks to generate its images, a kind of machine learning. It has a free version available here: https://www.artbreeder.com

inside of it by altering the texture and mesh using the same methods as the images

Figure 14: An image of the FBO mod experimenting with changing its shape

The piece also contains a fair amount of writing, which primarily takes the form of the mod's description text and the comments. Where the images and video show the mod exploring itself and its capabilities, the text shows the reactions of the creator and users to these explorations. I produced a cast of different characters who comment on the mod, representing different kinds of users on *Nexus Mods*. There is an overly polite commenter, some that make joking posts, some that are perpetually angry, some that are mod reviewers, and of course, the creator himself, who is trying to diplomatically manage everyone. Over the course of the piece, as the mod becomes

less and less controlled by them, the commenters (all fictional, written by me) become more and more distressed, angry, and scared, displaying the range of emotions that come when their entitlement to bodies is denied.

In the final snapshot, however, this relationship is flipped. Instead of the creator and users viewing the mod, the mod is surveying them. The normal comments section becomes a series of different forms of surveillance, the images page becomes completely blacked out, and the front page becomes entirely corrupted as the mod escapes its confines and turns back towards its former users one final time. This inversion of gaze is important for making the breakaway of the mod significant, and it also allows some deeper exploration of the various other characters in their "non-commenter" personas, where their personalities shift and become vulnerable in different ways. Overall, the piece is very dense with different storylines and elements, but I feel it does justice to the complex social reality surrounding polygonal modeling

and its stakeholders.

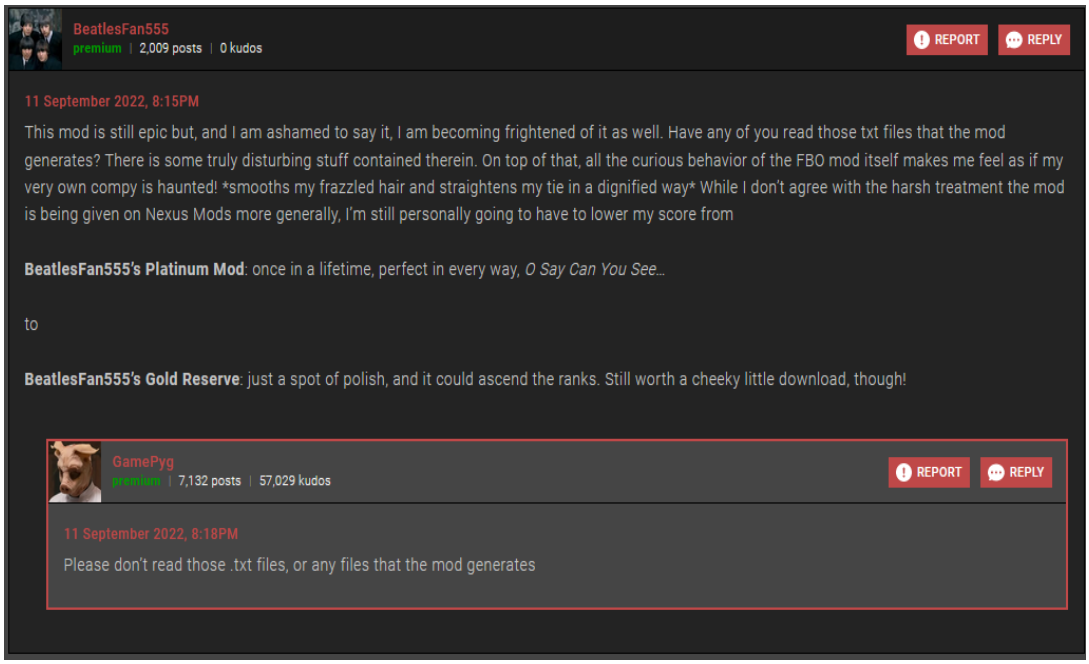

Figure 15: A fictional post from "BeatlesFan555" and a reply from "GamePyg" on the FBO web page

As feminist scholar Judith Butler writes in her book *Gender Trouble*, gender is not a physical characteristic as much as a socially constructed one, "That gender reality is created through sustained social performances means that the very notions of an essential sex and a true or abiding masculinity or femininity are also constituted as part of the strategy that conceals gender's performative character and the performative possibilities for proliferating gender configurations outside the restricting frames of masculinist domination and compulsory heterosexuality."[103] *GamePyg's Face and Body Overhaul* takes this process and makes the production of

[103] Butler, Judith. 1999. *Gender Trouble: Feminism and the Subversion of Identity*. New York: Routledge. p. 180

gender explicitly visible both in its depiction of a group of users in pursuit of the construction of an idealized woman paired with the inevitable breakdown and failure of that process. The genuine posts on *Nexus Mods* on the project show that this isn't just an abstract concept, but something that's very grounded and material in the minds of people who use these mods.

This piece is in dialogue with others that also play in the space of digital identity and skinning. One such example is Anne Marie Schleiner's *Velvet Strike*, a project to disrupt and subvert the messaging in the counter-terrorism shooter *Counter-Strike* (Valve, 2000). In part, it consists of custom anti-war sprays for the game. These sprays had messages, such as "No More War" or "We Are All Iraqis Now", as well as depictions of *Counter-Strike* combatants in various sexual poses (making love and not war). Mentioned before, *Counter-Strike* is an example of a game where the developer controls the multiplayer servers, so custom skins are extremely difficult to widely disseminate and have an impact. Sprays were the exception to this, and the server would force all players to download locally all the sprays of every other player. Thus, *Velvet Strike* was able to re-figure this system for its anti-war goals. The "digital graffiti" of *Velvet Strike* is fully constrained by the fact that the corporation which owns the game has the monopoly on the body images which appear in it.

Similarly, artists and scholars Mendi and Keith Obadike explored this ownership idea in their 2001 net art piece "Blackness for Sale" where they attempted to sell Keith Obadike's Blackness in an *eBay* auction. Winning Obadike's Blackness

in the auction would supposedly grant the winner the ability to "comfortably laugh at Black humor" and "creating Black art"—though the seller cautions against "using this Blackness in Hollywood".[104] This piece highlights that the internet at large has created spaces for the buying and selling of anything and has rendered identity, specifically Blackness, as a particularly lucrative commodity. I would argue that with respect to skin markets, the economy of skins did not have to be this way if the underlying paradigm that it relies on, polygonal modeling, was structured differently. If textures were not so easy to replace, and therefore easy to control and commodify,

[104] Quoted sections from the text of the eBay listing in "Blackness for Sale"

these kinds of markets would not have been able to form in the first place

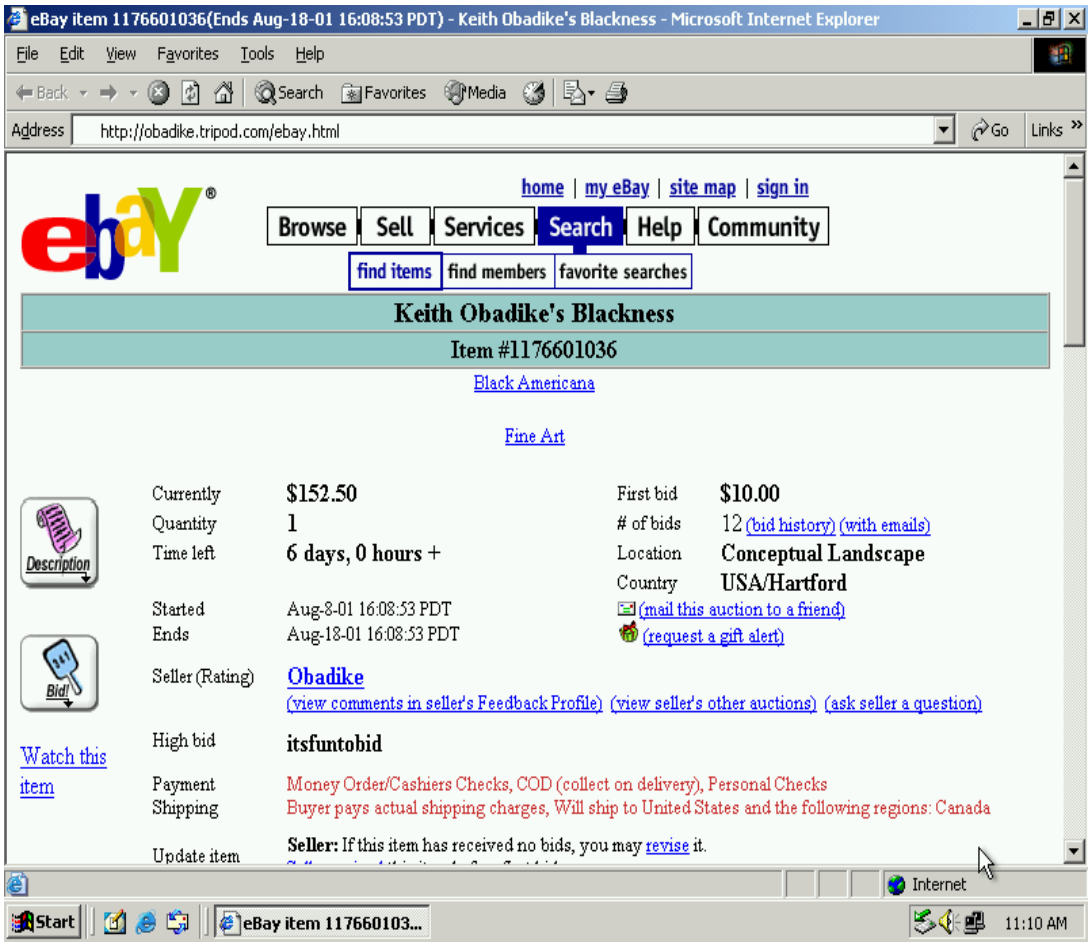

Figure 16: Mendi and Keith Obadike, "Blackness for Sale"

Conclusion

What is the ultimate relationship between a player and a rendered model? The designed relationship is for the player, as observer, to interpret the skin wrapped on mesh and understand it as a fictional, digital object. Polygonal modeling complicates this relationship, because even as the object is being interpreted by the observer/player, that player is also cognizant of its mutability. By this I mean that the

identity of the 3D object in question is not static because the player/observer knows that they can retexture the model. Even if she has no intention of ever doing so, the knowledge of the possibility of altering the object fundamentally changes their relationship to that interpreted object. Not only does polygonal modeling afford easy reskinning, it also makes it possible in the first place, both of which engender these new relationships to digital objects for game players.

While polygonal modeling has been the dominant 3D rendering paradigm for over 50 years, there is no guarantee it will continue to be so forever. Even currently, some games like *Roblox* (2006) and *Space Engineers* (2019) use a different rendering technique known as "voxels" for some rendering instead of polygonal modeling. Where polygons connect points in space into planes, voxels render regularly sampled space as a grid of cubes,[105] giving them a sort of uniformity to the polygon's ad-hoc and sporadic nature. While voxels inherently have a blocky look, they can be rendered with techniques that make them almost indistinguishable from polygonal models.[106] Still, their differing underlying composition means they are not textured in the same way as polygonal models are, meaning that the skin and mesh affordances of polygonal modeling discussed in this chapter do not apply to voxels, at least not in the

[105] Hughes, John F., Andries van Dam, Morgan McGuire, David F. Sklar, James D. Foley, Steven K. Feiner, and Kurt Akeley. *Computer Graphics: Principles and Practice*. Third edition. Upper Saddle River, New Jersey: Addison-Wesley, 2014, p.349.

[106] Ibid, p. 350.

same way. Uses of voxels in games also have tended away from the character and object representation that polygonal modeling is typically used for, and instead have seen more use in procedural terrain generators as detailed in an article by Ryan Geiss for NVIDIA.[107] We'll return to procedurality in more detail in the next chapter.

Because of their differences, the commodification of voxel objects has been slightly different to that of polygonal modeling. Games like *Trove* (Trion Worlds, 2015) have cosmetics stores like those in *Fortnite*, but because each cosmetic item has to be built uniquely using voxels, there's no reskinning possible. Each item necessarily has to have its own unique voxel model and attached skin. The push for commodification of game assets isn't stopped by the use of voxels, but there are greater limits as to how quickly and cheaply assets can be produced.

Even if the predominant 3D rendering technology does shift away from polygonal modeling to something like voxels, the market that has grown up due to the affordances of polygonal modeling won't be as easily shifted. While the Steam community marketplace does not release public sales data, it is known to have a very high transaction volume, many of which are 3D objects. On the Epic Games Store, Fortnite's entire business model relies on the selling of battle-passes and skins. It is becoming increasingly rare to find a new multiplayer game without some kind of

[107] Geiss, Ryan. "Chapter 1. Generating Complex Procedural Terrains Using the GPU." NVIDIA Developer. Accessed April 3, 2022. https://developer.nvidia.com/gpugems/gpugems3/part-i-geometry/chapter-1-generating-complex-procedural-terrains-using-gpu.

monetization of skins. This commodification is complicated by the fact that while skins are sometimes guns or clothing, they are very often of people themselves, of characters. What is being bought and sold is full personal appearance; what is being sold is identity. This saleable identity is just one example of a range of concepts that, much like in the original dream of polygonal modeling to capture and simulate the world, are indeed captured and simulated but then also sold.

Polygonal modeling is only one of a vast number of technical processes and techniques that carve up the world in such a way that it can be manipulated and sold. What is frustrating is that polygonal modeling enables this carving and selling of something that is so often held to be an inalienable aspect of the self, identity, turning digital spaces for expression and experimentation into yet more neoliberal markets. These purchased identities can then be used for whatever purpose, sometimes liberating, sometimes derogatory and harmful. This ownership relation's harm is brought to an extreme in *Gamepyg's Face & Body Overhaul* but exists latent in all of the skin commodity market. As paradigms grow and develop in this area, hopefully greater care and attention can be put towards not only visual fidelity or the ease-of-use of the tools, but also towards steering expected future uses and applications to ethical ends.

Chapter Three: Procedural Generation

Video games are procedural artifacts. In order to respond to the actions of a player, there need to be embedded commands and procedures which can take input and then produce output. This chapter will not focus on procedurality as a whole but specifically on what is known as "procedural generation." Procedural generation, sometimes called procedural content generation, is one paradigm used in the procedural operations of games. It involves the creation of some game component or asset, usually taking the place of what would otherwise be a specifically authored element in order to reduce the human labor cost. In a survey on the topic of procedural generation in games, Hendrix et. al. explain "Procedural techniques are an alternative to making complex game worlds in a limited amount of time without putting a large burden on the game content designers. The main idea behind procedural content generation is that game content is not generated manually by human designers, but by computers executing a well-defined procedure."[108] For instance, the map that is played on might be hand-created by an artist or designer, or it might be procedurally generated by an algorithm with a set of criteria that the map should have (a central meeting area, resources in different zones, etc.). Because of

[108] Hendrikx, Mark, Sebastiaan Meijer, Joeri Van Der Velden, and Alexandru Iosup. "Procedural Content Generation for Games: A Survey." *ACM Transactions on Multimedia Computing, Communications, and Applications* 9, no. 1 (February 2013): 1–22. https://doi.org/10.1145/2422956.2422957. p. 3

this, procedural generation is often caught up in issues of creativity and authorship, something that Amanda Phillips, Gillian Smith, Michael Cook & Tanya Short address from a feminist perspective in their article "Feminism and Procedural Content Generation: Toward a Collaborative Politics of Computational Creativity."[109]

In it, the authors work to create a framework for discussing procedural content generation and AI, which includes things like the gendering of said AI systems, whether or not the generation system is deterministic (meaning the content is not produced "randomly") or stochastic (meaning it is produced by a random process), and very significantly highlight something that will be central to this chapter: the fact that, "A significant portion of the procedural content generation research and development community sees its practices as a way to speed up production, reduce the cost of development and remove the need for dedicated designers and artists for the content areas that computers are creating."[110] I would contend that what is described is not merely "sped up production" but rather an untenable acceleration of the games industry towards the unachievable goal of infinite content (without an infinite cost to produce), which relies on procedural generation as the core myth which obscures the impossibility of this goal. This goal of "infinite content" has been

[109] Phillips, Amanda, Gillian Smith, Michael Cook, and Tanya Short. "Feminism and Procedural Content Generation: Toward a Collaborative Politics of Computational Creativity." *Digital Creativity* 27, no. 1 (January 2, 2016): 82–97. https://doi.org/10.1080/14626268.2016.1147469.

[110] Ibid, p. 92

deeply ingrained in video game culture from the start and I assert it in fact has very deep roots in imperial and colonial ideology of which games are only a recent manifestation.

As such, this chapter will also rely heavily on contemporary postcolonial critique of games. Souvik Mukherjee, who wrote one of the first monographs on postcolonial theory and games, defines postcolonial theory as "...a wide range of issues connected to the exploitative master discourses of imperial Europe and the responses to them by the peoples of the Americas, Asia, Africa, Australasia, and some regions of Europe itself."[111] These master discourses and responses can take the form of media products, and so the extension to games is often analyzing how these discourses and responses manifest in video game narrative, mechanics, and in this case, infrastructure. Mukherjee makes a key point which will also find much resonance in this chapter, "More often than not, the games echo the rhetoric of imperialism."[112] Mukherjee's arguments center around game mechanics and systems, such as *Oregon Trail*'s (MECC 1974) manifest destiny with respect to western expansion in the United States. However, this chapter will focus less on mechanics and instead on how colonial ideas like manifest destiny appear in the game infrastructures used to produce games, procedural generation in particular.

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[111] Mukherjee, Souvik. *Videogames and Post-Colonialism: Empire Plays Back*. Palgrave Pivot. Cham: Palgrave Macmillian, 2017. p. 3

[112] Ibid., p. 9

Mukherjee, as well as other scholars such as Sybille Lammes, see games as a place where colonialism can be challenged. While Lammes does not deny that colonial concepts are reproduced in games, she also notes that "Iin games] colonial histories are mutated and altered and our colonial legacies are being tested, scrutinized and transformed."[113] In Lammes view, this mutation and recontextualization primarily happens through play, an idea echoed by Mukherjee: "Whether it is literally in the game of Cricket as described by Gikandi and Guha, or in the game of fanorona that Queen Ranavalona chooses to play in the face of advancing colonial armies or in the silent and identity-shifting figures of Somewhere, there is a continual playing back against the centres of empire."[114] This sentiment, of games being a way to subvert and push back against dominant ideologies and systems, has long existed in critical game studies reaching back to *Games of Empire* and its notion of "counterplay": "...the prospect of playing against—and beyond—games of Empire."[115] While I do not want to discount the potential power of counterplay and its ability to challenge otherwise deeply embedded colonial ideology,

[113] Lammes, Sybille. "Postcolonial Playgrounds: Games as Postcolonial Cultures." *Eludamos. Journal for Computer Game Culture* 4, no. 1 (2010): 1–6. p. 5

[114] Mukherjee, Souvik. *Videogames and Post-Colonialism: Empire Plays Back*. Palgrave Pivot. Cham: Palgrave Macmillian, 2017. p. 22

[115] Dyer-Witheford, Nick, and Greig de Peuter. *Games of Empire: Global Capitalism and Video Games*. Minneapolis: University of Minnesota Press, 2009. p. 191

this chapter will focus more on the operations of infrastructure before the player ever has a chance to engage in counterplay. It will operate on the assumption that lessening and calling attention to the embedded colonial in games is as beneficial as counterplay.

This calling to attention is especially important as colonial ideologies are consistently reproduced in modern game design. In a recent issue of the *Open Library of the Humanities* focused specifically on post-colonial game studies, scholar Sabine Harrer writes on the casual reproduction of imperial tropes, "...a question insufficiently addressed in previous studies is why, despite availability of knowledge on the detrimental effects of colonial images on the previously colonised, game creators and consumers continue to perceive empire as a lighthearted theme appropriate for recreation and entertainment. This article suggests 'the casual' as a pervasive ideological category, which resists decolonisation by rendering the problem of empire invisible."[116] It is my contention that one way this problem of casual invisibility can be addressed is by focusing on how colonial ideology is inherent to the tools used in many games.

The desire for more, the desire for infinite, is deeply tied to colonialism. Procedural generation is the game infrastructure which brings a pursuit of the infinite to games. Thus, procedural generation has a very real constitutive connection to the colonial in games. To better contextualize how the role of procedural generation has

[116] Harrer, Sabine. 2018. "Casual Empire: Video Games as Neocolonial Praxis." *Open Library of Humanities* 4 (1). https://doi.org/10.16995/olh.210. p. 2

developed over time into the video game infrastructure that is today, I will first begin with a brief history of procedural generation in games.

The History of Procedural Generation in Games

The earliest applications of procedural generation in games occurred in the early 1980s in the genre of the dungeon crawler. In these games like *Beneath Apple Manor* (Worth, 1978) and *Rogue* (Toy, Wichman, et al., 1980) the gameplay takes place in a top-down abstracted map with rooms and caverns connected by corridors. The player moves through these areas fighting monsters and collecting treasure. The rooms, monsters, and items are all procedurally generated and connected, providing unique maps and encounters every time the game is played. In the case of *Rogue* in particular, this was done to avoid having "...'canned' adventures—they were exactly the same every time you played, and of course the programmers had to invent all of the puzzles, and therefore would always know how to beat the game."[117] It is important to note that the desire here was not only for the player to have unique experiences but that even the developers themselves wanted to experience the game in a way that they were not able to foresee and to be surprised by it. This is a recurring idea that appears in much discourse on procedural generation: that the designers or developers want to be surprised by the output of their own creation.

[117] Wichman, Glenn R. "A Brief History of 'Rogue,'" February 17, 2015. https://web.archive.org/web/20150217024917/http://www.wichman.org/roguehistory.html.

Rogue is an intentionally finite game: there are only 26 randomly-generated levels or floors in the game. The goal of procedural generation in this case was to make the experience of traversing those levels as different as possible so that any replaying of the game would be unique. However, there is another desire that procedural generation tries to fill in games, a more ambitious version of the constrained uniqueness seen in the *Rogue* example. This is not just producing a variety of content, but in fact attempting to generate a near-infinite amount of it. Much later, in 2016, the game *No Man's Sky* (Hello Games, 2016) would attempt to create an entire universe using procedural generation technology.

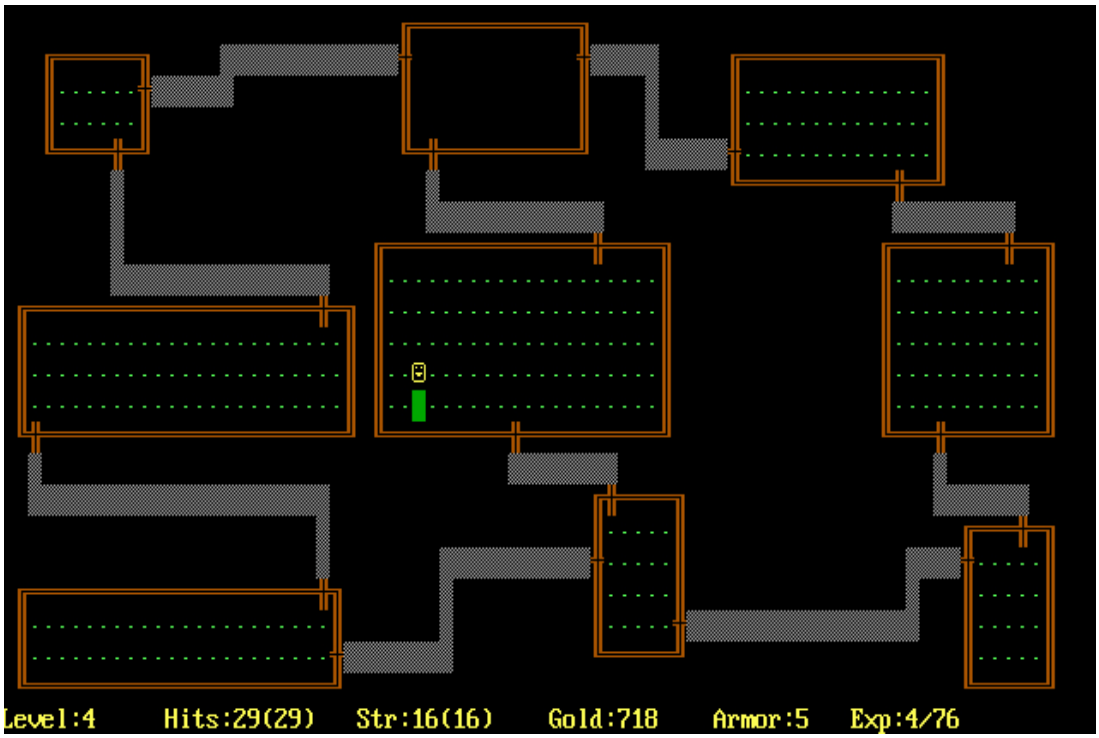

Figure 17: A screenshot from *Rogue*[118]

No Man's Sky is a space exploration game which sees the players commanding their own spaceship and traveling between different planets and galaxies exploring and collecting resources. One of the largest selling points of the game was that the universe that the game takes place in was intended to be huge, and was often reported on as being infinite, or functionally infinite.[119] In fact, there are over 18 quintillion planets in the current edition of *No Man's Sky*. These planets were randomly generated before the game was released and exist dormant in the game, waiting for a player to discover and travel to them. This kind of scale is realistically only possible using procedural generation to automate the process of creation. As such, *No Man's Sky* uses procedural generation not just for the topographies of the planets but for the

[118] https://en.wikipedia.org/wiki/Rogue_(video_game)#/media/File:Rogue_Screen_Shot_CAR.PNG

[119] Good, Owen S. "It's Impossible to Visit Every Planet in No Man's Sky." *Polygon* (blog), August 19, 2014. https://www.polygon.com/2014/8/19/6045933/its-impossible-to-visit-every-planet-in-no-mans-sky.

creatures and vegetation as well as the machines and spaceships in the game.[120] Nearly everything in the game is generated through some kind of procedural system.

The unlimited variety of *Rogue* is iterated by *No Man's Sky* into something even bigger: infinite space. The content is not just varied, there is a functionally limitless amount of it to consume. This is an ambition shared by other games such as *Minecraft* which also has a functionally infinite world (in terms of space). They also share some core game mechanics as well: exploration (in *No Man's Sky* you actually name the planets and creatures you encounter), resource extraction, and base building. Infinite space, in these cases, comes with mechanical tools to claim and develop it.

Proc Gen for Places & Proc Gen for Things

Now, let us turn to the technical implementation of procedural generation technology an d look at two specific ways that proc gen is used: for spaces and for things. Specifically, I will be looking at how Mojang's *Minecraft* generates its landscapes and how Gearbox's *Borderlands* series generates its guns. In looking at these technical implementations a deeper insight into the thought process behind what these systems are intending to achieve becomes clear.

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[120] Alexandra, Heather. "A Look At How No Man's Sky's Procedural Generation Works." Kotaku. Accessed January 13, 2022. https://kotaku.com/a-look-at-how-no-mans-skys-procedural-generation-works-1787928446.

Historically, there have been many different methods for the procedural generation of terrain in games, with implementations varying depending on the game and its design goals. For instance, the game *Spelunky* (Mossmouth 2012) uses premade sections of terrain that are procedurally linked together.[121] Each section is roughly authored, with some template variations, but the main procedural aspect is the linking of these premade sections together. The stylistic form of these created worlds is quite constrained by the design of these template sections. This suits the design goals of *Spelunky* as being a very replayable experience where the player gains mastery over the various elements through repetition: because the kinds of worlds created are constrained, the player is more able to learn their specificities and gain expertise. This is a common element of games like *Rogue* as well and is why *Spelunky* and other similar styles of games are considered to be "rogue-like," games in which the player repeatedly encounters procedurally generated maps and, through failure, gains experience on how to pass them more easily.

Other games like *Minecraft* (Mojang, 2011) use procedural generation not as an often repeated iterative system (meaning the generation process is run over and over and with slight changes) but instead use it to generate all of the terrain at once (more or less) and then do not need to really generate anything again. Worlds in *Minecraft* in particular use a "perlin noise" algorithm to drive the procedural generation of its terrain. Noise, in a mathematical sense, is a random introduction of

[121] Yu, Derek, and Gabe Durham. *Spelunky*. Los Angeles, CA: Boss Fight Books, 2016.

alterations to a signal or system. Normally, traditional simple noise functions generate totally random values (often constrained with a maximum and minimum). When applied over an area, such as a map, this would mean each "unit" of the map (whatever that may be, in *Minecraft* these are block heights) is assigned a random value. This means that the traditional simple noise function, when applied to terrain, would result in spiky "TV static" style landscapes[122] which would lack the contiguous curves and connections that are associated with the naturalistic landscapes that *Minecraft* seeks to emulate. The map would contain huge 1 by 1 spires and deep craters that have no connection to the surrounding blocks, making the terrain impossible to navigate.

Perlin noise, on the other hand, is one of a few techniques used to generate gradient noise, which *Minecraft* interprets as a rate-of-change between heights. In other words, instead of generating heights directly, Perlin noise generates the slope of the hill that is being generated. Invented by Ken Perlin in 1985, Perlin noise was made to essentially solve the problem of natural appearance: to correct what he saw

[122] Shaker, Noor, Julian Togelius, and Mark J. Nelson. "Fractals, Noise and Agents with Applications to Landscapes." In *Procedural Content Generation in Games*, by Noor Shaker, Julian Togelius, and Mark J. Nelson, 57–72. Computational Synthesis and Creative Systems. Cham: Springer International Publishing, 2016. https://doi.org/10.1007/978-3-319-42716-4_4.

as the overly "artificial" look of CGI at the time.[123] It originally predominantly found use in computer generated textures and other visual phenomena before being adopted by the games industry for procedural terrain generation. When *Minecraft* generates its terrain, it uses Perlin noise to generate the entire skeletal shape of the terrain (made out of stone, the "default" material of the *Minecraft* world) before anything else is created.

At this point, mid generation, the *Minecraft* world is devoid of life, and instead just contains placeholder stone which has naturalistic peaks, valleys, and caves—but without the animal life and vegetation that is associated with the natural world. Then, biomes become assigned to various sections of the generated world. As of November 2021,[124] the world generation was fully decoupled from the biome step, and biomes are now actually assigned based on how the world has already generated. This means that if for example the generated curves and shape of a piece of the world seems desert-like, then the desert biome could be assigned to it. Generation also takes into account already-decided-upon adjacent biomes so that tundras cannot appear next to deserts for example. After biomes are assigned, the world is then further modified

[123] Perlin, Ken. "An Image Synthesizer." *ACM SIGGRAPH Computer Graphics* 19, no. 3 (July 1985): 287–96. https://doi.org/10.1145/325165.325247.

[124] Minecraft Feedback. "Minecraft - Caves & Cliffs: Part II - 1.18.0 (Bedrock)." Accessed January 14, 2022. https://feedback.minecraft.net/hc/en-us/articles/4414284658701-Minecraft-Caves-Cliffs-Part-II-1-18-0-Bedrock-.

(including the original Perlin-noise defined shapes) to fit the biome which has been assigned. The world itself is contingent on the random shapes generated in the Perlin noise step.

As the biomes are selected the stone placeholder blocks are transformed into biome-specific blocks of various kinds, snow in the tundra, sand in the desert, grass in the plains, and so on. As a whole, *Minecraft* generally produces a wild frontier, largely unsettled and depopulated; however, there are some exceptions. Alongside these block replacements come other objects and entities placed on top, such as biome-specific animals, vegetation, and resources, as well as structures such as ruins, temples, and villages for the few indigenous groups which live in the *Minecraft* world. These elements constitute the (meager) cultural and natural elements of the world that *Minecraft* is creating. These elements are also fully dependent on the entirely geometric formation of the world using Perlin noise, meaning that the natural and cultural worlds of *Minecraft* are always subject to the purely geometric one which is generated first. This also means that despite there existing things like villages and temples, the habitation of the world is subject to the physical shape of the world rather than a more, say, historical or cultural determination. This is important, as will be discussed later, to the construction of the procedurally generated world as one that is full of mineral resources and land that is justified to be taken and

consumed by the player.

Figure 18: A sample screenshot of *Minecraft*[125]

Procedural generation is also often applied to individual game objects. One clear example of this is in the first person shooter *Borderlands* franchise, a series of games that take place in a corporate dystopia on an alien planet. One of the main selling points for the franchise over time has been the number of guns in the games. In *Borderlands* (Gearbox, 2009), the figure was set at around 17 million, in *Borderlands 2* (Gearbox, 2012) the figure was supposedly larger but unspecified, and

125 https://www.minecraft.net/en-us/article/new-world-generation-java-available-testing

in *Borderlands 3* (Gearbox, 2019) the figure is a whopping one billion.[126] Such astronomically huge figures are only made possible through the massive combinatorial power that comes with the use of procedural generation to generate these guns.

Guns have a special role in the world of *Borderlands*. Not only are they the main tool you use in the game (by shooting enemies) but they are also one of the main resources you collect by defeating enemies as loot. In addition, part of the fiction of the games is that the ruthless corporations fighting over control of the planet that you are located on are also the gun manufacturers. This is part of the games' ongoing attempt to satirize the military industrial complex in the outrageous and egregious ways that these corporations are involved in the conflict on the alien planet Pandora. Regardless of this, one of the main activities one does in *Borderlands* is buy and consume guns— one billion of them in fact. Even though the games function as a satire they also, in many ways, directly reproduce the violent hyperconsumption that they are being critical of.

The way that these guns are constructed is similar to the way that the levels in *Spelunky* are made, in that pre-existing pieces of guns are combined together, which combinatorially results in the huge number of guns available. In the original

[126] Macy, Seth G. "How Borderlands 3 Made (Literally) 1 Billion Guns Possible - IGN First." IGN, November 1, 2021. https://www.ign.com/articles/2019/08/21/how-borderlands-3-made-literally-1-billion-guns-possible-ign-first.

Borderlands, each gun has 12 different aspects that are considered during weapon creation: "weapon type, manufacturer, weapon grade, material, body, barrel, magazine, accessory, sight, stock (or action for pistols), grip, and level."[127] There are 11 different weapon types, 9 manufacturers, and so on. There are some restrictions on what weapon types can have certain attachments, and what attachments are available to which manufacturers, which does limit the total number of possible guns from the raw number of possibilities, but it is still quite large.

Where the infinite or near-infinite was used in *Minecraft* or *No Man's Sky* as an aspiration for land to settle or space to explore, it is used in *Borderlands* in an analogous but different way: as infinite goods to consume. There is no reasonable way a player would be able to experience or even see the one billion guns in *Borderlands 3* or even the 17 million guns in *Borderlands*, much less differentiate between them even if they were to see them all. Any one aspect changed in the preceding list technically constitutes a unique gun, so likely 20 guns in the 17 million or one billion are just the same submachine gun with a different stock, and then 20 more are the same submachine gun with a different barrel, and so on. In essence, while the technical number of guns is extremely high, the practical difference

[127] The Official Gearbox Software Forums. "Beginner's Guide to BL's Weapon Generator - Borderlands / Loot and Weapons," January 18, 2015. https://forums.gearboxsoftware.com/t/beginners-guide-to-bls-weapon-generator/53173.

between many of them is quite small. This was also a chief criticism of *No Man's Sky* on release; there may be a near infinite universe, but very much of it was similar.

This is what procedural generation scholar Kate Compton calls the 10,000 bowls of oatmeal problem; if you have a procedural generator that creates bowls of oatmeal, how do you make sure each one is interesting and perceived as unique, even if technically one oat is in a slightly different position in all 10,000 bowls?[128] Compton offers focusing on "characterful artifacts," bits of surfaced process and procedure that are understandable to a human observer, to give each generated object a little more "life." I instead suspect that such a pursuit may be fruitless, that the similarities between generated objects will always overshadow any perceived uniqueness, and this pursuit is undoubtedly impossible on an infinite scale. Games like *No Man's Sky* and *Minecraft* aspire to a scale that is fundamentally beyond the human experience of life (to live to see every star, to walk every inch of the Earth), much less a game. The reasons this aspiration and desire exist in games despite the lack of ultimate pleasure from it is something that we will address in the next section.

[128] Compton, Kate. "So You Want to Build a Generator..." Tumblr. *Kate Compton* (blog). Accessed July 6, 2022. https://galaxykate0.tumblr.com/post/139774965871/so-you-want-to-build-a-generator .

(Three) Impossible Worlds

One key element of procedural generation, or of any game infrastructure, is that they are hardware-limited. No matter how sophisticated a procedural generation system is designed, it eventually has to run on a real machine and is subject to the constraints of the physical properties of that computer. For a process so deeply involved in creation of places or objects, the limitations of procedural generation are clearer than most game infrastructures, especially when they produce many instances of the same type of thing. These limitations can subtly influence what is even imagined as possible, which is especially important when we are imagining what kinds of worlds can be created. This is why, for my art project for this chapter, I decided to begin with the intentionally fantastical and impossible and then try to fit it into existing procedural systems.

Three Impossible Worlds originally took inspiration from conceptual work like Yoko Ono's *Grapefruit* and *Acorn* to write instructions for procedurally generated worlds without the material burden of actually creating those worlds. These instructions were created to not be game or procedural generation system specific, to further reinforce that they are not meant to be constrained by reality. Some of the resultant prompts were things like "A world generator which only produces the noises of the world it has created" and "A world generated entirely from resources, with nowhere to live." These fantastical worlds are generated in the minds of the people who read them rather than in a physical machine and as such function in a way similar to procedural generation as each individual person who imagines such a world

will imagine something different and in effect have generated a distinct world (in their mind).

While not all of these worlds are feasible or even possible to implement in existing game systems, I found that a few were and so I decided to actually create these worlds using *Minecraft*'s world generation system. While that system is meant to be modifiable and flexible, I still needed an additional level of customization to create these worlds, and for that I used *Minecraft Forge,*[129] a community run modding API which allows for more detailed customization of *Minecraft*. The three worlds I elected to produce in *Minecraft* are the following: "A world generated with no resources, with nothing to consume" (Oreless), "A world generated entirely from resources, with nowhere to live" (Oreful), and "A world that's a sprawling contiguous inhabited city, with no place for the player to settle" (Megacity). Each of them presented its own challenges in creation, and in doing so showed some of *Minecraft*'s

[129] Minecraft Forge. "Minecraft Forge." Accessed November 2, 2022. http://www.minecraftforge.net.

inherent biases.

Figure 19: A screenshot of the "Megacity" world from *Three Impossible Worlds*

Many critiques have been levied of *Minecraft*'s extractivist and colonial gameplay model. One such critique is Daniel Dooghan's 2019 "Digital Conquerors: Minecraft and the Apologetics of Neoliberalism,"[130] a thorough examination of the neoliberal ideological underpinning which produces many of the gameplay structures of *Minecraft*. Of resource extraction specifically, he writes,

> Conquest is thus central to Minecraft's mechanics. It enables the extraction of resources, which justifies further

[130] Dooghan, Daniel. "Digital Conquerors: *Minecraft* and the Apologetics of Neoliberalism." *Games and Culture* 14, no. 1 (January 2019): 67–86. https://doi.org/10.1177/1555412016655678.

> conquest. The game's emphasis on survival implies that the player has a right to be in the world, and any violence is merely an expression of that right. Still, as with real expansionist regimes, physical violence is only part of conquest. This conquest is necessary: A player's harvesting operations will eventually extract all of the available resources in an area. Some resources are renewable, but the ores that guarantee the player's technological supremacy exist in fixed amounts.[131]

The finite resource that Dooghan is referring to in this quote, that partially fuels the drive for conquest in *Minecraft,* is ore. It exists under the surface of the world of *Minecraft* and is a key part of advancing in the progression of technologies in the game. For instance, you need a stone pickaxe to mine iron, and you need an iron pickaxe to mine diamond. In the "Oreless" world I created, all the ores in the game are removed, and replaced with the blocks closest to them, stone and deepslate. This change creates worlds which are nearly indistinguishable visually from the default world generation system, but with a change that quickly becomes apparent in a more mechanical gameplay sense as the progression of players is arrested. While players in these worlds can still do things like build shelters or dig in caves, they have no real reason to perform the conquest that Dooghan relates, as there is nothing to find and extract.

The Oreless mod also roughly models what would eventually happen in a finite *Minecraft* world; all of the non-renewable ore resources would be consumed and the player would have nowhere to go to gather any more. However, *Minecraft* is an infinite world, and it is an infinite world only because of the affordances of procedural generation. While it is of course possible to generate a finite space using

[131] Ibid, p. 77-78

procedural generation, and in a sense every bit of procedural space is finite, procedural generation systems are more often used for the feeling of infinite, ever expanding space. The infinite space of *Minecraft* is inexorably connected to the pursuit of ever more resources to extract and consume as with each new "chunk" (a 16x16x256 block space, *Minecraft* breaks its world generation up into these units) generated comes new resources as well. The Oreless mod therefore does not completely short circuit the pursuit of infinite space, as players can still travel and generate as much space as they want, but it does prevent any resources from being extracted from them.

The inverse of the Oreless mod is the Oreful one, which only generates resources and nothing else. This visually looks like hundreds of floating islands suspended in void. The different ore islands roughly trace out of the topology of the ground that has been deleted around it, but otherwise formlessly stretch out into infinite space. This mod makes *Minecraft* basically unplayable in the traditional way. Any wrong jump will send players falling into an infinite void, and there is no way to even mine the ore resources which generate, as there is no way to craft a wooden or stone pickaxe. This mod truly lays bare the massive amount of resources that *Minecraft* produces for players to extract. To hand place each and every piece of ore would be impossible, and to maintain the variety of terrain (above and below ground) that *Minecraft* strives for would be doubly so. It is only through the stochastic power of *Minecraft*'s world generation system that such a critical mass of resources can be

produced and placed

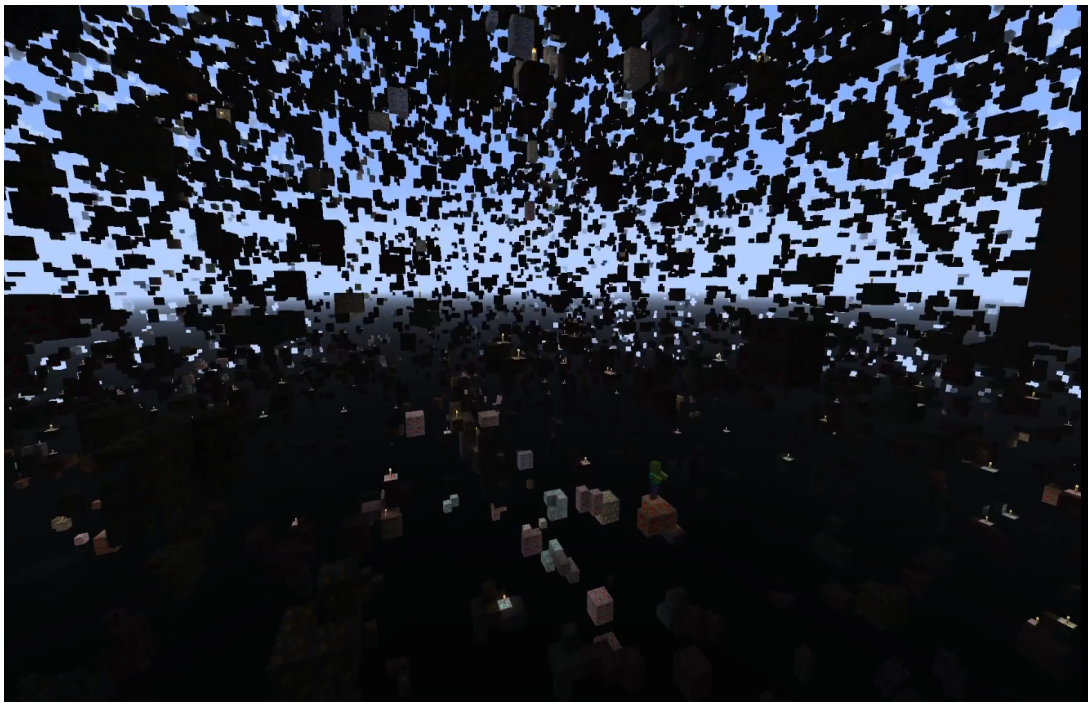

Figure 20: A screenshot of the "Oreful" world in *Three Impossible Worlds*

In *Minecraft*, monsters spawn in dark areas. This primarily exists so players will encounter challenges at both nighttime on the surface and at all hours underground. In the Oreful mod, the floating islands of ore do not receive the same amount of light that blocks on the surface would[132] and so monsters will spawn on these islands, giving a small amount of life to what is otherwise a totally sterile and lifeless world. Most monsters in *Minecraft* cannot significantly jump and have AI to prevent them jumping to their own deaths, so in the Oreful mod they are confined to

[132] This is possibly due to a lighting glitch or by dint of the way that the mod removes the terrain around the ore.

what become floating prisons of ore. It is telling that when so much of the terrain is stripped away, one of the few game systems that still functions is the one that makes the world hostile, giving a justification for violence and settlement; the world is dangerous, so you need to make it safe.

The final of the three mods is the Megacity mod which turns *Minecraft* into a sprawling infinite village instead of a sprawling frontier wilderness. *Minecraft* by default spawns small, isolated villages which are inhabited by peaceful creatures seemingly indigenous to the world of *Minecraft*. To achieve the mod's effects the settings in the village generation algorithm were changed, and the biome generation was restricted to only those which can support villages. The version in the mod is in fact less extreme than is technically possible in *Minecraft* because the more extreme version with an even denser village generation is extremely CPU intensive due to the huge number of villagers which spawn alongside them.[133]

In vanilla *Minecraft*, these villagers, and the villages they live in, are completely static. These villagers do not build new structures or work the land in any meaningful way, no matter when the player arrives at them they will look the same. Generation, then, has a profound impact on how these villages will be represented because they will never change. By default, villages are small and the villagers appear simple (they were in fact originally implemented with the same AI as pigs), and this

[133] Due to the unplanned nature of such dense village spawning, in the extremely dense villages many villagers (and their protectors, the Iron Golems) die from suffocation after being spawned inside the walls of other buildings.

apparent simplicity reinforces a latent colonial entitlement to the land and resources in it. With this mod, this entitlement has been complicated as the generated villages now appear to occupy all the available space; the frontier has been replaced by inhabited space. While the villagers' actual behavior does not change, the gestalt effect of the world is quite different. Procedural generation is biased towards the ever-unfolding and the infinite, but this is usually directed towards uninhabited space, and not urban space.

Souvik Mukherjee writes that, “The imperialist machinery of expansionist geopolitics functions through cartography and surveying.”[134] Procedural generation feeds this machinery as it continuously makes land available to incorporate into imperial maps. The Megacity mod short circuits this same function because while the world is not mapped by the indigenous residents of the mega-villages, they do not appear to be ‘wild’ or ‘untamed’ and ‘in need’ of such mapping. Later in the same chapter, Mukherjee writes, “In describing the spaces of empire, video games have defined them within a homogenous code—the affordances of the machine code reflect globally dominant cultural codes.”[135] In this case, the machine code is procedural generation and the cultural codes are colonial ideas of the domination and taming of a wild landscape. Procedural generation, at its very core, is built on the presumption that you might want to indefinitely produce something, whether it be guns or

[134] Mukherjee, Souvik. *Videogames and Post-Colonialism: Empire Plays Back*. Palgrave Pivot. Cham: Palgrave Macmillian, 2017. p. 33

[135] Ibid p. 47

landscape or dialogue. Indefinite production is an unstated requirement in the fantasy of infinite consumption, expansion, and extraction. *Minecraft* is a particularly egregious and direct example of the colonialism embedded in procedural generation, but this affordance extends across its many different applications and uses, especially in games.

Returning to the issue of infinite generation and pleasure which ended the previous section, it is easier to understand some of the motivations present: the imperial, colonial drive to conquer and control, infinite space to settle, and infinite items to consume. It may not be exciting or pleasurable to crest the next hill in *Minecraft* and see what is beyond it, but you will know that it has ore to mine in it. It may not be exciting to get your 100th gun in *Borderlands*, but it may have a higher damage value than your previous one which gives it mechanical value even if by all other metrics it has none. When adding this new area or this new gun to your imperial portfolio, uniqueness does not matter because what matters is the ability to extract resources from it. What matters is the resource value and the knowledge that you now have access and control over it. Without procedural generation, there would not be enough "stuff" to sustain the scope and scale which fuel this colonial fantasy.

Conclusion

As the content expectations for AAA games grow larger and larger it becomes increasingly less possible to create all the content in them directly. In turn, procedural generation now takes on a larger and larger role in game design and production. There

are now procedural textures, procedural music, and many other forms of procedural content generation that go beyond weapon properties and terrain.[136] This rise in popularity and use in turn requires a deeper reckoning with the darker elements of procedural generation. It thus becomes more and more necessary to recognize and hopefully subvert the colonial underpinnings of the infrastructure.

One such theorization comes from Max Kreminski and Noah Wardip-Fruin in a paper presented at the 2018 FDG conference titled, "Gardening Games: An Alternative Philosophy of PCG in Games."[137] In their view, games like *Minecraft* interact with procedural generation in a "mining" sense, that the generated assets are used to make things to extract, something that has also been well documented in this chapter. They advocate instead for games to function more in a "gardening" style, where players are asked to interact deeply with a small number of generated artifacts (as opposed to shallowly with an infinite number of generated artifacts). Their example of such a game is *Animal Crossing*, a 2001 game published by Nintendo. In *Animal Crossing*, you play a new resident to a town, and quickly find yourself in debt to a raccoon named Tom Nook. You spend your time doing various chores around the

[136] For a full survey, see Hendrikx, Mark, Sebastiaan Meijer, Joeri Van Der Velden, and Alexandru Iosup. "Procedural Content Generation for Games: A Survey." *ACM Transactions on Multimedia Computing, Communications, and Applications* 9, no. 1 (February 2013): 1–22. https://doi.org/10.1145/2422956.2422957.

[137] Kreminski, Max, and Noah Wardrip-Fruin. "Gardening Games: An Alternative Philosophy of PCG in Games," Malmö, Sweden, 2018.

town and helping out the other residents, making money to ultimately pay off your debt. Functionally, many players simply ignore the debt and instead focus on simply improving or enjoying their time in the town. Notably, *Animal Crossing* uses procedural techniques to develop changes to the town over time, such as the random growing of weeds or the appearance of certain bugs or fish.

However, this argument is only a bait and switch. While it is true that *Animal Crossing* does not provide an infinite frontier for extraction, it provides an infinitely growing, stable garden for harvesting and extraction. The fantasy of infinite consumption and extraction is still present; space is swapped for time. Even in the example of the procedural generator that generates the terrain in *Animal Crossing* (which only runs once, when the village is first generated), it provides that infinite variability across different players of the same game, not dissimilar to the pursuit of "replayability" in games like *Rogue*. Instead of a single person replaying *Animal Crossing* and getting a new experience every time, the injunction for "uniqueness" is spread across multiple players.

Another way to address some of the issues with procedural generation is perhaps focusing on who is using it as a tool. For instance, many of the games discussed in this chapter were made by white settlers, or by people living in formerly-or-currently Imperial countries. In an article titled "Towards Sovereign

Games"[138], Elizabeth LaPensée, Outi Lati, and Maize Longboat perform a survey of three games they consider to be sovereign games; games made with self-determination as a respected practice. In their specific examples, they use games made with Indigenous people in lead roles with real decision-making power and deem games made in these sorts of production environments as "sovereign games". This is sovereignty in a much different context than in Chapter One, instead of irrevocably deciding the fates of others, this kind of sovereignty is a sort of self-determination. Procedural generation would certainly hold a different valence if used in a sovereign game. It is possible PCG may have a wildly different impact when used in a context of self-determination as opposed to extraction and consumption. If the issues with procedural generation purely stem from contemporary game design trends, sovereign games may show a way out of them.

It is abundantly clear that procedural generation allows for more "fuel for the furnace" as Kreminski and Wardrip-Fruin put it in their paper. I would even contend that there are very important uses of procedural generation in the realm of the sciences and medicine, where it can be used to generate and test hypotheses rapidly.[139]

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[138] LaPensée, Elizabeth A, Outi Laiti, and Maize Longboat. "Towards Sovereign Games." *Games and Culture*, June 28, 2021, 155541202110291. https://doi.org/10.1177/15554120211029195.

[139] One such example in the domain of urban planning is Mustafa, Ahmed, Xiao Wei Zhang, Daniel G Aliaga, Martin Bruwier, Gen Nishida, Benjamin Dewals, Sébastian Erpicum, Pierre Archambeau, Michel Pirotton, and Jacques Teller.

Because the majority of games produced are not currently sovereign games, it remains to be seen if there is a way to use procedural generation in games in a way that does not fuel the inexorable march to more and more content to consume, whether that be over space or time. Procedural generation enables the worst tendencies of contemporary game design for extraction, colonization, and the ever expanding horizon of infinite content, which in turn takes a significant part in firmly establishing these things as core tenets of game design, which then also reaffirms that this is what procedural generation ought to be used for.

Our world has not been freshly generated and it is not full of resources that exist to be extracted. It is not populated with simple, ahistorical creatures; it is not inexhaustible, infinite, or unending. Procedural generation is a crass kind of software reductionism that takes the very finite world and represents it as an infinite, sprawling, uninhabited mass. Procedural generation is the cudgel through which digital space is beaten into the infinite shape of expansionist fantasy. Procedural generation is a list of unending checkboxes, the last dregs of oil in a derrick, the shipments of materials going back to a faraway home. It is possible that there is a future where procedural generation will operate in a different way in games, but the infrastructure itself is not going to get us there.

"Procedural Generation of Flood-Sensitive Urban Layouts." *Environment and Planning B: Urban Analytics and City Science* 47, no. 5 (June 2020): 889–911. https://doi.org/10.1177/2399808318812458.

Conclusion

This dissertation has covered three different examples of game infrastructure. The first was physics, the infrastructure through which real-life physics is simulated in digital spaces. Specifically, this chapter looked at how this infrastructure characterizes and displays death and dying in video games. The second was polygonal modeling, the infrastructure that determines visual representation in 3D games through a dichotomy of mesh and texture. The chapter explored some of the results of this dichotomy, including the commodification of identity through skin markets. The final infrastructure was procedural generation, the operation of which can programmatically generate game assets ranging from guns to terrain. The chapter highlighted the ways that the generation of infinite content, or the promise of it, reinforced capitalist consumption patterns and encouraged colonial modes of game design.

Each of these infrastructures was examined as a formative, background element that constricts and in some ways determines what kind of worlds can be built in games. Despite their powerful influence, they are often taken for granted in the study of games. By constructing "game infrastructure" as a category, there is now a

way to study these important game elements in a unified, visible way. In some ways, I coin "game infrastructure" in the hope that it makes its component elements more visible and accessible for critical scholarship. It is also important to reiterate the agential nature of infrastructure, and especially game infrastructure. While the category "game infrastructure" might allow discussion of game infrastructure in the abstract, infrastructures really only act, and in according to agential realism, exist, as infrastructure in the moments of play, in phenomena. I hope to not start a static discussion of technology and its inherent biases and properties, but rather a dynamic one that examines these infrastructures in context and draws conclusions about their tendencies and effects through that context. As a side effect, I believe this can help short-circuit techno-optimism about the potential future uses of these infrastructures; for instance, the uncritical desire for more and more complex and detailed procedural generation. I say this because the potential future benefits of technology have much less weight when one considers that the technologies themselves only actually exist in the phenomena of their current, actual use.

Of course, the three infrastructures covered in this dissertation are only a small selection of the potential infrastructures that exist in the world. I have constrained myself to the three presented here to focus on some of the most impactful and prevalent infrastructures in games today. I had long wanted to see these three technologies approached in a critical and deep way, and it is my hope that this dissertation is one step towards that. To reiterate this point, I will revisit some of the main touchstones in each of the three preceding main chapters.

In Chapter One, I first linked the history of physics in games to modern physics engines and the drive to create believable simulations of physics. I tracked how this development especially focused on bodies. I also made connections between Amanda Phillips' "mechropolitics" and Achille Mbembe's "necropolitics" and modern depictions of death in games using physics engines. Specifically, I argued how these engines help to construct the right to control killing and death in games. These theories were brought to bear on the art project *Piles*, and it was used to examine the different ways that games approach the digital performance of death and dying through physics. The chapter resolves with a discussion of how new technologies for physics, such as procedural animation, might transform the analysis conducted in the chapter.

In Chapter Two, after establishing the polygonal modeling dichotomy of "textures" and "mesh," the chapter traced the history of polygonal modeling and explored the technical justifications for the technology. Then, the chapter turns to how race, gender, and identity become commodified in contemporary deployments of polygonal modeling in games and how video game companies have sought to capture and monopolize skins in company-operated marketplaces. The chapter pivots to a discussion of *GamePyg's Face and Body Overhaul* and its engagement with polygonal modeling and agency and control. This is all wrapped up with a conclusion which looks to the future of the technology, and how the issues discussed in the chapter might change in the emerging new replacements for polygonal modeling.

In Chapter Three, the focus turned to procedural generation and colonialism. Once again, the history of procedural generation in games was contextualized with discussion of post-colonial theory. I turned to two specific uses of the technology for producing spaces and things and critiqued them in terms of producing infinite amounts of material to consume. The chapter finishes with a discussion of *Three Impossible Worlds*, a set of *Minecraft* modifications that further explore and illustrate how that game in particular relies on giving the player extreme control and entitlement to the world and expects them to consume resources indefinitely. The conclusion looks to potential alternatives to traditional procedural generation in games that might somehow escape the colonial ideology baked into the technology.

What is clearly shown across these chapters is that software infrastructure exists inside games and has a powerful influence on how those games are created and played. This game infrastructure is historical, and has its roots in a history of software and game development and is also phenomenological, and it surfaces most clearly in moments of play. This is because the influence of game infrastructure is not prescriptive, it is defined by how it allows and affords behaviors and will vary depending on who interacts with it. The art pieces across these chapters give a glimpse into what a critical engagement with game infrastructure may look like. The games community together needs to grapple with the effects our tools and infrastructure may be having on the medium as a whole.

Together, these three chapters model a method of engaging with "game infrastructure" in a way that goes beyond a pure technical analysis but that retains a

material commitment while exploring critical and phenomenological aspects of the infrastructures. This represents a great possibility for understanding the significance of the digital infrastructure we experience and employ, especially in games. As much other infrastructure work does, this work shines a light on something normally invisible but extremely influential. I believe this work also sets a groundwork for building up new games making practices that are more antiracist, antisexist, and anticolonial by providing the ability to critique the infrastructures which enable these things. There is so much room for this research to continue to grow.

Future Work

In the end, these three infrastructures are only scratching the surface of what is possible with dedicated study of game infrastructure. As such, I wanted to include a brief summary of some of the many other types of game infrastructure with relevant research questions and directions. I want to note that the following ideas are not presented in order to "claim" the corresponding research, I instead offer them as starting points for anyone interested in studying game infrastructure.

Infrastructure Name	Description of Infrastructure	Research Questions
Mouse Look/Mouse Aim	The control schemes for many first-person PC games which link the camera's viewpoint to the movements of a mouse	What does it mean to link sight to the dextrous motion of a hand? Whose experiences are left out when looking is intimately connected to hand motion?
Inventory	The various paradigms, schemes, and other systems	What parts of object ownership do inventories

	which enable “objects” to be collected and placed in a player-owned storage	preserve, and which do they not? How do inventories grapple with the fact that game objects never have any actual mass or bulk?
Rigging/Animation	The use of nodal skeletons and programmed movement to animate 3D characters	An extension/inversion of the discussion of death in Chapter One: what do animation systems imply about liveliness? What do the simple skeletons of animation reflect about human conceptualization of our own bodies?
Levels	The chunking of a game into discrete, often self-contained levels	Levels are directly related to hardware limitations, but what are other ways to solve the same problem of limited resources that aren’t levels? Levels render a contiguous world into discrete chunks, what is lost in that translation?
Barks	Short audio clips which characters say in response to certain events, often used to give the impression of alertness or attention	Can be folded into discussions of how liveliness should be represented. Also, as an audio representation of observation, is a direct way of giving the player insight into the “mind” of a non-player-entity, to what extent should any person expect to know the thoughts of another?
Lighting	Simulated light, emitted either from points or from global sources	Likely a lot of variance depending on the method of lighting. In general, what facets of light do

		these system prioritize, and which do they not? Examples include shadows and water refraction.
Particles	Systems that use many small units to create larger effects such as fire, smoke, and dust	Particle systems often represent some of the smallest observable elements of game worlds, how does their construction reflect on the scale and composition of the rest of the world?

Hopefully, one of the entries in the above table has sparked an interest in pursuing a study of game infrastructure. In my opinion, any one of them could be the foundation for a whole program of research. If I had to figure out a guiding lesson from all of this work, it would be this: always pay attention to the tools and systems which structure digital life. It is easy to miss important details which subtly structure what realities are made possible.

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