A Grid-Based Approach to Simulating Hair
(Technical Paper)

Animating Representation: Diversity in Computer Graphics Technology and Storytelling
(STS Paper)

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Prospectus

Technological Influence on Storytelling

One way that media can shape and reflect our societal views is in its representation of different groups of people, or lack thereof (Giroux, 2008). Media representation can easily shift or solidify existing views towards the represented or misrepresented groups especially in the context of race (Brooks & Hébert, 2006). Representation is also key in the formation of individual self-image, especially for disadvantaged and underrepresented groups (Jang et al., 2019; Schmader et al., 2015).

While racial diversity in films has increased in the past decade in terms of numbers (Smith et al., 2018), analyses of media representation that focus solely on numerical representation fail to present a complete picture of diversity in media (Erigha, 2015; Keys, 2016). The quality of representation, which itself is highly influenced by the centrality of creators who are members of the represented groups, is just as influential in terms of shaping societal views towards the represented group (Erigha, 2015). A lack of diversity in behind-the-scenes leadership roles in media creation—i.e. directors, producers, and writers—can easily translate to a dearth of quality representation of diverse groups on screen (Erigha, 2015). Yet as recently as 2019, when considering the top 100 highest grossing films in the U.S., only 22.3 percent and 19.6 percent of such leadership roles were filled by women and members of underrepresented racial groups respectively (Smith et al., 2018).

Not only do the forces behind the camera influence the stories that are disseminated into our culture (Erigha, 2015), but the tools that creators work with—while often overlooked in discussion regarding diversity and representation—are undoubtedly influential as well. Particularly in the realm of 3D animation and computer-generated imagery (CGI), the software that artists use are vested power over the stories that are told (Villemin et al., 2015). Since media consumers tend to gravitate towards characters they see as similar to themselves, the power of the technology used to create CGI is especially relevant in narratives that center human characters (Keys, 2016).

Historical film and film technology have undoubtedly influenced and continue to inform the development of computer graphics technology. As such, the biases present in these earlier techniques also continue to be preserved over time (Kim et al., 2021). Graphics research on features that are often characteristic of different racial/ethnic groups predominantly focuses on typically Caucasian characteristics, pushing a narrative of whiteness as the norm (Kim, 2021). For example, there is very little research on simulating and rendering hair types that are generally thought of as non-white—such as afro-texture hair—and a similar trend can be seen in regards to rendering darker skin tones (Jensen et al., 2001; Kim, 2021).

This project seeks to provide an overview of hair simulations in computer graphics, as well as explore different methods with which to represent a variety of hair textures and styles. I will also analyze how the development of computer graphics has shaped, and has been shaped by, the stories we wish to tell through the lens of diversity and representation in popular media.

Simulating Hair

Hair has been the focus of numerous research papers in computer graphics due to its complexity and importance to characterization in animation, modeling, simulating, and rendering (Sadeghi et al., 2019; Thyng et al., 2017). However, very few of these papers explicitly focus on hair types that are not characteristically Caucasian or East Asian (Kim et al., 2021). Even papers that claim to create graphics which concentrate on curly hair fail to include kinky, natural African-type hair, which is inarguably a subset of curly hair (Bertails et al., 2006; Iben et al., 2013). For this project I will be researching hair simulations, with the goal of creating a hair simulation that I can use to explore a variety of hair styles.

One way in which hair simulation can be approached in computer graphics is with methods similar to that of fluid simulation. This is because human hair shares several properties with fluids. Much like a fluid, hair is a deformable mass that generally needs to interact with internal and external forces without noticeably losing volume, while abiding by the perceived physical laws of the surrounding environment. The particles that comprise the mass should be able to collide with each other as well as the surrounding environment without creating strange visual artifacts. Additionally, it is generally preferred for hair dynamics to be simulated rather than animated by hand, though there are instances where artists and animators want to control hair movement manually. (Sadhegi et al., 2019; Thyng et al., 2017; Villemin et al., 2015). For this project, I will begin by reviewing current works and implementing a 2D Particle-in-Cell (PIC) simulation, which is a hybrid Lagrangian/Eulerian system that has historically been used for simulating fluids (Jiang et al., 2017).

Fluid simulations often involve modeling the fluid as a large collection of particles. Particle system simulations usually fall into one of three types: Lagrangian, Eulerian, or a hybrid of the two (Jiang et al., 2017). Lagrangian approaches consist of simulating each particle individually, changing the velocities and positions of particles by applying forces to them at a particle level. Eulerian approaches involve breaking the simulation space into a grid and focusing on the concentration of flow in each grid cell, rather than tracking individual particles. Forces are applied at a grid-based level, and Eulerian systems keep track of the flows in and out of each grid cell based on the forces present to determine what the concentration of fluid should be for each cell (Jiang et al., 2017).

The two systems each offer advantages and disadvantages. Lagrangian systems are generally more intuitive to understand and control, and are as a consequence more desirable when designing tools that artists and animators may want to use (Sadhegi et al., 2019). Lagrangian systems also allow for the advection of fluid particles to be a trivial issue, while this is more difficult to achieve in Eulerian systems (Zhu & Bridson, 2015). However, Eulerian systems are better at enforcing incompressibility, so that the fluid does not appear to lose volume, which is an important trait in most physically based simulations (Zhu & Bridson, 2015). Hybrid Lagrangian/Eulerian simulations aim to reap the benefits of both types of systems by taking elements of both.

The PIC simulation technique involves moving Lagrangian particles through a Eulerian grid. At each time step, mass, momentum and velocity are calculated for each cell of the grid by taking weighted averages of the particles in and near the grid cell (Jiang et al., 2017). These velocities are then updated on the grid level and applied back to the particles in the cells (Jiang et al., 2017). However, PIC simulations have shortcomings which cause the technique to be less desirable in several use cases. PIC systems are highly energy dissipative, which results in PIC-based fluids inevitably having a viscous look (Jiang et al., 2017). The Fluid-Implicit-Particles (FLIP) technique is designed to counter this. FLIP builds on PIC but calculates and directly applies the changes of velocity themselves to particles, rather than applying the new velocities to the particles. This allows FLIP simulations to preserve energy and rotational motion better than PIC (Jiang et al., 2017).

I will build out a Fluid-Implicit-Particles (FLIP) simulation following the completion of the PIC implementation. This will enforce incompressibility in the simulation. Then, to create the final hair simulation, I will use a tridiagonal matrix solver to force particles to form inextensible (unstretchable) strands (Han & Harada, 2013). I will then explore different shapes and styles hair-like volumes I can achieve with my simulation by experimenting with and building input files for the inextensible strands.

Investigating Bias in Computer Graphics Technology and Storytelling

While my technical project will focus on hair simulation, I will broaden this perspective to analyze the dynamics between the development of computer graphics and racial diversity in popular media, and the societal and historical contexts of these developments. I will use the theory of co-production to guide this analysis. Co-production maintains that natural, social, and technological order are simultaneously developed (Jasanoff, 2004). Proponents of the co-production framework stress the importance of acknowledging the recursive relationship that exists between separate parts of systems due to the influence they exert on each other (Jasanoff, 2004, p. 19). The framework also places emphasis on the nature of scientific knowledge and technology as entities that are embedded into and shaped by sociological landscapes, rather than as pure mirrors of the real world (Jasanoff, 2004). These tenets make co-production an appropriate framework for my analysis of how developments in computer graphics have shaped and been shaped by social order and demands for diversity in media.

Co-productionist theory lends itself to several ordering instruments, the four most prominent of these being the making of identities, institutions, discourses, and representation (Jasanoff, 2004, p. 38). Representation plays a crucial role in the formation of social identity (Brooks & Hébert, 2006). Children latch onto representations that they deem similar to themselves and internalize the traits--and stereotypes--that those representations display during the formation of gender and racial identities (Jang et al., 2019; Keys, 2016; Signorielli, 1990).

Members of historically underrepresented and disadvantaged social groups are also particularly affected by media portrayals (Brooks & Hébert, 2006; Schmader, 2015). When shown stereotypical, negative portrayals of their own social group, members of disadvantaged minority groups felt greater negative emotions towards their own ethnic identity than their majority group counterparts (Schmader, 2015). It is therefore critical for media creators to not only increase numerical representation for these groups, but also ensure that these representations avoid stereotypes (Erigha, 2015). Identity is also central to the creation of media itself. When creators who identify in underrepresented groups are involved in leadership roles behind the scenes, representation of those groups tends to be more common as well as higher in quality (Erigha, 2015).

Representation in media and graphics technology both build upon and sustain existing institutional norms. For instance, the preference for research on rendering pale skin tones over darker tones upholds the narrative of lighter skin tones being the default and darker tones as abnormal and "other" (Kim, 2021). The effect of this is then compounded in other norms as well: Caucasian features continue to hold center stage in documentation and image galleries for modeling software, and popular media made with those tools (Kim, 2021; Smith et al., 2019). This overrepresentation of Caucasian traits is not solely rooted in graphics research. Rather, the development of graphics technology itself stems from a social and historical context that offered—and continues to offer—Whiteness as the so-called normal state (Kim, 2021). A brief foray into the history of film technology reveals the pervasiveness of this biased narrative. As early as the inception of the camera, images used for color correcting video cameras exclusively featured White models, and this itself stems from the social context of the time period (Roth, 2009). Subsequently, early films fail to depict darker skin tones with the clarity that they afford light tones (Roth, 2009). Thus, as Jasanoff claims, “Institutionalized ways of knowing things are continually reproduced in new contexts” (Jasanoff 2004, p. 40).

The language describing computer graphics technology, derived from societal standards and technological development, also continues on to implicitly uphold the societal standard that shaped it. Through the example images that are rendered and shown, research papers have a hand in defining what different traits mean. For example, “hair” in research literature implicitly means “straight hair” with a need to differentiate “curly hair” explicitly (Iben et al., 2013; Jiang et al., 2017; Sadhegi et al., 2019). This dichotomy may have formed due to it being more technologically complex to simulate and render curly hair than straight hair, making straight hair the first viable type in early graphics (Bertails et al., 2006). Interestingly, the differentiated “curly hair” rarely encompasses the full range of hair types (Kim, 2021). It is rare to see the tight curls that are more common among African hair types in papers that claim to successfully simulate curly hair (Kim, 2021).

Finally, it is vital to analyze the representations of the world that computer graphics technology presents and the behind-the-scenes forces that influence that representation. Media created with computer graphics technology continues to center narratives around White characters (Keys, 2016; Smith et al., 2019). Media representation is able to dictate what groups are “worthy” of being depicted in media and how those groups are depicted, creating an image of what the real world should look like. Again, however, numerical diversity cannot be the only measure of success (Erigha, 2015). Quality of representation, and subsequently the centrality of underrepresented groups in the creation of these media, are also important factors in the way that media creates representations of the world (Erigha, 2015). The effect of these representations on shaping and reflecting the dynamics of the real world cannot be ignored in this analysis.

Today, it is increasingly important to question and identify the implicit bias found in the stories and media that we consume. Media representation can have far reaching effects at both individual and societal levels, as it has the power to support both informal societal norms and formal structures (Brooks & Hébert, 2006). However, discussion of representation when it comes to computer generated media would be incomplete without considering the technology used as well. Science and technology are far from purely objective fields. Rather, scientific knowledge and technological artifacts carry implicit messages that stem from and support the society they were developed in, and the technology behind CGI is no different (Jasanoff, 2004).

Investigating Bias in Computer Graphics Technology and Storytelling: Methods

To shed light on this issue, I will search for further evidence of the biases present in computer graphics technology and animated media, while exploring the following research questions: What social and historical values have contributed to the formation of this bias? How are these values both sustained and molded by the technology at hand? What are the implications of these biases on the stories told through computer generated mediums?

In order to provide more thorough evidence of the bias existing in computer graphics technology, I will review and analyze a variety of types of sources through a lens of racial diversity. Similar to Theodore Kim's (2021) exploration of this topic, I will approach this analysis through the different perspectives of the various spheres or groups that interact with the technology at hand. First, for the academic sphere, I will aggregate data by reviewing relevant graphics research papers. I will collect data regarding the diversity of features the researchers present, both in the example images they generated and in their discussion of their research. To address the more industry-focused sphere, I will review the documentation created for software tools used in industry, as well as their default settings and options. To address the sphere of independent creators, I will analyze popular add-ons and packages used in modeling and animation softwares, as well as example galleries of images and videos generated by users utilizing the software tools.

To analyze the relationship between the development of computer graphics technology and social and historical factors, I will employ the co-production framework, and identify the ways in which the relationship creates and reinforces identities, institutions, discourse, and representations (Jasanoff, 2004). I will search for scholarly writing that provides background knowledge of historical and social factors and values in order to guide this analysis. Finally, to provide insight into the implications of the existence of these biases, I will search for graphics papers that actively seek to acknowledge and counter biases, be that through discussion of these biases within the text or the inclusion of underrepresented groups and features in example images created by the new technology. I will also search for sources that address the current state of computer generated media creation, as the recent pervasiveness of digital technology has shifted the landscape of content creation (Erigha, 2015).

Creating Environments for Inclusive Storytelling

Popular media not only reflects the society that it is created in, but also has the ability to spark conversations and implore audiences to consider new or challenging perspectives or, alternatively, perpetuate existing notions (Giroux, 2008). Computer generated media occupies a unique position in that it encourages creators and viewers alike to tell more exploratory stories and promotes “contemplations of pluralism” (Herhuth, 2016). It is necessary to analyze the stories told through these mediums through the lens of diversity and representation due to their highly formative nature (Keys, 2016).

An analysis of diversity and representation in animation would be incomplete without a discussion of the development of the technology these stories are told through. I will be simulating and researching current literature regarding hair, a key trait for characterization as well as a feature that can be quite distinct to different racial and ethnic groups. I will also investigate areas of implicit bias within computer graphics technology and analyze these biases in terms of their historical and social contexts. I will study the implications of their presence, so that it might be possible to actively address these points of bias embedded within the technology and community. I ultimately hope to explore and identify ways in which researchers, developers, and creators alike might be able to actively recognize biases so as to create technology that promotes more inclusive storytelling.

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