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Dynamic Hair Aging System

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ABSTRACT

The modeling and rendering of hair in Computer Graphics has seen a lot of progress in the last few years. However, there has not been much progress on the modeling and rendering on the subject of hair aging. This work aims to simulate the hair aging phenomena by developing a procedural shader using Blender as the development platform. The project is based on the biology of hair and the results show that our system is capable of creating visually realistic hair aging.

Keywords: 3D, CG, hair, aging,shader, Blender, greying, simulation.

CONTENTS

1 INTRODUCTION

Hair aging is a natural phenomenon that affects every human being. At about 30 years old on average, our hair starts to lose pigmentation at a rate of $10 - 20\%$ every 10 years (TOBIN, 2008). Even though there has been a lot of advances on the rendering of human hair (REN et al., 2010; OU et al., 2012; CHIANG et al., 2016), the dynamic aspect has not been addressed before, although game companies and movie studios have their in-house solutions. There are currently no movies nor games with characters that age in real time, although some games like “Fable” (Big Blue Box, 2004) and “The Watchmaker” (Micropsia Games, 2018) and some movies such as “The Curious Case of Benjamin Button” (FINCHER, 2008) attempted to do it using *ad hoc* techniques that will be explained later in Chapter 3.

We developed a biologically-inspired simulation of the hair aging phenomena including animation. The loss of pigments is noticeable as the original color of the hair turns to gray and finally to white. Our model has two main parts: graying of individual hair strands and how the graying propagates on the scalp. As a first approximation, our focus was on aging for males, and we use a simpler model where the desaturation of the hair (loss of pigmentation) is modeled as a single gradual transition of hair with an initial amount of melanin to no melanin, so the effect is more visible. The whole project was developed using Blender (ROOSENDAAL, 2002), an open source 3D software that allows state-of-the-art hair rendering. The development using Blender has been recorded on videos. It is available to watch on YouTube under the title of “Aging Hair Simulation”, therefore the whole thought process applied can be followed. In total, it took nearly 20 hours of development time, if we compress it all together. The next chapter presents a biological background on the biology of hair and data regarding the natural aging effect on human hair. The related work chapter is presented next followed by the chapter on the methodology. Chapter 5 presents our experimental results followed by the conclusions.

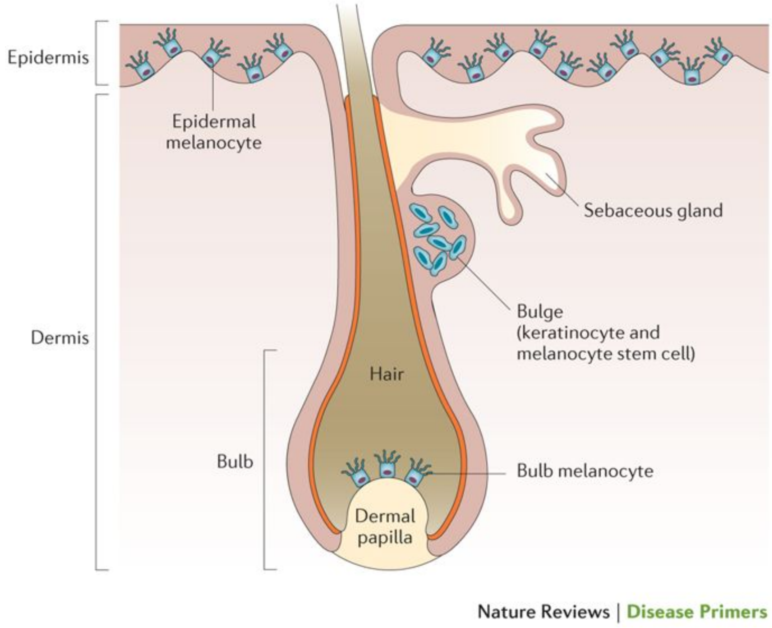
2 BACKGROUND

In this chapter we present basic information on the biology behind the hair greying effect, along with how it is possible to use Blender to replicate that effect on a 3D simulation.

2.1 Biological Background

When we are born we have around 100,000 hair follicles on our scalp and with time they start to lose density, lose pigmentation and thickness. Until the age of 30 no loss is noticeable on an average human being, but at that age, according to (TOBIN, 2008), there is an average rate of pigmentation loss between 10% and 20% every 10 years.

Figure 2.1: Hair Follicle



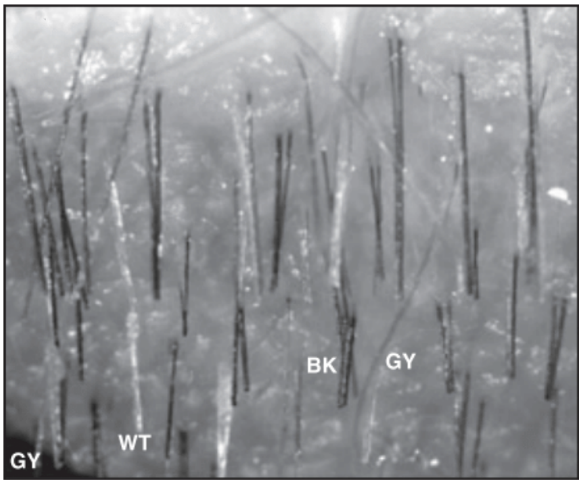
Source: (DELL'ANNA; PICARDO, 2006)

Figure 2.1 is a representation of a hair follicle together with the biological elements that distribute the hair's pigmentation, the melanocytes. A follicle turns grey because it loses melanocytes, meaning grey hair contains fewer melanocytes on its bulb and therefore produce less eumelanin (dark pigment).

It is important to point out that depending on a person's origin, background and lifestyle, the rate and the starting point of greying may differ. For example, (PANHARD; LOZANO; LOUSSOUARN, 2012) mentions that asians and africans descendants show a slower rate of greying compared to caucasians. Therefore, to accurately simulate the hair aging phenomena, the character's ethnicity must be taken into account. The same work explains that in men the temporal regions of the scalp (marked on Figure 3.2) show a significant higher rate of greying, followed by the vertex, also known as crown. For women the temporal and vertex regions showed similar values between them.

Figure 2.2 is a microscopic picture taken from a human scalp. It shows that the pigmentation loss does not affect all the follicles the same way, so at any moment there could be black, white and gray hairs all in the same region.

Figure 2.2: Microscopic view of hairs on the scalp. GY: gray, WT: white, BK: Black.



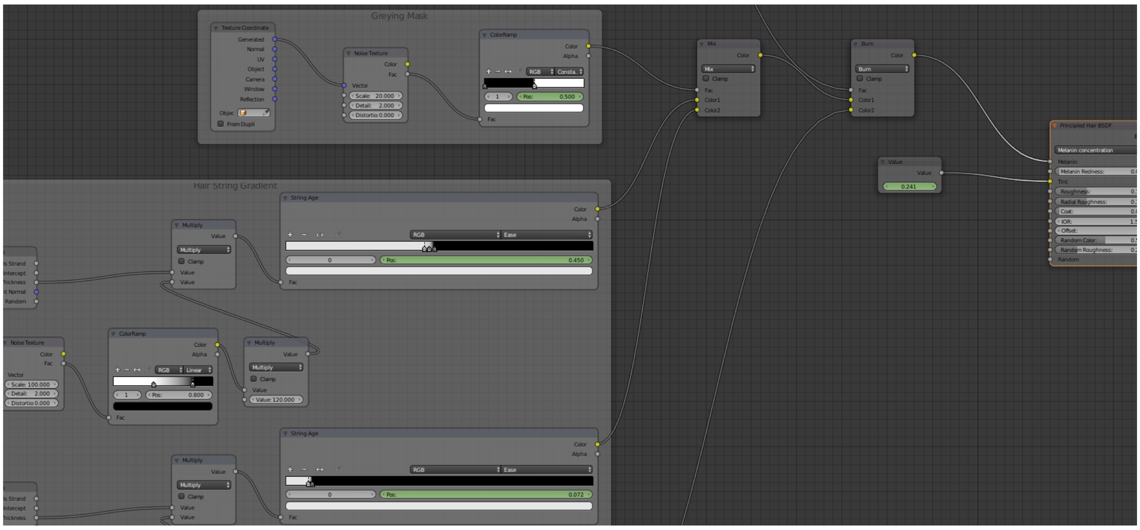
Source: (TOBIN, 2008)

2.2 BLENDER

Blender is a free tool used to develop the hair aging simulation system. It is simple to customize, easy to learn and allows for quick previewing of results. Besides, it has available a particle system that can be used to simulate hair, together with a recent new shader that is adequate for our purposes, the *principledHair shader*, developed based on (CHIANG et al., 2016) and explained later.

The engine used for rendering and manipulating the simulation is called "Cycles". It is currently considered the standard engine to use to achieve realism and to have more control over the shaders on a scene. Cycles uses a node system to manipulate shaders. A node is a basically a script representation with x inputs and y outputs, an example is given on Figure 2.3 showing the controls for the follicle thickness masks (bottom left) and the random follicle selection control (top center) connecting to the *principledHair shader* (right).

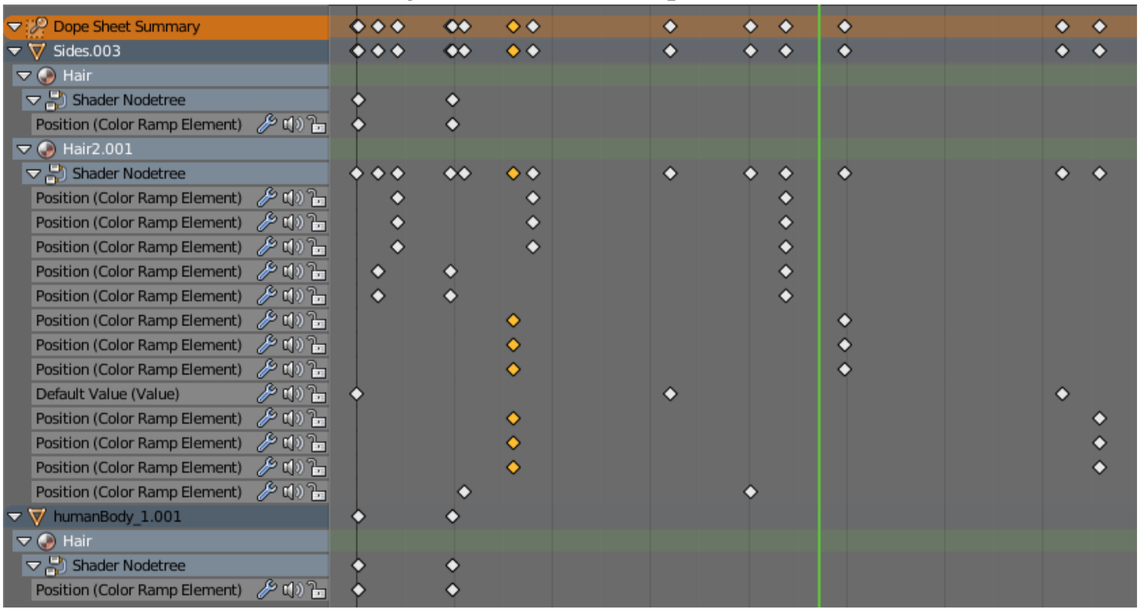
Figure 2.3: Part of the simulation node setup in Blender



Source: created by the author

With nodes, we have access to thickness information of a hair particle, we can change colors in textures, mix images and mask regions, all done by connecting nodes with other nodes, creating a complex web of interconnecting scripts.

Figure 2.4: Blender dopesheet



Source: created by the author

The main nodes used for the simulation are the following:

- *colorRamp*: allows to control a black and white texture input, changing the black or white into another color, increasing how much white there is and inverting the color scheme;

- *principledHairShader*: output shader that allows control of hair based on its melanin levels. It was developed based on the research presented on (CHIANG et al., 2016);
- *mixRGB*: allows masking and mix colors or textures.

Another important part of Blender used for the simulation is the Dopesheet, shown on Figure 2.4. It allows the creation of keyframes marking the value of a variable for part of the timeline. During animation, it will interpolate from one keyframe to the next, causing physical differences to occur on the hair. Therefore the created node setup can be changed overtime in a very controlled way. This setup allows for quick experimentation and simplifies the math required for most functions.

3 RELATED WORK

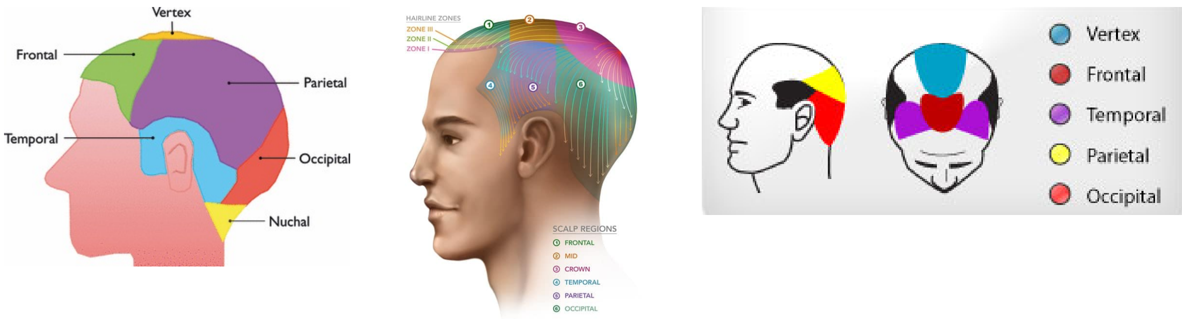
In this chapter we present the relevant articles, papers and projects related to the topics of this work. First, we refer to projects regarding the Biology in the hair aging process, followed by Computer Graphics research, explaining how it is possible to represent realistic hair in 3D, and finally an overview of games and movies that attempted character aging techniques.

3.1 Biology of Aging Hair

For quite sometime in the academic community, there was a 50/50/50 "rule of thumb" stating that at age 50 years, 50% of the population has at least 50% grey hair (KEOGH; WALSH, 1965). This rule was revisited by (PANHARD; LOZANO; LOUSSOUARN, 2012) who found that the actual global rate of 50% graying at 50 years old is between $6 - 23\%$. The greying of hair is significantly more prevalent in men then in women. For men, it starts at the temporal regions of the scalp and then spreads to the vertex/crown, whereas in women the rate of greying of the temporal and vertex regions are similar. They also mention that the person's place of origin and ethnicity highly impacts the rate of hair aging, delayed on people of African and Asian roots and faster for people of European roots.

Figure 3.1: Unclear regions of the scalp

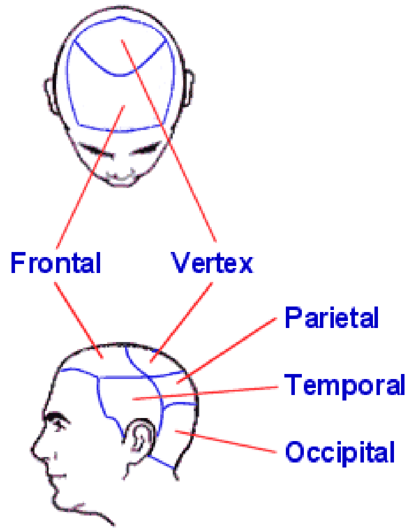
(a) Reference 1 (b) Reference 2 (c) Reference 3



Source 1: <https://www.researchgate.net/figure/Anatomic-regions-of-the-scalp_fig2_51522615> | Source 2: <http://www.ilht.com/scalp-regions/> | Source 3: <http://hairfax.ca/hairloss-info/regionsofscalp/>

Geographically, gray hair first appears in men on the temporal area (60.6% observed), while in women it seems to appear first in the frontal area (38.6% observed),

Figure 3.2: Scalp regions used in this work.



Source: <http://www.holyoak.co/scalp-regions-diagram.html>

according to (JO et al., 2012). Also, the first appearances of gray hair happens at an average age of 40 years old. The naming and localization of these regions vary slightly according to different authors, as shown on Figure 3.1, therefore we used the definitions shown in Figure 3.2 as the reference to determine those regions.

(TOBIN, 2008) goes in depth about the hair biology, with a section on hair aging, including that after 30 years there is a 10-20% reduction in pigment production every decade, at least in caucasians.

3.2 Computer Graphics and Hair

The rendering of hair has seen great advances over the last years. From the pioneering work of Anjyo and colleagues (ANJYO; USAMI; KURIHARA, 1992) to more recent approaches (REN et al., 2010; OU et al., 2012; CHIANG et al., 2016) hair rendering has reached increased levels of visual faithfulness. In Figure 3.3 we compare results from (ANJYO; USAMI; KURIHARA, 1992) and from (CHIANG et al., 2016). The more recent result has more depth, subtle shadows and self-shadowing. These increased levels of realism are partly due to increasing understanding and modeling of more complex hair structure and its interaction with light.

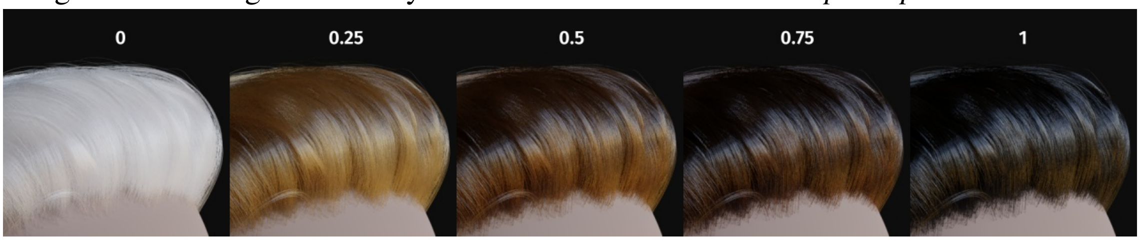
The model presented in (CHIANG et al., 2016) is now offered in the recent version of Blender (v2.79). It is called *principledHair shader* and one of its parameters is

Figure 3.3: Results comparing the evolution of the state-of-the-art.

Source Left: (ANJYO; USAMI; KURIHARA, 1992) | Source Right:(CHIANG et al., 2016)

the melanin concentration of the hair. The shader defines the hair color as the quantity (melanin) and ratio (melanin redness) of the pigments commonly found in hair and fur: *eumelanin* (prevalent in brown-black hair), shown on Figure 3.4, and *pheomelanin* (red hair), shown on Figure 3.5.

Figure 3.4: Changes caused by different melanin levels on the *principledHair shader*



Source: <https://docs.blender.org/manual/en/latest/render/cycles/nodes/types/shaders/hair_principled.html>

The more melanin, the darker the hair. The amount of melanin is modeled as:

$$melanin\_qty = -ln(max(1.0 - Melanin, 0.0001))$$

and $Melanin$ varies from 0 to 1. *Melanin redness* is modeled as the ratio of pheomelanin to eumelanin, also between $[0, 1]$:

$$eumelanin = (Melanin)(1.0 - MelaninRedness)$$

$$pheomelanin = (Melanin)(MelaninRedness)$$

The resulting quantities are converted (after randomization which slightly changes the

Figure 3.5: Changes caused by different melanin redness levels on the *principledHair shader*

Source: <https://docs.blender.org/manual/en/latest/render/cycles/nodes/types/shaders/hair_principled.html>

melanin levels of random follicles, if applied) to absorption concentration via the following formula:

$$\sigma_a = (eumelanin)\begin{bmatrix}0.506\\0.841\\1.653\end{bmatrix} + (pheomelanin)\begin{bmatrix}0.343\\0.733\\1.924\end{bmatrix}$$

3.3 Hair Aging in Games and Movies

The indie game “The Watchmaker” (Micropsia Games, 2018) is about a man who lost his memory but is able to control time to solve puzzles. During the game his age advances rapidly and for that purpose a system to dynamically change the character’s appearance was implemented. For every year the hair gets more desaturated, some of it is lost and his skin gets paler and wrinklier. This is only possible because the game art style uses polygonal hair, meaning it is made out of solid blocks that can be moved, as illustrated on Figure 3.6. If the character ever reaches 90 years old, it is game over. A mechanism to revert the the character’s age is also available in the game.

In “Fable” (Big Blue Box, 2004), the player begins as a child and gets older as the plot progresses and the player gains levels. There are no dynamic changes to the player’s appearance, but his height, hair saturation, and beard length change slightly whenever he gains a level. The game community has pointed out a few flaws with this system, one being that if you grind too much and become too high level for part of the story, some events may be contradictory for the character’s age. For example, there is a section where you talk to your 20 year old wife, but the player could be 60 years old by that point,

Figure 3.6: The Watchmaker Aging System

(a) 30 years (b) 45 years (c) 61 years (d) 81 years

Source: <https://youtu.be/EXxq1LxH4ns>

effectively breaking the immersion.

Figure 3.7: Fable Aging System

Source: <http://travieupclose.blogspot.com/2010/10/fable-3-preview.html>

The problem with having a real time aging system is that the player may not be able to finish the game by the time the simulation reaches its peak. To avoid this a sufficiently long time frame must be provided so that the player has enough time to complete all goals. Perhaps capping how far the simulation can go for each chapter or section of the game would provide a more controlled environment.

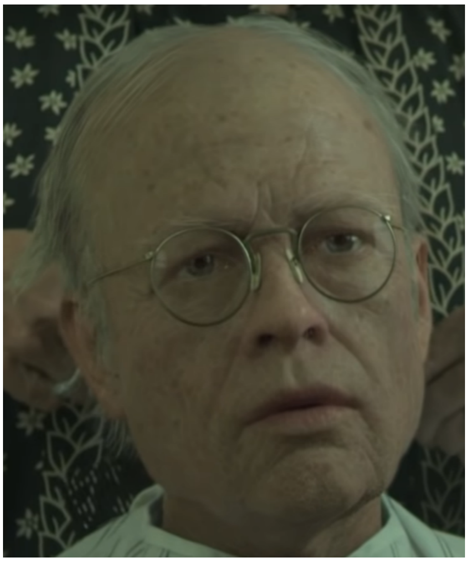
Movies make this kind of effect harder to track due to camera tricks and transitions. A notable exception is the movie “The Curious Case of Benjamin Button” (FINCHER, 2008), shown in Figure 3.8. In this movie the main character is constantly getting younger as the plot progresses. The technique used for this movie allows that in every sequence where the character is at a different age, a new hair model or skin texture is used, meaning they lack a dynamically changeable system to control the current age of the CG character.

As we can see, aging is certainly an interesting subject to tackle and art studios try simpler approaches that solve their needs, even though a dynamic simulation would be a more flexible and robust solution.

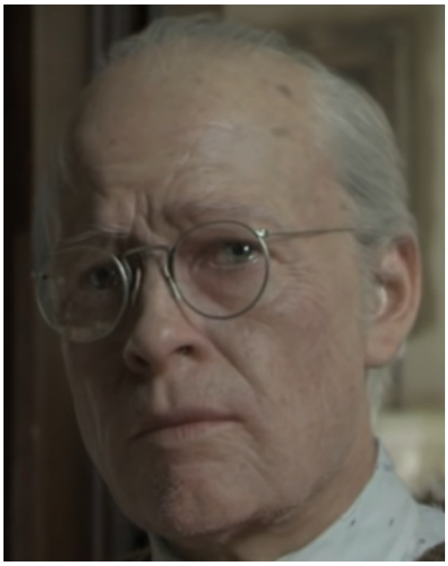
Figure 3.8: Benjamin Button CG setup

(a) 3D Model

(b) Final Render



(c) Final Render 2



Source: <https://youtu.be/Y9twsVqWRR8>

4 METHODOLOGY

In this chapter we present the development of our hair aging simulation system. We explain the whole process and show examples on specific steps and provide conceptual explanation along with the steps taken using Blender.

To begin, we need a hair particle system attached to a scalp model. We defined the following settings for our experiments, shown in Table 4.1: the **thickness** of the root is set to 1, so it is easier to visualize the effect, and we get a better range difference in thickness from the root to the tip; the **scalp size** is about 2 by 2 by 2 meters, this setting is more arbitrary, but the particles do get influenced by it since their size is independent, meaning a bigger head would require larger particles (thickness and length); the **thickness scaling** is 0.01 so the hair follicles are thin enough to look like real hair, but thick enough to allow us to see their color changing; finally, the **inital melanin** value, used to describe the original hair color, in our case a dark brown. For best results the hair style should be kept short, but it could be curly or straight.

Table 4.1: Parameters table

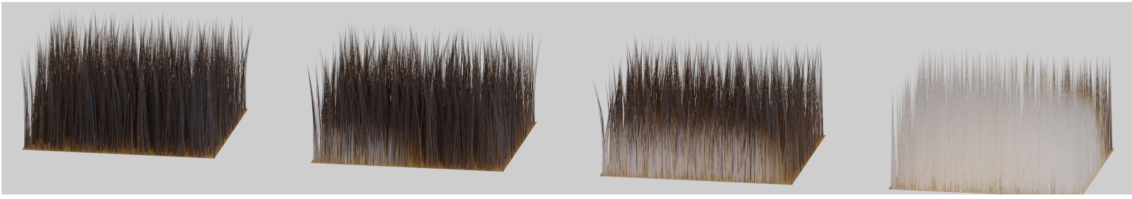
	Value
Root Thickness	1
Scalp Size	x=1.7m ; y=1.9m ; z=1.9m
Thickness Scaling	0.01
Inital Melanin Value	0.9

To transition from young to old hair, a mask was created for each hair particle based on its thickness. This way the removal of melanin starts at the particle's base and slowly advances towards its tip. The thickness information can be used because the base of a hair strand is thicker than its tip, even if by an insignificant amount. Figure 4.1 exemplifies the effect. Unfortunately, the same mask cannot be used on every hair strand since biologically the effect happens in some strands and not in others. Therefore two different kinds of greying effects based on thickness were created, one that starts early and another that starts later.

To randomly select hair strands to be affected, a modified noise texture with just pure white and pure black dots was used, shown in Figure 4.2 mapped to the scalp.

If a white dot is at the same position of a particle, that particle will be affected by the early effect; if a black dot is in the same position, then the particle will be affected by the late effect. The node setup in Blender for this control is shown in Figure 2.3.

Figure 4.1: Prototype for the individual melanin transition on the hair strands.



Source: created by the author

Figure 4.2: Modified noise texture for hair follicle selection.

(a) Frame 115 (b) Frame 170 (c) Frame 185

Source: created by the author

The noise is manipulated over time to increase the number of white dots present, thus a few late follicles will become white faster, and better represent the character's hair aging. Figure 4.3 shows the mask changing through the animation, stoping at frame 200 where around 50% of the particles are being affected by the early aging effect while the other half is affected by the late aging effect.

The next steps define the advancement of the greying effect globally on the scalp. First, we have to mask the temporal regions, so we can make it age first. We achieve this effect by using a local "object coordinates" system, exemplified in Figure 4.4. To every vertex we assign a color based on its position related to the origin of the object. All vertices with a positive x are painted red, positive y are painted green and positive z are painted blue. All the other vertices are assigned colors according to their relative position to the main axes. This way, based on the region's color, it is possible to separate regions of the mesh, not requiring a masking texture.

Since isolating a certain color channel from that system would leave a straight and evident seam (transition between black and white color), the approach taken instead was to use a gradient texture and rotate it such that the top of the hair is black, while the rest is white. This mask is shown in Figure 4.5, and note that the greying effect is only allowed

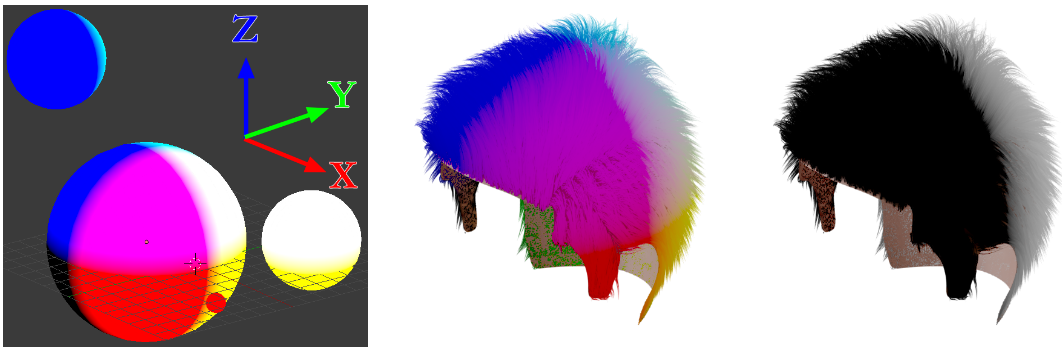
Figure 4.3: Random follicle selection using Figure 4.2 as a mask to define thickness based aging.

(a) Frame 115 (b) Frame 170 (c) Frame 185

Source: created by the author

Figure 4.4: Object Coordinate system used to segment the mesh and separate regions of the scalp.

(a) Object Coordinates (b) Applied to the Hair (c) Isolating the Green color channel



Source: created by the author

to show through on the white region.

After that, a new mask of spherical shape must be defined to control the advance of the mask on the temporal regions, as if a wave is spreading the old age on the hair. Blender has a node that creates a gradient 3D sphere texture. The mask progression is shown in Figure 4.6 and the node setup in Blender can be seen in Figure 4.7. Note that the number highlighted in green is the position of the white colored pivot, which is decreased as the simulation advances to diminish the gradient between black and white of the masking texture by increasing the pixel values of the texture. In other words, it is effectively brightening the colors and limiting them to white, resulting in the effect shown in Figure 4.6, where the white "wave" is progressing through the hair.

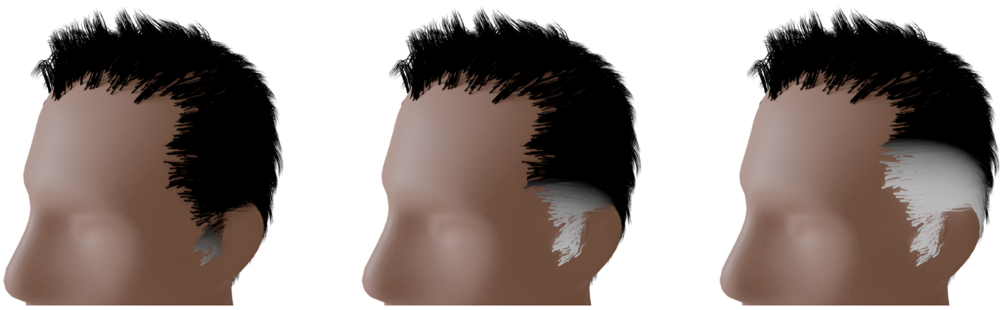
Having the gradual aging for each hair particle and the onset regions of the phenomena defined, it becomes a matter of adjusting speed and colors, by moving the key-

Figure 4.5: Mask to stop the temporal mask from spreading to the top

Source: created by the author

Figure 4.6: Temporal region mask to spread the greying effect

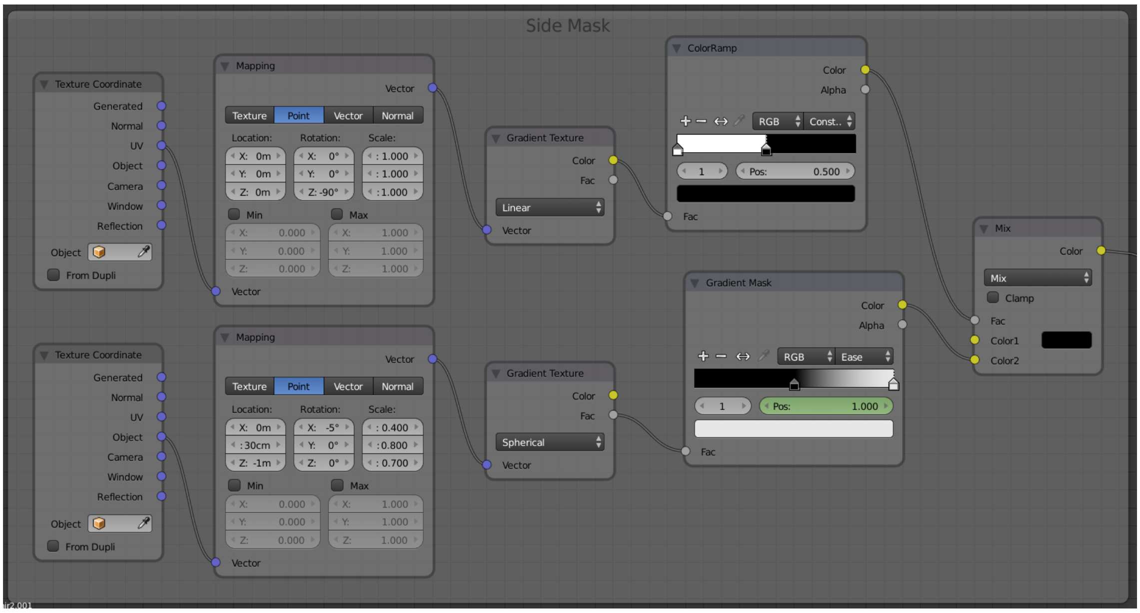
(a) Frame 0 (b) Frame 35 (c) Frame 90



Source: created by the author

frames around the timeline and adjusting their interpolation, to simulate the aging effect as seemingly realistic as possible, meaning that the temporal regions should become gray first, and the rate at which the hair loses pigmentation should be around 15% every 10 years, according to (TOBIN, 2008).

Figure 4.7: Node setup in Blender for side mask



Source: created by the author

5 RESULTS

In this chapter we showcase and validate the results of our simulation, making it clear that it is biologically plausible and can easily replicate a wide range of ages. However, validation is always a hard task in computer graphics, and for that we used a subjective assessment by providing visual side-by-side pictures of our results together with real people at approximately the same age, for increasing ages as shown in the sequence of figures, from 5.1 to 5.5.

Our visual results prove accurate in terms of predicting the pattern of aging and the overall coloration, however it does not match the pictures exactly, mostly due to the universal aspect of the simulation and the differences in background and lifestyle of the subjects, but the parameters may be adjusted to better match the examples.

It is important to note that having different hair styles does imply in slight differences on the simulation, making it likely that long hair styles would not work with the current setup, since the temporal region masks would not reach the tips of follicles in the region.

Figure 5.1: Young man with no signs of aging

(a) Frame 50 of the Simulation

(b) 31 year old man

Source left: created by the author | Source right: https://www.gettyimages.com/

Let us describe a few of the settings used and the specs of the computer we used to render the 1080p x 1080p images shown in Fig. 5.6. We used 8-bit color channels, and the built-in denoiser in Blender with radius of 4, strength of 0.2, and feature strength of 0.5. We used an Intel i5 processor with 10GB of RAM, a GTX 960 graphics card and Windows 10. With these settings and 64 samples, it takes about 1 min 30s for the

Figure 5.2: Middle aged man with slight signs of greying on the temporal regions

(a) Frame 100 of the Simulation (b) 45 year old man

Source left: created by the author | Source right: https://www.gettyimages.com/

first frame of the simulation and 2 min and 30s for the last, note that it takes longer to render hair that lacks melanin because it has transmission data, meaning the follicles are somewhat transparent, taking longer for the ray tracing and denoiser to compute.

That render time would be impractical for games given their real-time rendering requirement, however it would not take more than a second to render any frame of this simulation with a game engine, but it was not possible to test it in that environment since Blender shaders cannot be imported and the built in real-time renderer "EEVEE" was not available during the development of this project. We have provided a gif animation showing the full simulation in action (Frames 0-400) with the results from Figure 5.6. It is available at “Daerik_Gamedev” Instagram (<https://www.instagram.com/p/BqqG_dhFdxZ/>)

Figure 5.3: Middle aged man with completely grey temporal areas, but just a few grey hairs in other regions

(a) Frame 170 of the Simulation (b) 51 year old man

Source left: created by the author | Source right: https://www.gettyimages.com/

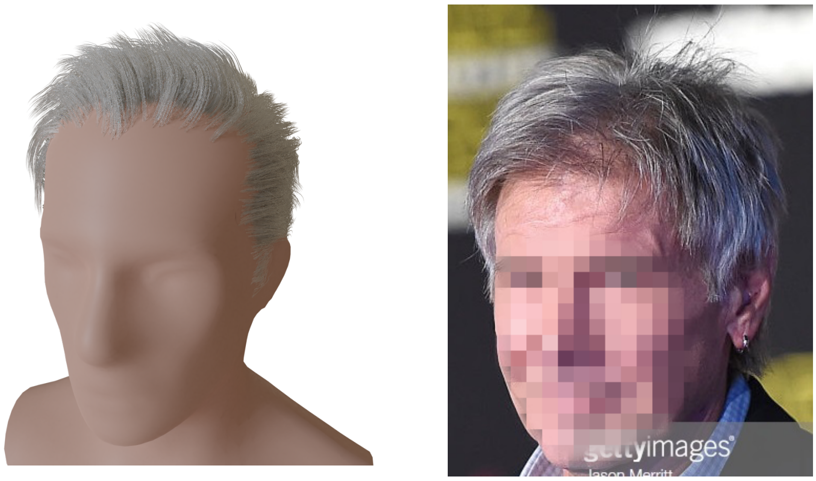
Figure 5.4: Middle aged man with several follicles lacking pigmentation

(a) Frame 205 of the Simulation (b) 64 year old man

Source left: created by the author | Source right: https://www.gettyimages.com/

Figure 5.5: Senior man, very few follicles with pigmentation remaining

(a) Frame 360 of the Simulation (b) 73 year old man



Source left: created by the author | Source right: https://www.gettyimages.com/

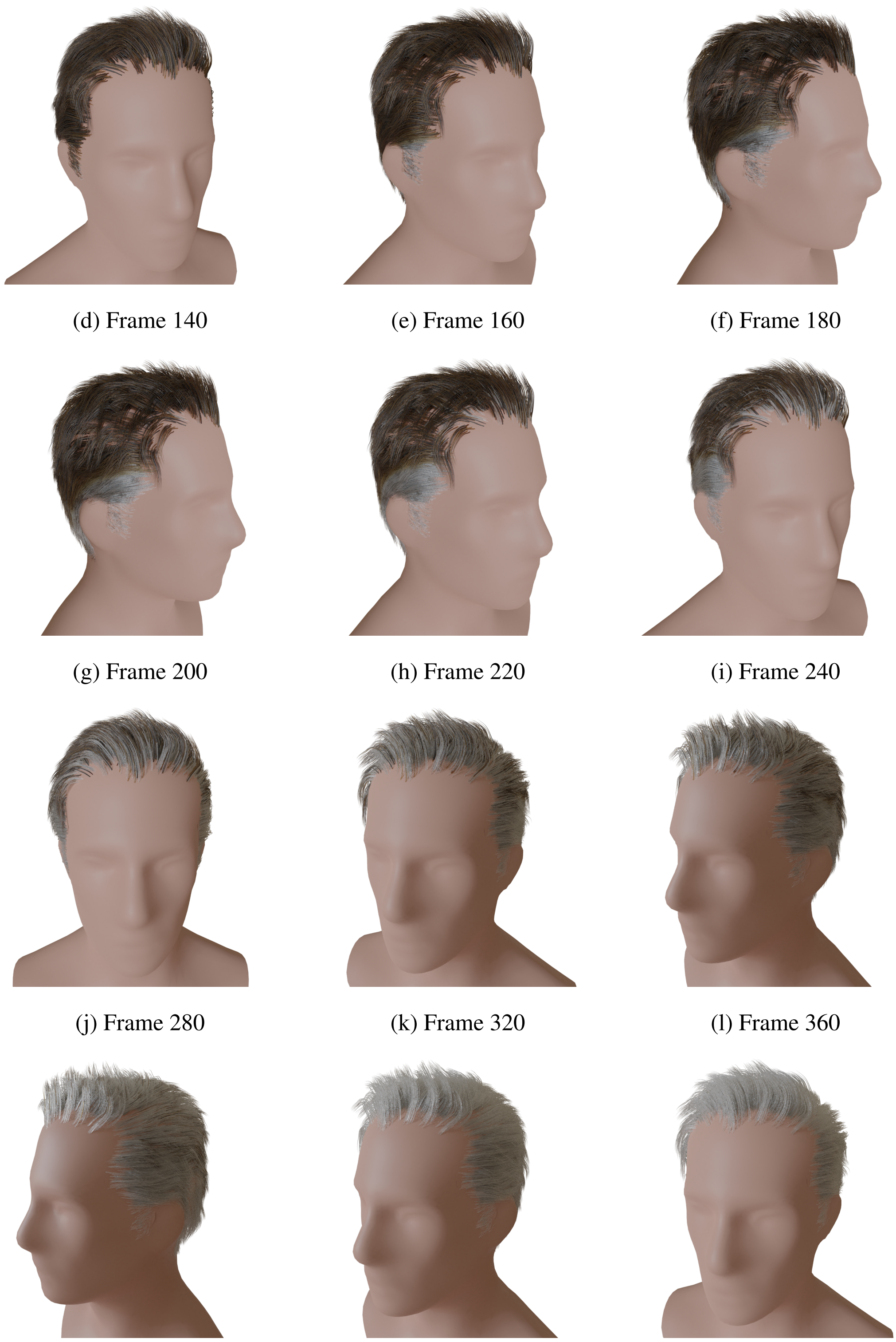
Figure 5.6: A few frames of the aging simulation to illustrate the age progression.

(a) Frame 40 (b) Frame 80 (c) Frame 120

(d) Frame 140 (e) Frame 160 (f) Frame 180

(g) Frame 200 (h) Frame 220 (i) Frame 240

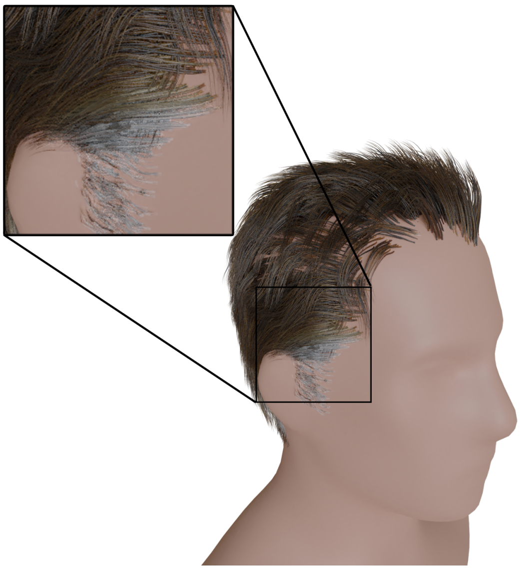
(j) Frame 280 (k) Frame 320 (l) Frame 360



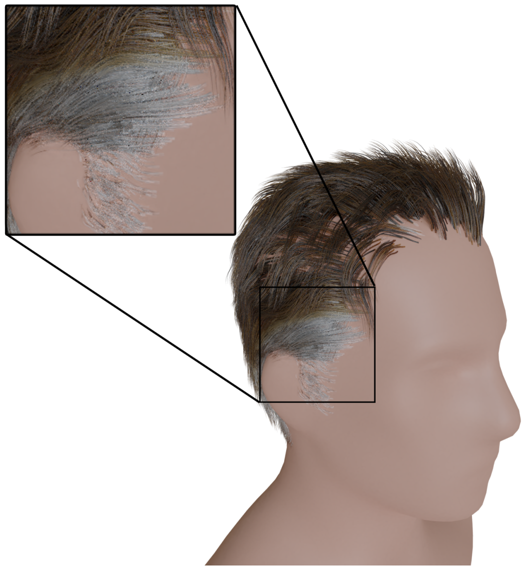
Source: created by the author

Figure 5.7: Zoom in on the effect at the early stages

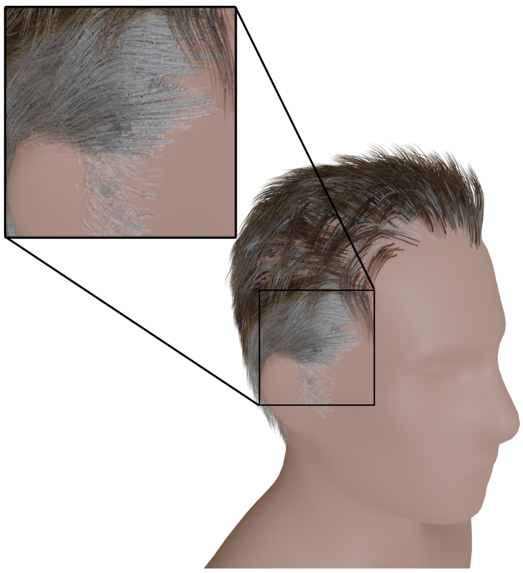
(a) Frame 100



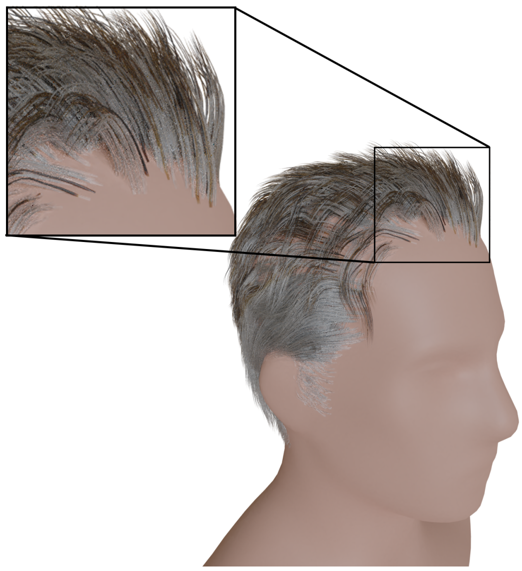
(b) Frame 140



(c) Frame 180



(d) Frame 220



Source: created by the author

6 CONCLUSIONS AND FUTURE WORK

In this work we presented a basic understanding of the hair aging phenomena and how movies and games studios try to replicate it. We then proceeded to explain a dynamic approach for simulating the greying effect in real-time by creating a procedural shader on top of a hair particle system.

The hair shader being procedural means it should work on any male model as long as the rules here defined are followed, such as having short hair modeled with particles. Our visual results show that many levels of greying are representable according to the character's age. Although we are not fully modeling the melanin transition, our visual results show visual quality for many graphical applications.

As expected, the use of Blender proved valuable. There were no complications figuring out how certain aspects of the simulation could be implemented thanks to author's experience and the community that extended their hand to help more than once. Blender also allowed our system to be simple, easy to control and fast. It could be used as is to create a short movie or animation, and using the knowledge obtained in development a new system could be adapted inside of a game engine to be used in video games.

We believe that we have provided an initial simple model that can be explored in future investigations. For instance, it would be interesting to provide a slow and gradual loss of pigmentation on the hair follicles, adapting the simulation based on the ethnicity of the character, implementing hair loss and hair thinning to further support the greying effect and expanding it to allow females models to be represented as well. The simulation could also be adapted to simulate other types of greying, like facial hair, for example.

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