Influence of Dynamic Wrinkles on the Perceived Realism of Real-Time Character Animation

Javier Alcon
Universidad Rey Juan Carlos
Modeling and Virtual Reality Group
c/ Tulipàn, s/n
28933, Mòstoles, Spain
Javier.Alcon@gmail.com

David Travieso
Universidad Autonoma de Madrid
Perception and Action Research Group
c/ Ivan Pavlov, 6
28049, Madrid, Spain
David.Travieso@uam.es

Caroline Larboulette
University of South Brittany
IRISA-UBS Lab
Campus de Tohannic
56000, Vannes, France
Caroline.Larboulette@gmail.com

ABSTRACT

When creating a real-time character animation (e.g. for video games), fine grain details such as cloth wrinkles are very often omitted due to the limitation of available resources. However, we believe that they are crucial to increase realism, hence user immersion. In this paper, we present a perceptual study of dynamic wrinkles on clothes to show that they indeed have an important impact on realism. The models, animations and textures we used are *game* realistic and the wrinkling algorithm is fast enough to be used in a game. We have found that parameters influencing the perception of dynamic wrinkles include movement type and speed, viewing angle, and texture colors. Our results should be useful for animators or game designers to help them add wrinkles only where they are necessary, and activate them only when they have an impact on realism.

Keywords

Perceptual Study, Wrinkles, Character Animation

1 INTRODUCTION

According to game industry professionals [Buc05a], the overall perception of a virtual character can be split into three main components: the rendering (*how it looks*), the animation (*how it moves*), and the artificial intelligence (*how it behaves*). For a consistent perception of a virtual environment, it is essential that these three aspects be in harmony.

In real-time animations however, secondary animations such as wrinkles of skin or cloth, soft tissues dynamics or muscles are generally omitted because their impact on realism is unsure for an increased cost in computation time and memory consumption. This yields to a large difference in quality between the rendering and the animation.

Low cost techniques such as [Lar04a, Lar05a, Dec06a, Ram09a] have been developed to add details to character animations but no study so far has shown their effectiveness. Alternatively, a number of physically based

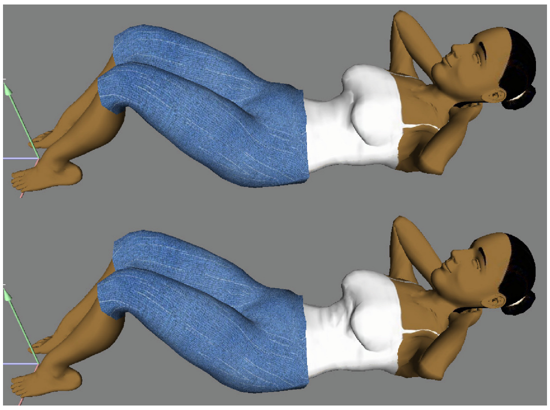

Figure 1: Two frames of two different videos included in our experiment: top- without dynamic wrinkles; bottom- with dynamic wrinkles in the abdominal region. Other parameters such as movement, viewing angle and textures are identical.

techniques exist that produce more accurate dynamic deformations [Jam02a, Cap02b], wrinkles [Wan10a] or muscles [Lee09a]. However, *physically correct* does not mean *perceived as realistic*, simply because humans have wrong believes and expectations that are often not physically correct [Bar96a]. The opposite is also true, because there are many different but similar motions that can be generated from roughly the same initial conditions with unknown variables (for example, an unknown wind gust changing the trajectory of a baseball), humans will perceive all of them as *visually plausible* although a physically based simulation would always produce the exact same movement. It is thus necessary to study the impact of secondary animations on realism by including human perception into the design of efficient algorithms.

In this paper, we propose a study of dynamic wrinkles on clothes of characters in a game environment. We first study the impact of dynamic wrinkles on realism for different movements and viewing angles (section 4). We then study the influence of texture colors on the perception of dynamic wrinkles and overall realism (section 5). This is done by showing the same videos with or without dynamic wrinkles in all the possible configurations to participants (see figure 1). We finally expose a summary of our findings before proposing future directions of study (section 6).

2 RELATED WORK

Perceptual Studies

Recently, researchers have started to investigate the role of perception to reduce rendering times where it was not necessary. To mention only a few, [Cat03a] showed the use of task maps in a task oriented environment to help select the areas of interest that should be rendered with more accuracy. [Sun04a] studied to what level viewers notice degradations in image quality when the quality of the rendered image decreases. It has been then discussed [Osu04a] how human perception could be taken into account to animate deformable objects and humans in virtual environments.

Early work [Oes00a] on the perceptual study of character animation in virtual environments showed that even if observers are often unaware of specific details, they will still perceive an animation with a different level of realism. We observed the same in our study as participants graded better the videos with dynamic wrinkles although most of them were not aware of what was different from one animation to another.

More directly related to our work, [Mcd07a] studied the minimal pose update rate necessary to achieve smooth perception of movement of characters in a virtual environment. They detect that cycle rate, linear velocity (which is how fast a character moves accross the screen) and movement complexity influence the perceived smoothness of a movement. In addition, the *contrast sensitivity function* defines a range of perception of black/white patterns that depends on the contrast and spacial frequency of the patterns. There is an optimal size of such patterns that makes their visual perception higher [Lue01a].

In our study, to avoid any uncontrolled effect due to the change of the contrast and spatial frequency, we kept both illumination and distance of the character to the viewer constant. In addition, the camera followed the character that remained in the center of the screen, so we had no linear velocity. However, we studied the effect of dynamic wrinkles on animations with different movement complexities.

[Mcd08a] showed that it is possible to generate a crowd composed of different characters using a single 3*D* model by changing the textures used for the clothes, hair and skin. While it is efficient as it reduces the ability of people to spot clones, we have been wondering how that would affect the realism and the perception of wrinkles in such an environment. We have thus studied how the perception of wrinkles is affected when the texture of clothes and the skin color of a character are changed.

In [Cou09a], the impact of facial expressive wrinkles is studied in relationship with emotions. We study the impact of wrinkles of clothes on realism.

Dynamic Wrinkles

In the past ten years, a few algorithms have been proposed to add wrinkles to a character animation. They range from physically based [Kan02a, Wan10a] to geometrically based [Lar04a, Dec06a] techniques. Other methods to generate wrinkles include bump-mapping techniques [Ban02a, Wu96a]. As we show, bump-mapping techniques fail to accurately represent wrinkles when viewed from the side as it corresponds to both, the angle where the wrinkles increase the most the realism, and the angle when the mesh appears flat.

Physically based techniques are more accurate but generally require more resources than geometrically based techniques, which makes them difficult to use in video games. While we keep the study of visually plausible versus physically accurate for a later study, we have decided to use the technique of [Lar04a] because the wrinkles generated are fast and simple, and in harmony with the type of animation and texture we have used.

3 FRAMEWORK

We have conducted 2 experiments for a total of 4 different analyses in order to study the influence of dynamic wrinkles on character animation in a video game environment (one character in real-time). To this end, we have used a simple real-time algorithm to add wrinkles [Lar04a] to an animation we have generated under Autodesk Maya [May13a]. The wrinkles are manually defined by a wrinkling curve that serves as the profile of the wrinkles. The wrinkles form perpendicularly to the profile and are attenuated towards the borders. During animation, the length of the wrinkling curve is kept constant by forming waves. The mesh vertices are then displaced according to this profile.

To be sure no bias was introduced due to contrast, the background color of each animation was automatically computed as a grey color, the brightness of which was computed as the average brightness of the textures. We also kept constant the scene lighting by using the default ambient OpenGL light that is non-directional.

In order to keep the spatial frequency of the wrinkles constant, we kept the distance of the character to the camera constant. In addition, we used a chin-rest as depicted in figure 2 so that the participants also remained at a constant distance to the screen, and this distance was the same for all participants.

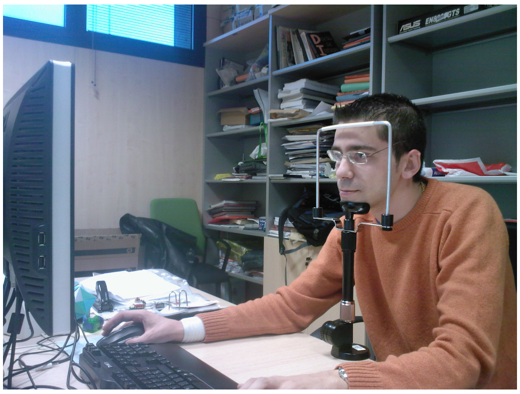

Figure 2: To fix the distance of the user to the screen, we used a chin-rest for all of our experiments.

Finally, we used the same hardware and software during each experiment and the conditions of luminosity in the room were fixed (closed curtains, constant illumination from the ceiling).

We have studied the perception of wrinkles according to the following parameters: type of movement, type of skinning, viewing angle and texture color (see figures 1, 3 and 8). The videos have been generated at 24 fps with a *MPEG-2 Blu-Ray* format to obtain high quality.

30 participants took part in each of the experiments, 20 males and 10 females in the first one, 14 males and 16 females in the second one, aged from 18 to 58. All of them had a normal vision. They came from various backgrounds and were more or less familiar with Computer Graphics and video games. They were not told what the experiment was about and received a chocolate bar for participating. Each experiment took about 5 to 10 minutes, depending on the participant.

In the *abdominals* animation, wrinkles were added on the character's belly (given that the rest of the character was static, no extra wrinkles were needed). In the *walk cycle* and *kick boxing* animations, the wrinkles were added on the pants, in the knee region, both in the front and in the back. The wrinkles parameters were the same for both animations.

The video sequence was randomly chosen for each participant to avoid any learning effect. Before starting the video sequence, participants were explained the task on screen and asked a few questions of sex, age and background. They were asked to grade each video from 1 to 7 from *not realistic* to *highly realistic*. The participant was responsible for starting each video when he or she was sure to be ready to watch it.

For the statistical analyses, we used a repeated measures ANalysis Of VAriance (ANOVA) with three intra-participants factors, which means that each participant who took the test saw all of the videos (see Annex for details).

4 MOVEMENT AND VIEWING ANGLE EXPERIMENT

In the first experiment, the hypotheses were the following:

- dynamic wrinkles enhance the perception of realism of an animation even if those wrinkles are barely visible;
- this enhancement depends on the type of movement (fast movements versus slow movements);
- the perception of wrinkles depends on the viewing angle.

4.1 Experimental Setup

The variables of the experiment were:

- the type of movement:
  - *abdominals*, slow movement;
  - *walk cycle*, medium speed movement;
  - *kick boxing*, fast movement.
- the type of skinning (see figure 1):
  - without dynamic wrinkles;
  - with dynamic wrinkles.
- the position of the camera in relation to the character (see figure 3):
  - front (twice 0 degree);
  - diagonal (45 and -45 degrees);
  - side (90 and -90 degrees).

Thirty participants took part in the experiment, 20 males and 10 females. The experiment trials were run on a standard Dell PC under Windows Vista with an LCD monitor (see figure 2). Input from the user was recorded on the same computer, the videos were graded after each viewing.

We have shown 36 videos in total: 3 movements $*$ 2 types of skinning $*$ 6 different viewing angles. All of the videos lasted 5 seconds.

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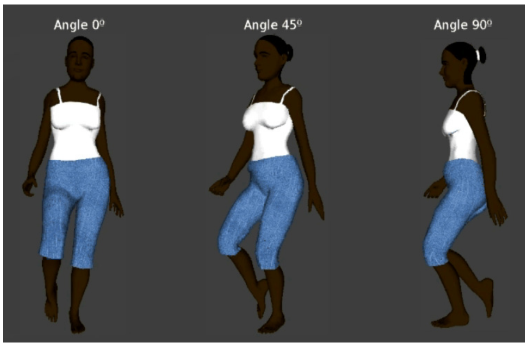

Figure 3: Three frames of three different videos included in our experiment with a viewing angle varying from 0 to 90 degrees.

4.2 Movement Analysis

A repeated measures ANOVA was performed on the perceived realism ratings, the within-subjects factors being the type of movement, the type of skinning and the position of the camera. There were three main effects: in the type of movement ($F_{(2,118)} = 7.17$, $p < 0.001$), in the type of skinning ($F_{(1,59)} = 5.617$, $p < 0.05$) and in the viewing angle ($F_{(2,118)} = 1.97$, $p < 0.01$). In addition, there was an interaction effect between the type of movement and the type of skinning ($F_{(2,118)} = 4.16$, $p < 0.018$). No more significant effects were found.

Main Effects

The main effect in the type of movement means that the type of movement influences the perception of realism, the *abdominals* animation being perceived as the most realistic one, followed by the *walk cycle* and the *kick boxing* animation. This can be seen on figure 4.

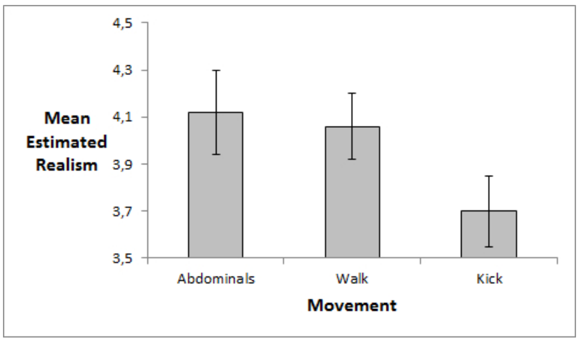

Figure 4: Mean estimated realism and SEM as a function of the type of movement (x-axis). Error bars show the standard error of the mean.

The main effect in the type of skinning shows that animations with dynamic wrinkles are much more realistic than animations without those wrinkles. This can be seen on figure 5.

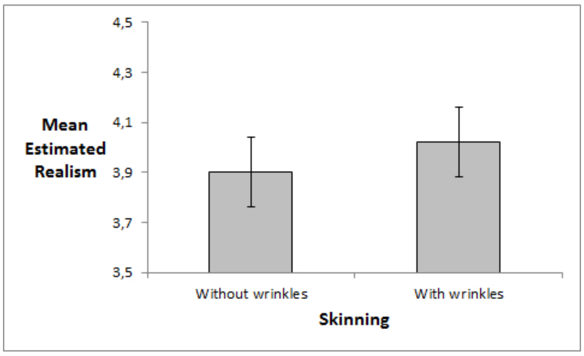

Figure 5: Mean estimated realism and SEM as a function of the type of skinning (x-axis). Error bars show the standard error of the mean.

Interactions

In addition, we detected an interaction between the type of movement and the type of skinning. The *abdominals* animation with dynamic wrinkles was perceived as the most realistic one, followed by the *walk cycle* with dynamic wrinkles, the *walk cycle* without the dynamic wrinkles, the *abdominals* without the dynamic wrinkles and the *kick boxing* animations, with and without wrinkles, with very little difference between both (see figure 6).

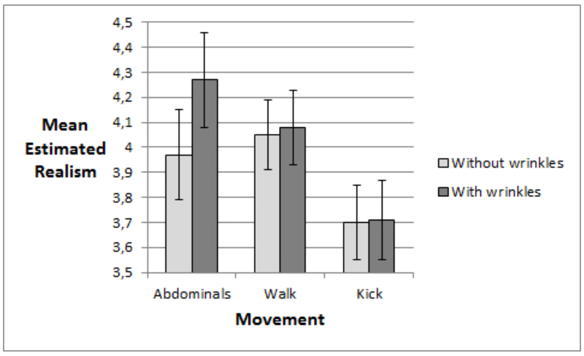

Figure 6: Mean estimated realism and SEM as a function of the type of movement (x-axis) and the type of skinning. Error bars show the standard error of the mean.

The results concerning the *abdominals* animation show that on a very simple and slow animation, the dynamic wrinkles are much more important for realism, as the difference between both bars is the biggest. Dynamic wrinkles are less important on fast movements as we can see for the *kick boxing* animation, probably because it is more difficult to perceive the wrinkles.

Moreover, the bars for the animations with dynamic wrinkles are always higher than the ones for the animations without wrinkles, which means that whatever the animation, dynamic wrinkles always increase realism, although this is better appreciated for slow movements.

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Another interesting observation is that most people who took the test were not able to tell afterwards what we had tested. This means that the realism is increased, but people cannot tell why or what is different.

4.3 Viewpoint Analysis

The position of the character with respect to the camera had an effect on the perceived realism. As we can see on figure 7, when the character was seen from the side, it was perceived as more realistic than when seen from the front.

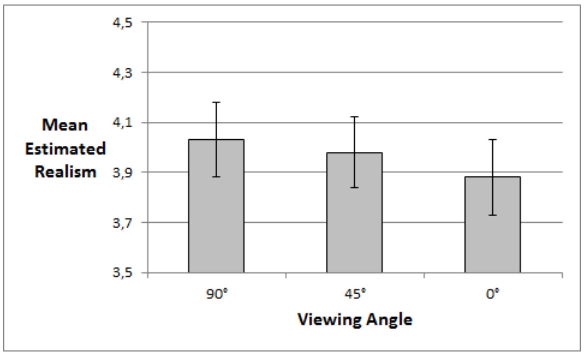

Figure 7: Mean estimated realism and SEM as a function of the viewing angle (x-axis). Error bars show the standard error of the mean.

More surprisingly however, we did not find any interaction between the viewing angle and the presence/absence of wrinkles. As the viewing angle is not constant in the *kick boxing* animation due to the fact that the character rotates, we first eliminated the corresponding video samples from the test to make a second analysis. We found an interaction between the movement type and the skinning type ($F_{(1,59)} = 5.514$, $p < 0.05$) as in our first analysis but still no interaction between the skinning type and the viewing angle.

We then also removed the *walk cycle* animation samples for two reasons. Firstly, there are wrinkles in the front and in the back of the pants, meaning that when the angle is of 45 degrees with the wrinkles in the front, it is 135 degrees with the ones in the back. Secondly, the wrinkles being on a non-uniform texture might create additional uncontrolled effects.

We thus did an analysis on the *abdominals* video samples only but we did not detect any effect ($F_{(2,118)} = 0.37$, $p = 0.0691$). As we will see in the second experiment, this was probably due to the fact that because we removed many samples, the analysis was done on only 12 ratings which is too little to obtain significant results.

5 CONTRAST EXPERIMENT

In the second experiment, we wanted to study the effect of texture colors on the perception of realism. As the *abdominals* animation was the one where dynamic wrinkles had the highest effect on realism and the only one where the angle between the wrinkles and the viewing angle was meaningful, we used this animation for the experiment.

Our hypothesis was that wrinkles on the white top would be more visible than wrinkles on the black top, simply because the contrast would be higher. We verified this hypothesis and also discovered that the overall contrast with the skin of the character also influences the perception of realism of the animation.

As we were studying contrast, to avoid any effect due to the background color, its color was set to grey, the brightness of which was computed as the average brightness of the textures (see figure 8).

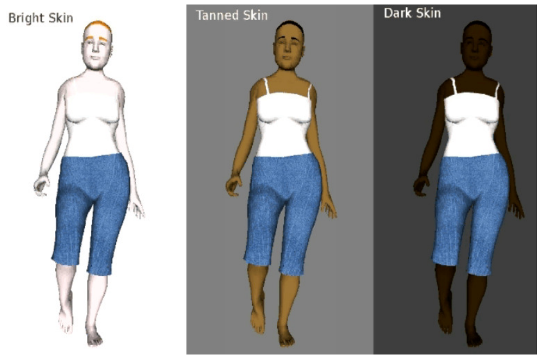

Figure 8: The same character with three different skin colors. The background color is a grey, the brightness of which is computed as the average brightness of the textures.

5.1 Experimental Setup

The variables of the experiment were:

- the type of texture:
  - bright skin, white top;
  - bright skin, black top;
  - tanned skin, white top;
  - tanned skin, black top;
  - dark skin, white top;
  - dark skin, black top.
- the type of skinning:
  - without dynamic wrinkles;
  - with dynamic wrinkles.
- the position of the camera in relation to the character:
  - front (twice 0 degree);
  - diagonal (45 and −45 degrees);

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– side (90 and −90 degrees).

Thirty participants took part in the experiment, 14 males and 16 females. The experiment trials were run on a DELL XPS 1530 laptop PC, using the same conditions of room illumination and distance to the screen for all participants. Input from the user was recorded on the same computer, the videos were graded after each viewing.

In this experiment, we have shown a total of 72 videos: 6 different textures ∗ 2 types of skinning ∗ 6 different angles. All of the videos had a duration of 5 seconds.

5.2 Texture and Angle Analysis

Main Effects

A repeated measures ANOVA was performed on the perceived realism ratings, the within-subjects factors being the type of skinning, the texture and the position of the camera. There were main effects in the type of skinning ($F_{(1,59)} = 18.43$, $p < 0.001$), the viewing angle ($F_{(2,118)} = 21.88$, $p < 0.001$) and the texture ($F_{(5,295)} = 11.02$, $p < 0.001$). This analysis confirms the results of the first experiment regarding the influence of the presence of dynamic wrinkles and the viewing angle. It also shows that the texture influences the perception of realism as characters with white tops are rated more realistic than the ones with black tops (see figure 9).

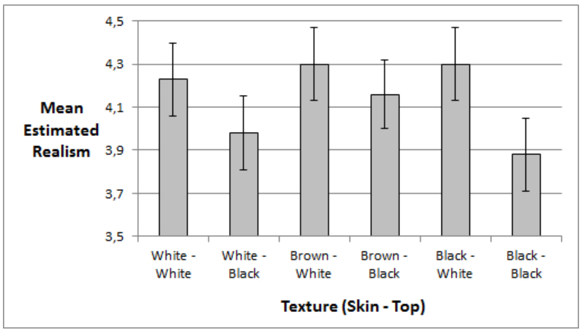

Figure 9: Mean estimated realism and SEM as a function of the texture (x-axis). Error bars show the standard error of the mean.

Interactions

We observed an interaction effect between the texture and the type of skinning ($F_{(5,295)} = 12.105$, $p < 0.001$) indicating that on the white top, the presence or absence of dynamic wrinkles makes a huge difference while on the black top, there is no significant difference (see figure 10).

We detected an interaction effect between the texture and the viewing angle ($F_{(10,590)} = 2.381$, $p < 0.01$).

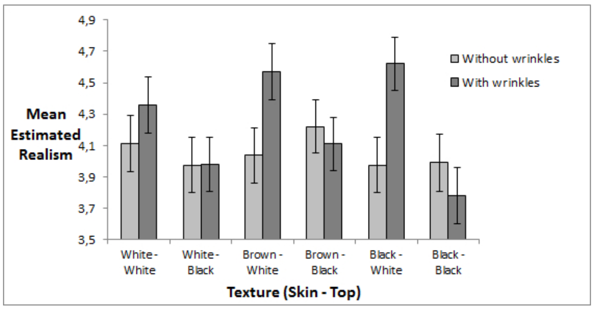

Figure 10: Mean estimated realism and SEM as a function of texture (x-axis) and skinning type. Error bars show the standard error of the mean.

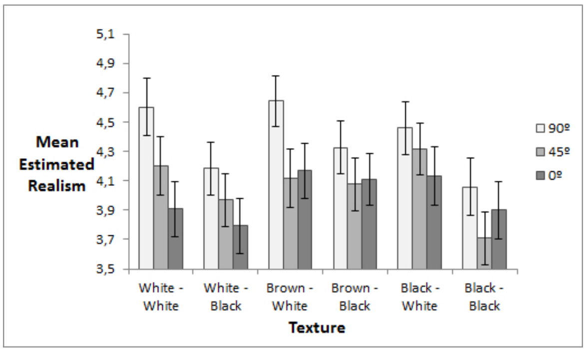

Figure 11: Mean estimated realism and SEM as a function of texture (x-axis) and viewing angle. Error bars show the standard error of the mean.

The effect is stronger for brighter tops and decreases for darker ones (see figure 11).

Finally, we also found an interaction effect between the type of skinning and the viewing angle ($F_{(2,118)} = 6.174$, $p < 0.005$). When the angle between the camera and the wrinkles profile is of 90 degrees (side view), the difference in perception of realism between the presence or absence of dynamic wrinkles is the highest, followed by an angle of 45 degrees and 0 degrees (front view). In the last case, there is almost no difference whether there are dynamic wrinkles or not. The same result was observed in our second analysis (see figure 16).

Those results confirm our hypothesis. Wrinkles increase realism more onto white tops. On the black tops, there is much less contrast possible, so the wrinkles cannot be properly perceived which makes the animations less realistic. In addition, when wrinkles are present, the realism increases when the viewing angle increases.

5.3 Skin Color Analysis

We have done a second analysis on the same data by removing the black tops and keeping only the white tops for the three different skin colors, the presence or absence of wrinkles and the six angles. This corresponds

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to 36 videos in total: 3 different textures $*$ 2 types of skinning $*$ 6 different angles.

The aim of this analysis was to detect if the texture influences the perception of realism even if the wrinkles are not on the varying texture. That is why we kept the white tops only (i.e. when the wrinkles are more visible), but we used 3 different colors of skin. Our initial hypothesis would be that it would not influence the perception of realism.

Main Effects

As we predicted, the texture itself did not influence the realism of the animation which means that in the previous analysis, the difference in perceived realism was due to the top color, not to the skin color. We found main effects in the type of skinning ($F_{(1,59)} = 36.079$, $p < 0.001$, figure 12) and in the viewing angle ($F_{(2,118)} = 17.859$,$p < 0.001$, figure 13).

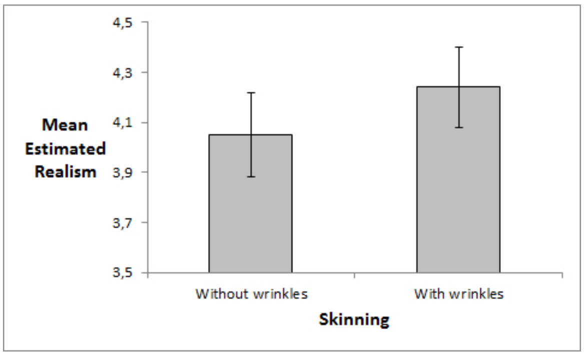

Figure 12: Mean estimated realism and SEM as a function of the type of skinning (x-axis). Error bars show the standard error of the mean.

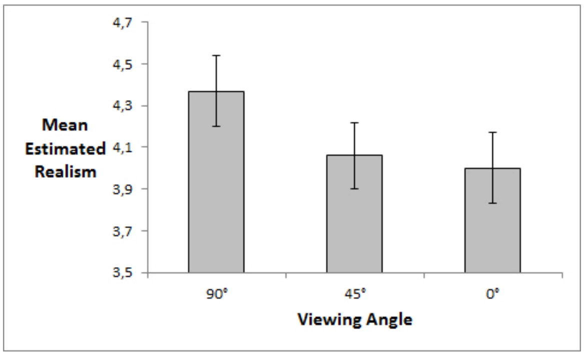

Figure 13: Mean estimated realism and SEM as a function of the viewing angle (x-axis). Error bars show the standard error of the mean.

Interactions

We found an interaction effect between the skin color and the type of skinning ($F_{(2,118)} = 5.547$, $p < 0.01$). The darker the skin, the higher the contrast with the white top, the better perception of the presence of wrinkles. We can thus conclude that when dynamic wrinkles are present and when the contrast between the skin and the cloth increases, the animation is perceived as more realistic (see figure 14).

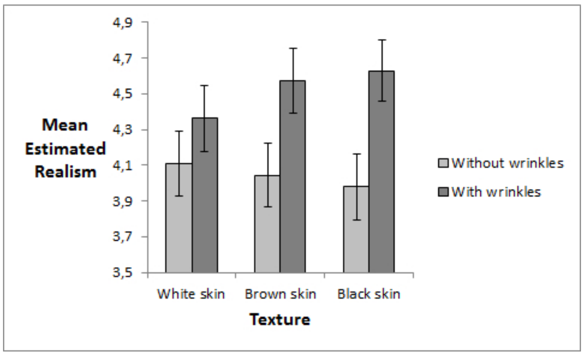

Figure 14: Mean estimated realism and SEM as a function of skin color (x-axis) and skinning type. Error bars show the standard error of the mean.

There was also an interaction effect between the skin color and the viewing angle as in our first analysis ($F_{(4,236)} = 2.442$, $p < 0.05$, figure 15).

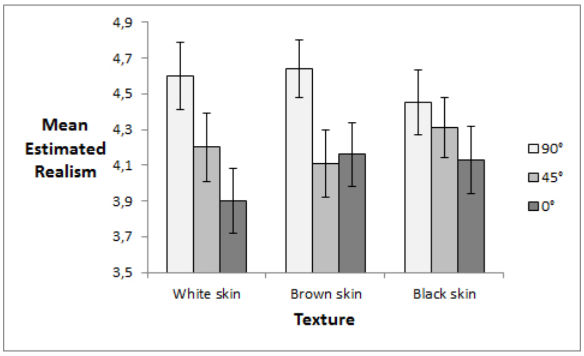

Figure 15: Mean estimated realism and SEM as a function of skin color (x-axis) and viewing angle. Error bars show the standard error of the mean.

Finally, we also found an interaction effect between the type of skinning and the viewing angle ($F_{(2,118)} = 16.17$, $p < 0.001$), which confirms that the second analysis of our first experiment done with only a few samples of the *abdominals* animation was invalid due to the small amount of data analyzed.

On figure 16, we can clearly see that when there is no dynamic wrinkles, the perception of realism is low and similar for all angles whereas when dynamic wrinkles are present, the realism increases when the viewing angle increases towards 90 degrees.

However, it would be interesting to create another experiment with different slow movements of a non-rotating character to reinforce our result.

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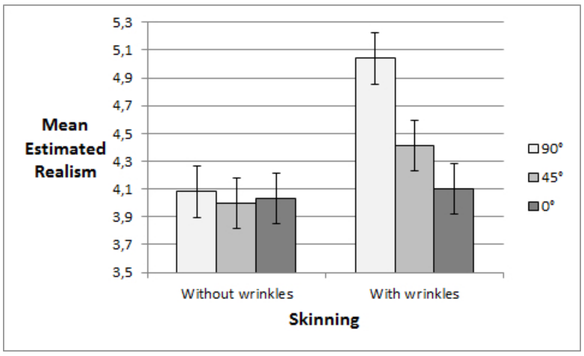

Figure 16: Mean estimated realism and SEM as a function of skinning type (*x*-axis) and viewing angle. Error bars show the standard error of the mean.

6 CONCLUSION AND FUTURE WORK

We have presented a perceptual analysis of the influence of dynamic wrinkles on the realism of a real-time character animation. We have shown that the presence of wrinkles always increases the realism of an animation, even if this gain is much lower for fast movements. As a fast movement usually necessitates more keyframes, a further study could be to determine what the minimal number of keyframes per second is so that dynamic wrinkles cannot be perceived anymore.

In addition, we have found that the viewing angle also influences the perception of realism, especially when wrinkles are viewed from the side. This means that bump mapping techniques [Wu96a, Ban02a] actually fail in simulating dynamic wrinkles because they are only accurate in the front view, i.e. when they are not needed, especially on dark surfaces. Wrinkles increase the realism a lot when seen from the side, something a bump mapping technique cannot achieve as the silhouette then appears flat.

As we initially hypothesized, dynamic wrinkles do not increase the realism as much on dark surfaces as it does on bright surfaces. From the front view, they were almost not detected. This is due to the contrast that is much lower (close to zero). As contrast is the only hint a viewer has in the front view, it is thus useless to create wrinkles on a black surface when only the default OpenGL ambient light is used for rendering.

A further study with more efficient lighting models would be needed to refine that result. More surprisingly, we have found that the overall contrast of the surface with wrinkles and the surrounding surfaces (skin color) also influences the perception of realism, the more contrast, the more realistic the animation.

One more useful parameter we did not include in this study is the distance parameter. It is obvious that from a certain distance, wrinkles won't be perceivable anymore. We would like to perform an additional experiment to determine a threshold (ratio wrinkle size / distance) from which is it not necessary to include dynamic wrinkles as those won't be perceived anyhow.

Finally, we would like to study the effect of wrinkles generated with different algorithms. In this study, we have used video game technology for the character with a simple real-time technique to create the wrinkles. We would like to study, on the same character, the influence of dynamic wrinkles on realism, whether the algorithm is simplistic or more physically correct like in more recent work such as [Wan10a].

7 ACKNOWLEDGMENTS

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ANNEX

ANOVA stands for ANalysis Of VAriance. The analysis is done using a dependent variable (the level of realism from 1 to 7 in our experiments) and a number of independent variables such as movement type, skinning type, viewing angle and texture in our experiments. When an experiment is done using 3 independent variables, it will be referred as a *three factor ANOVA*.

To display the results, we used the following standard notation: F is the statistical value and p the significance level of the results. F is computed as

$$F(x,y) = \frac{\text{Effect} + \text{Error}}{\text{Error}}$$

with x, the degrees of freedom (number of scores in the sample that are independent and free to vary) between treatments and y the degrees of freedom of the error. Hence, if $F = 1$, there is no effect detected. The higher the value of F, the more important the effect.

In addition, for the results to be reliable, it is necessary to compute how much of the value of F is due to an actual effect compared to the experimental error. This is obtained by computing p, the probability that F is observed due to experimental error. For the results to be significant, p needs to be lower than 0.05 which means that the results have 95% reliability. The lower the p, the more reliable the results.

For more information, the reader may consult [Gra08a].

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