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The Effect of Ambient Occlusion Shading on Perception of Sign Language Animations

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***Abstract*—**The goal of the study reported in the paper was to determine whether Ambient Occlusion Shading (AOS) has a significant effect on users' perception of American Sign Language (ASL) finger spelling animations. Seventy-one (71) subjects participated in the study; all subjects were fluent in ASL. The participants were asked to watch forty (40) sign language animation clips representing twenty (20) finger spelled words. Twenty (20) clips did not show ambient occlusion, whereas the other twenty (20) were rendered using ambient occlusion shading. After viewing each animation, subjects were asked to type the word being finger-spelled and rate its legibility. Findings show that the presence of AOS had a significant effect on the subjects' perception of the signed words. Subjects were able to recognize the animated words rendered with AOS with higher level of accuracy, and the legibility ratings of the animations showing AOS were consistently higher across subjects.

***Keywords*—**Sign Language, Animation, Ambient Occlusion Shading, Deaf Education

I. Introduction

DEAF education, especially in science, technology, engineering, and math (STEM), is a pressing national problem in the US. Deaf individuals are significantly underrepresented in STEM fields and historically have had difficulty entering higher education leading to STEM careers [1, 2]. In general, by age 18, deaf students do not have the linguistic competence of 10-year old hearing children in many English structures [3]. Fewer than 12% of deaf students at age 16 can read at a 4th grade reading level or higher [4]. An important underlying cause of the educational lag is that deaf students have limited access to grade-level curriculum materials. Computer animation of American Sign Language (ASL) has the potential to improve learning outcomes by making educational content deaf accessible, thus providing deaf children with the same learning opportunities as hearing students. Computer animation provides a low-cost and effective means for adding signed translation to any type of digital content.Despite the substantial amount of ASL animation research, development and recent improvements, several limitations still preclude animation of ASL from becoming an effective, general solution to deaf accessibility to digital media. One of the main problems is low rendering quality of the signed animations, which results in limited legibility of the animated signs and low appeal of the virtual signers. The rendering algorithms used so far in ASL animation utilize very simple illumination models which assume that scene surfaces receive light only through direct exposure to light sources. These models ignore the light that reaches a surface indirectly, through intermediate reflections off other objects; the result is images that lack detail and do not convey shape clearly. Ambient occlusion is a shading method that adds realism to local reflection models by taking into account attenuation of light due to occlusion. It approximates the way light radiates in real life, especially off what are normally considered non-reflective surfaces. Unlike local methods, ambient occlusion is a global method, meaning the illumination at each point is a function of other geometry in the scene. Although not physically accurate, AOS adds realism to 3D scenes and can improve perception of complex 3D shapes. So far, AOS has not been implemented in ASL animation.The objective of the study reported in the paper was to answer the research question of whether the implementation of Ambient Occlusion Shading in ASL fingerspelling animations can improve the legibility of the animation significantly. The paper is organized as follows. In section 2 (Background) we discuss computer animation of sign language, we define Ambient Occlusion, and we explain the importance of ASL fingerspelling. In section 3 (Study Design) we describe the user study and in section 4 (Findings) we report and discuss the results. Conclusive remarks and future work are included in section 5 (Conclusion and Future Work).

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II. Background

A. Computer Animation of Sign Language

Compared to video, animation technology has two fundamental advantages. The first one is scalability. Animated signs are powerful building blocks that can be concatenated seamlessly using automatically computed transitions to create new ASL discourse. By comparison, concatenating ASL video clips suffers from visual discontinuity. The second advantage is flexibility. Animation parameters can be adjusted to optimize ASL eloquence. For example, the speed of signing can be adjusted to the ASL proficiency of the user, which is of great importance for children who are learning ASL. The signing character can be easily changed by selecting a different avatar. Hence the possibility of creating characters of different age and ethnicity, as well as cartoon characters appealing to young children

Several groups have been focusing on research, development and application of computer animation technology for enhancing deaf accessibility to educational content, including ViSiCAST [5], Vcom3D [6], the Technical

Education Research Center (TERC) [7], and Purdue University [8].

The ViSiCAST project [5], later continued as eSIGN project [8], aims to provide deaf citizens with improved access to services, facilities, and education through animated British Sign Language. The project is developing a method for automatic translation from natural-language to sign-language. The signs are rendered with the help of a signing avatar. A website is made accessible to a deaf user by enhancing the website's textual content with an animated signed translation encoded as a series of commands.

Vcom3D commercializes software for creating and adding computer animated ASL translation to media [9]. The SigningAvatar® software system uses animated 3-D characters to communicate in sign language with facial expressions. It has a database of 3,500 English words/concepts and 24 facial configurations, and it can fingerspell words that are not in the database.

TERC collaborated with Vcom3D and the National Technical Institute for the Deaf (NTID) on the use of SigningAvatar® software to annotate the web activities and resources for two Kids Network units. Recently, TERC has developed a Signing Science Dictionary (SSD) [10, 11]. Both the Kids Network units and the science dictionary benefit deaf children confirming again the value of animated ASL.

The Purdue University Animated Sign Language Research Group, in collaboration with the Indiana School for the Deaf (ISD), is focusing on research, development, and evaluation of 3-D animation-based interactive tools for improving math and science education for the Deaf. The group developed Mathsigner™, a collection of animated math activities for deaf children in grades K-4, and SMILE™,an educational math and science immersive game featuring signing avatars [12, 13].

Despite the substantial amount of ASL animation research, development and recent improvements, several limitations still preclude animation of ASL from becoming an effective, general solution to deaf accessibility to digital media. One of the main problems is low rendering quality of the signed animations, which results in limited legibility of the animated signs and low appeal of the virtual signer.

B. Ambient Occlusion Shading

The visual quality of the ASL visualization depends in part on the underlying rendering algorithm that takes digital representations of surface geometry, color, lights, and motions as input and computes the frames of the animation. The rendering algorithms used so far in ASL animation are crude primarily because they use simplistic local illumination models. Such models assume that scene surfaces receive light only through direct exposure to light sources and hence they ignore the light that reaches a surface indirectly, through one or several intermediate reflections off other scene surfaces. Images rendered under the local illumination assumption lack detail and do not convey shape well. The amount of indirect illumination is an important cue in shape perception: depressions, creases, and closed regions are darker, while convex exposed regions are brighter, which accentuates the three-dimensional appearance of the scene imaged. In ASL hands and faces are dynamic communication canvases whose expressivity relies on global illumination models that quantify the fractional exposure of each surface patch to the environment (i.e. Ambient Occlusion).AO is “the attenuation of ambient light due to the occlusion of nearby geometry” [14]. It approximates the shadows objects cast on other objects in a 3D environment based on their shape, size, and location relative to one another, and hence provides clarity in terms of shape and definition, especially in complex shapes [15]. Although AO is less computationally expensive than other global illumination algorithms such as radiosity and ray-tracing-based methods, it still produces a realistic (though not physically accurate) effect, and requires shorter rendering times [16].Many commercial 3D animation packages like Maya, 3D Studio Max, SoftImage, Blender offer ambient occlusion shading, however AO has not been implemented in ASL animation yet.

C. ASL Finger spelling

Learning finger spelling (dactylology) is a prerequisite to learning to sign in ASL. Finger spelling is essential for four reasons. It is used in combination with sign language for (1) names of people, (2) names of places, (3) words for which there are no signs and (4) as a substitute when the word has not yet been learned. It is generally learned at the beginning of any course in sign language also because the hand shapes formed in finger spelling provide the basic hand shapes for most signs [17].In spite of its importance and its apparent simplicity, high proficiency in finger spelling is not easy to acquire, mainly for the reasons outlined. Finger spelling is done by a person's dominant hand, and being able to sign and recognize four characters per second dictates fluency. Achieving fingerspelling proficiency requires the visual comprehension of the manual representation of letters. One reason students experience difficulty in fingerspelling recognition is its high rate of symbol presentation. Most signs in ASL use no more than two hand symbols [18], but fingerspelling uses as many symbols as there are letters in a word.

III. STUDY DESIGN

The objective of the study was to determine whether Ambient Occlusion Shading allowed the subjects to better recognize the word being signed to them. The independent variable for the experiment was the presence of AOS in ASL animations. The dependent variable was the ability of the participants to understand the signs, as well as their perception of the legibility of the finger-spelled words. The null hypothesis of the experiment was that the presence of AOS in ASL animations has no effect on the subjects' ability to understand the animations presented to them and on the perception of their legibility.

A. Subjects

Seventy-one (71) subjects age 19-64, fifty-five (55) Deaf, eight (8) Hard-of-Hearing, and nineteen (19) Hearing, participated in the study; all subjects were fluent in ASL. None of the subjects had color blindness, blindness, or other visual impairments.

B.Stimuli

Animations: Forty animation clips were used in this test. The animations had a resolution of 640x480 pixels and were output to Quick Time format with Sorensen 3 compression and a frame rate of 30fps. Twenty animation clips were rendered with AOS, and twenty animation clips were not. Both sets of animations (with and without AOS) represented the same 20 finger-spelled words. Camera angles and lighting conditions were kept identical for all animations. The animations were created and rendered in Maya 2011 and the ambient occlusion pass was calculated in Maya using the mental ray plug-in. The final rendering was obtained by compositing the diffuse pass with the occlusion pass in Adobe AfterEffects software. Figure 1 shows a screenshot of one of the animations in Maya; figure 2 shows the diffuse and occlusion passes and the final composited image.

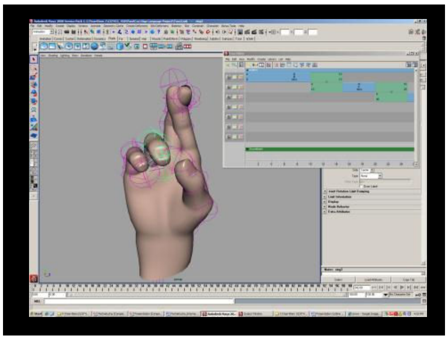

Fig. 1 Screenshot of one of the animations in Maya software

The twenty words shown in the animations included: “cracker,” “heavy,” “can,” “drain,” “fruit,” “milk,” “Kyle,” “child,” “movie,” “awesome,” “axe,” “bear,” “voyage,” “kiosk,” “wild,” “adult,” “year,” “duck,” “love,” and “color.” The words were selected by a signer with experience in ASL. The choice was motivated by two factors: (1) the words include almost all the letters of the manual alphabet (20/26); (2) the majority of these words present challenging transitions between hand-shapes. Since finger-spelling does not rely on facial expressions or body movements, the animations showed only the right hand.

Fig. 2 From left: diffuse pass; occlusion pass, final composited image

Web survey: The web survey consisted of 1 screen per animated clip (represented in figure 3), with a total of 40 screens (2x20). The animated sequences were presented in random order and each animation was assigned a random number. Data collection was embedded in the survey; in other words, a program running in the background recorded all subjects responses and stored them in an excel spreadsheet. The web survey also included a demographics questionnaire with questions on subjects’ age, gender, hearing status and experience in ASL.

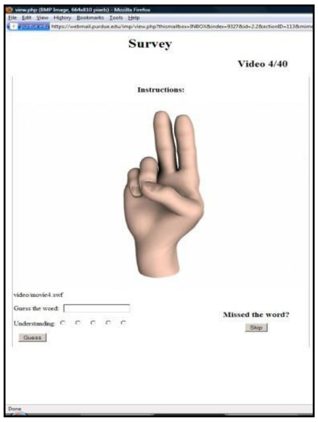

Fig. 3 A screenshot of the web survey

C. Procedure

Subjects were sent an email containing a brief summary of the research and its objectives, an invitation to participate in the study, and the http address of the web survey. Participants completed the on-line survey using their own computers and the survey remained active for 2 weeks. It was structured in the following way: the animation clips were presented in randomized order and for each clip, subjects were asked to (1) view the animation; (2) enter the word in the text box, if recognized, or leave the text box blank, if not recognized; (3) rate the legibility of the animation using a 5-point Likert scale. At the end of the survey, participants were asked to fill out the demographics questionnaire.

IV. FINDINGS

For the analysis of the subjects’ legibility ratings a paired sample T test was used. With twenty pairs of words for each subject, there were a total of 1,420 rating pairs. The mean of the ratings for animations without AOS was 2.19, and the mean of the ratings for animations with AOS was 2.13. Using the statistical software SPSS, a probability value of .048 was calculated. At an alpha level of .05, the null hypothesis that the presence of AOS had no effect on the user’s perceived clarity of the animation was therefore rejected.

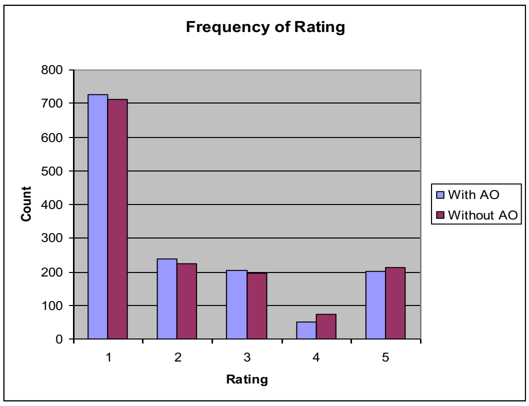

Fig. 4 A graph showing the breakdown of the subjects’ ratings of the animations. Lower ratings, which indicate higher legibility, were more frequent with AOS, whereas higher ratings were more common for animations without AOS

For the analysis of the ability of the subjects to recognize the words, the McNemar test, a variation of the chi-square analysis, was used (table 1). Using SPSS once again, a probability value of .002 was calculated. At an alpha level of .05, a relationship between the presence or absence of AOS and the subject's ability to identify the word being signed was determined. Figure 5 shows the ability to recognize the words with AOS and w/o AOS based on subject's hearing status. Word recognition was higher with AOS across all subjects; deaf and hard-of-hearing subjects were able to recognize the words with higher level of accuaracy with and without AOS.

TABLE I
CHI-SQUARE ANALYSIS OF WORD RECOGNITION; A '0' IS AN INCORRECT GUESS AND A '1' IS A CORRECT ONE.

*AOcorrect * NOcorrect Crosstabulation*

		NOcorrect		
		0	1	Total
AOcorrect	0	207	72	279
	1	115	1026	1141
	Total	322	1098	1420

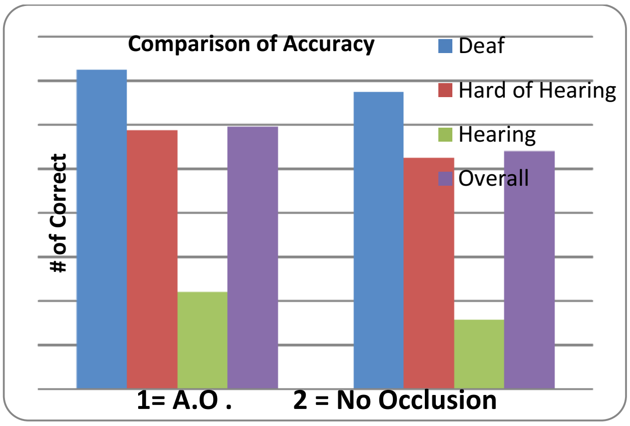

Fig. 5 The bar chart showing a breakdown of the subjects' ability to recognize the word based on their hearing status

Two extraneous variables that were not considered during the design phase were revealed by the feedback provided by the subjects at the end of the survey: (1) variation in subjects' computer screen resolution and (2) variation in subjects' internet connection speed. (1) Some subjects had a low screen resolution which forced them to scroll down to see each animation. This might have caused the subjects to miss a part of the word being signed. (2) Since the survey was posted online, connection speed was also a problem. Several subjects mentioned that the animations were choppy and jumpy at times and caused them to miss some letters. In both cases, since the results from the survey were being compared within the subjects, that is, one subject's responses in one category were being compared to his/her responses in the other category, those extraneous variables did not have a substantial impact on the results. There was no experimenter effect in this study since the survey was online and the subjects never met the experimenters face-to-face [19].

V. Discussion and Future Work

In this paper we have reported a user study that aimed to determine whether the presence of Ambient Occlusion Shading has an effect on subjects' perception of ASL fingerspelling animations. Findings from the study confirmed our hypothesis: the presence of AOS improves subjects' recognition of the finger-spelled words and perceived legibility of the animated signs. Although the study produced significant results, it was limited to ASL finger spelling and the animations showed only the 3D model of the right hand. In future work we will extend the study to full-body avatars and complex 2-handed signs that involve body movements and facial expressions.

As mentioned in the introduction, the authors believe that sign language animation has the potential to improve deaf accessibility to digital content significantly. The overall goal of this study, and other previous studies [20, 21], is to advance the state-of-the-art in sign language animation by improving its visual quality, and hence its clarity, realism and appeal.

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