Using Lightweight Formats in Computer Graphics Education

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ABSTRACT – *Lightweight file formats are an effective means of sharing and storing 3D data. Currently several different format options are available that increase the availability of the 3D database in various applications. This paper examines the background and current industry applications of these lightweight file formats. Three applications in educational/training settings are provided and reviewed in detail. In all of the cases, the Adobe 3D PDF lightweight file format was used to provide interactive 3D graphics. Survey instruments were used to capture participants' perceptions and opinions on the effectiveness of the lightweight formats as a display and communication tool in two of the cases. The third research case involved the use of 3D lightweight graphics in an airplane maintenance operation using a comparison of task completion time using traditional and 3D PDF format methods. Results of all three studies are reported. Advantages and disadvantages of the lightweight formats are considered, as well as potential applications in both industrial and educational settings.*

I. Introduction

The use of lightweight CAD/CAE file formats is becoming more prevalent in management of product information throughout the lifecycle, including embedding in websites for customer support, use in long-term data archival scenarios, and within the manufacturing supply chain (Butkovich, 2006). Such applications enable the power of the 3D CAD model as a conceptual and systematic design tool to be shared across dissimilar platforms and varied geographic locations. Multiple products currently exist for sharing data in lightweight form, including JT, 3DXML, U3D, X3D, Collada and others. The nature of lightweight 3D formats makes them suitable for use in many scenarios due to their compressed file size along with scaleable and relative geometric accuracy (Hartman & Lim, 2008).

II. Background

Data exchange typically falls into one of three categories: paper-to-CAD, part-to-CAD, or CAD-to-CAD (Hudspeth, 2006). The problems surrounding data exchange (e.g., accuracy, design intent, corporate standards) exist in these various scenarios primarily due to incompatibility between geometry kernels within current CAD systems and a lack of standard modeling methodologies when converting paper-based designs. The movement of digital data is of primary concern, since most organizations will only re-model paper-based design as necessary, and this is facilitated by more traditional technologies, such as IGES and STEP. However, contemporary technologies, such as JT, U3D/PRC and 3DXML exist to fill a void in the data sharing scenario.

Indeed, many companies have begun adopting the latter options for communication within and outside their organizations, in addition to use within typical engineering design tasks. With the proliferation of emerging visualization formats, confusion exists in industry with regard to the use of these formats relative to STEP and other standard data formats. As technology vendors advance the capability of "lightweight" file formats, selecting the appropriate file format for a specific purpose is critical to the communication and collaboration process (Hartman, 2009).

Companies are spending millions of dollars implementing PLM tools sets, reasoning that they will be able to communicate more effectively the design of their products (Amann, 2004; Daratech, 2004).. However, this thought is based on the assumption that the toolsets within the PLM environment will share data in such a way that product data communication is promoted. Unfortunately, data sharing in the PLM environment is often sabotaged by incompatibilities between software tools, and by the lack of functionality in emerging technologies within the CAD software suite, including neutral file formats. Studies have shown that companies spend billions of dollars dealing with communications issues resulting from data incompatibility (Brunnermeier & Martin, 1999; Gallagher et. al., 2004). In a recent survey by Kubotek USA (Kubotek, 2006), more than 2800 CAD managers and users were surveyed regarding the issues they face regarding CAD interoperability. They reported substantial issues with needing to re-model geometry, inaccurate data transfer, and loss of embedded intelligence and functionality in the resulting geometry.

III. Research Studies

The following section presents three research studies conducted at Purdue University by senior capstone students in Computer Graphics Technology. While limited in scope, they represent work conducted in alignment with the references cited above. In addition, Hartman (2009) conducted interviews with major aerospace, construction, and agricultural machinery companies, and found they use graphics-based work instructions for assembling and servicing their products, which use 3D lightweight formats for shop floor communications. The three studies presented here use technology on par with that used in the aforementioned industrial settings.

Knee Replacement Project

A recent project by Purdue University students in a capstone design course led to the development and testing of an interactive website that utilized a dynamic simulation of knee replacement hardware (Connolly, Batta, Morgan, Wack, & Wheeler, 2009). The goal was to provide an informative, simple to use, and understandable resource for individuals seeking information on joint replacement surgery. In order to show the physiology and complexity of the knee joint and joint replacement hardware, a complex CAD model was developed. For the model to be effective in the resultant simulation, 3D PDF lightweight formatting was used via Adobe Acrobat to capture the model geometry. The use of 3D PDF formatting allowed for viewer control of the 3D image on the website, including real time rotation, panning, zoom operations, default viewing angles, projection, lighting and shading, and cut-away representation (see Figure 1).

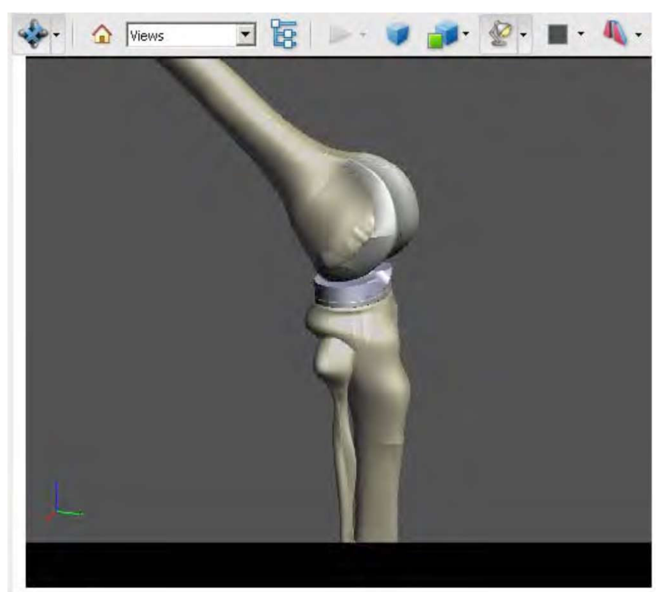

Figure 1. 3D PDF Knee Joint Simulation

A survey was utilized to gather user perception of the effectiveness of the 3D simulation and website. Participants in the research and survey were 100 individuals from 20 - 70+ years of age.

Bicycle Repair Project

A second research study involved the development and testing of an interactive manual for mechanics in the bicycle repair field. Many small bicycle businesses utilize an inordinate amount of resource attempting to retain knowledge of experienced personnel and training replacement personnel in basic bicycle repair tasks. While many options exist for such training, very few of these allow for user interaction with dynamic images in a real time environment. The study involved the creation of a bicycle headset assembly simulation utilizing CAD models and reverse engineering techniques. A PDF training manual was created, with 3D PDF animations imbedded (see Figure 2). Participants in the study were 15 employees from two bicycle shops. The age of the participants ranged from 18 – 59, and experience in bicycle repair ranged from minimal to very experienced. Survey data was gathered from this group to measure the perceived effectiveness and usefulness of the 3D PDF portion of the repair manual.

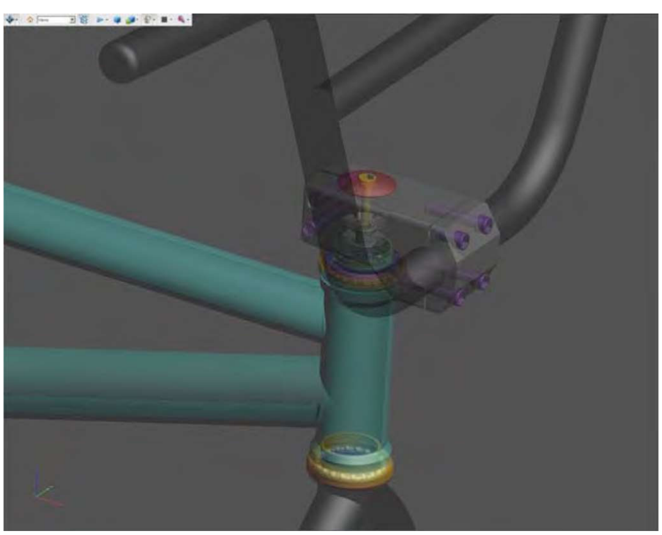

Figure 2. 3D PDF Bicycle Manual

Carburetor Assembly Project

Currently students and technicians in aviation education programs are using only static paper and electronic reference manuals. Because the manuals are static, the potential exists for inaccurate and incomplete information, which causes interpretation and safety issues with maintenance workers. There is a team of Purdue students from a variety of majors who are working on a project called “Hangar of the Future”, which is attempting to make aircraft hangars more technologically advanced. One part of their vision is for aircraft maintenance workers to be able to use mobile devices such as PDAs and cell phones to view 3D models that convey the same information as current manuals.

To support this research, it needs to be known whether or not using models is an easier and quicker way to perform maintenance operations. In order for this to be successful the models would need to be paired with the same information and directions as current manuals. One possible solution to address this concern is Adobe’s 3D PDF package. The study involved the use of static (control group, n=11) and 3D (experimental group, n=11) repair manuals for assembly and disassembly of an aircraft engine carburetor during routine maintenance. During the task, data was recorded and analyzed relative to time on task and mental workload. The basic premise was whether or not the 3D PDF version of the maintenance manual was *at least as good* at conveying information as the static paper manual. Safety and accuracy requirements imposed by the FAA were also in question during this project. No matter how novel the approach, if the digital version of the manual could not provide the same information as the paper manual, then its use in flight-certified operations would be unlikely. Figure 3 shows the traditional representation of the carburetor in the paper-based repair manual.

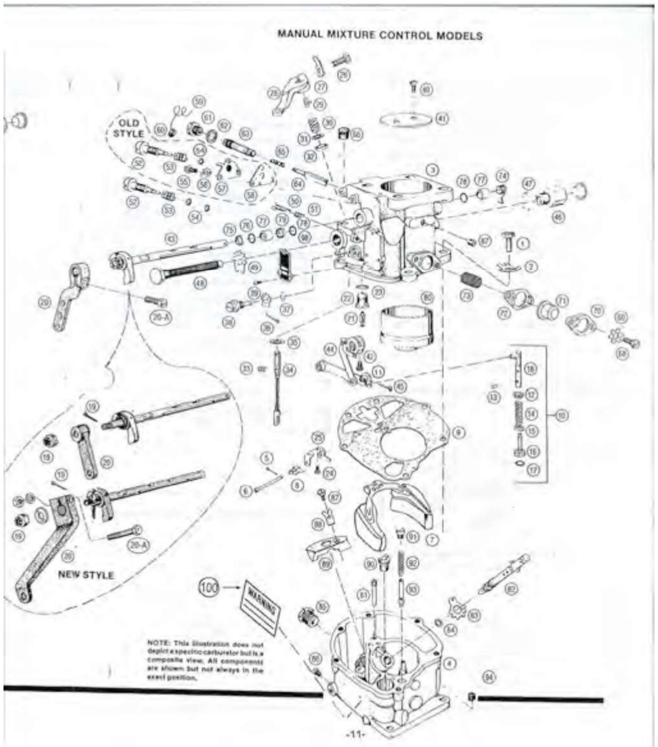

Figure 3: Traditional Exploded View of Carburetor

IV. Results

Knee Replacement Website

ANOVA results from the survey data showed that age was not a factor in the responses to the survey questionnaire, indicating that the informational website was an effective tool for all ages. Survey responses showed that 84% of the participants reported increased information from the site. 55% stated that the 3D PDF simulation was the most effective way of communicating the necessary information (see Figure 4), and 95% reported that they would recommend the site to others.

Bicycle Repair Manual

The results of the survey given to the participants in the bicycle repair manual project showed that there was a wide variety in preferences for information sources, ranging from computer/Internet-based to traditional paper-based and face-to-face communication. However, 47% of the participants reported that they experienced increased knowledge from

Figure 4. Knee Replacement Simulation Effectiveness

using the PDF manual. All of the participants stated that they would use the PDF solution in their work if given the opportunity, and that they would recommend the PDF solution to others. Additional feedback from the respondents indicated that they felt the PDF tool could be helpful in training those with language barriers. 55% of the participants reported that the animated 3D PDF model was the most effective method of instruction for the given task, and 54% stated that the 3D PDF simulation was the fastest method of instruction for the assigned task (see Figures 5-6).

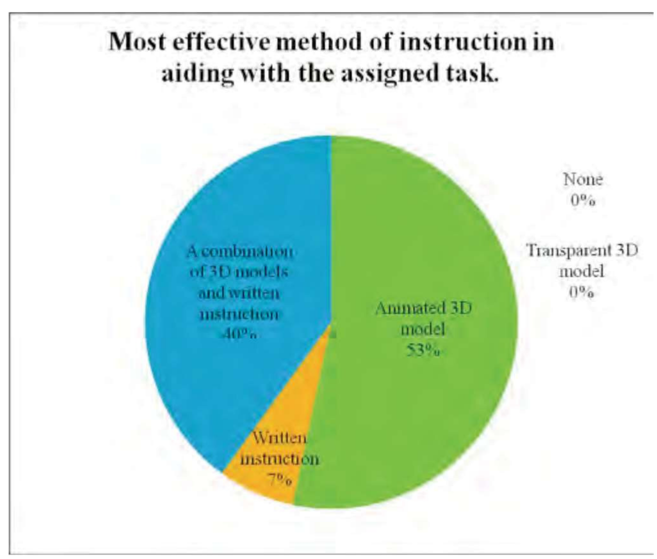

Figure 5. Bicycle Repair Simulation Effectivenes

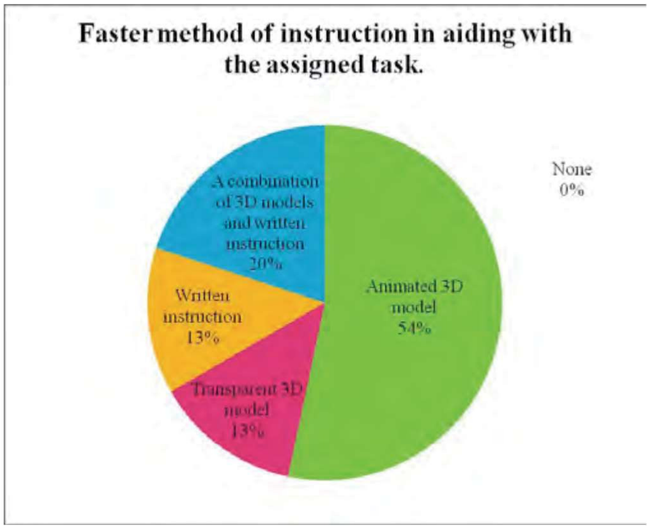

Figure 6. Bicycle Repair Simulation Speed of Instruction

Carburetor Repair Manual

Figure 7 shows the CAD model of the carburetor that was used for this test. Figure 8 shows that same CAD model imported into the 3D PDF environment. Notice the 3D DPF "wrapper" captures the product structure form the native CAD model. This was particularly useful to the participants as they performed the assembly work.

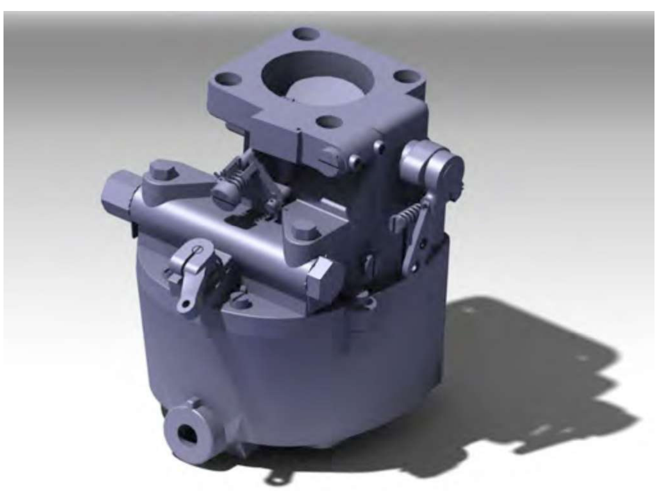

Figure 7: CAD Model of Carburetor

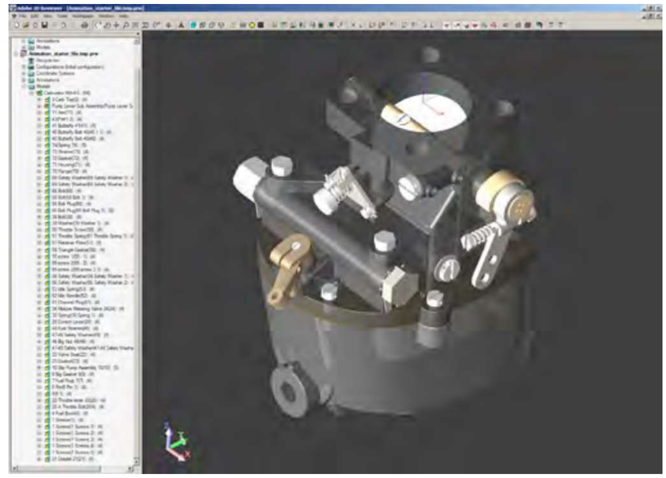

Figure 8: 3D PDF Representation of Carburetor Model

The results of the study (shown in figures 9 and 10) exhibit a tendency towards reduced time on task and reduced mental workload. While these studies are not conclusive or exhaustive as to the use of lightweight format in the performance of assembly and maintenance tasks, they do appear to point towards viability in that domain. Both time on task and mental workload appeared to be reduced at statistically significant levels.

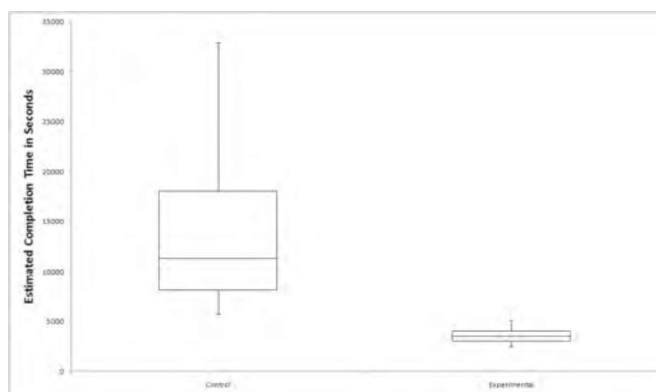

Figure 9: Time on Task Comparison of Carburetor Assembly

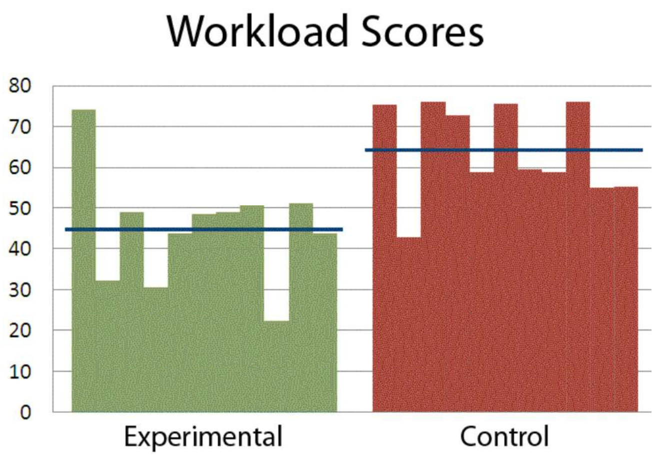

Figure 10: Mental Workload Comparison of Carburetor Assembly

V. Conclusions

The implications for this work are promising and potentially wide-reaching. The main focus of this paper was not to expose sophisticated research with this technology, although that is a plan going forward. It was to expose this technology as a potentially viable communications medium to be leveraged throughout the product lifecycle. However, if it is to be used effectively, it is important that accurate and usable geometric definitions of the product be created in the design stage of the product lifecycle. As such, the establishment and use of modeling standards is important. Standards that stress the creation of flexible models and the re-use of model geometry (versus re-creating one's own geometry) are key to this process. Consistent data in the communications channels is critical in order to support the supply chain and the service sector. The ability to leverage the 3D geometric database continues to become a reality with the use of lightweight formats. The level of resources put into the creation of the model is considerable, and the ability to use lightweight 3D models to communicate is an effective return on those investments. In addition, it allows organizations to free monetary resources from being tied up in CAD licenses. No longer does a person need a license of CAD software just to view or interrogate a CAD model. They can use one of a host of free or low-cost viewing tools exactly for this purpose.

Future studies point towards the devices that enable communication, such as mobile computing and web dissemination. HCI issues, mobile networks and device technology, accuracy and openness of standards are all areas that need to be examined if these data formats are to be accepted as an equal substitute to their "heavyweight" CAD-based counterparts. In addition, task analysis in specific contexts is also necessary. Similar to the study above in the aviation domain, other contexts may have operating procedures, safety requirements, communications protocols, or other ways of communicating that render these technologies difficult to use. Those issues must be addressed, as this technology represents an improvement to typical communications in the engineering and product design spaces.

VI. Credits

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