Integration of Blender 3D in Basic Computer Graphics Course

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Abstract: Computer graphics (CG) is an important component of computer science curriculum. Concepts like transformations are known to be difficult for the students to understand, since it involves visualization. Literature has shown that this understanding can be improved by computer based training. Most existing techniques cannot address 3D, require programming and are based on proprietary software. We developed a three-hour training module for CG concept using Blender, open source software. In this paper, we present experimental details of the effect of our training on using Blender to visualize transformations. We used think-aloud method and a survey to capture the behaviour and motivation of six masters students about using Blender. We analyzed the qualitative and quantitative results and found that students used Blender features to solve the CG problem.

1. Introduction

Computer graphics (CG) is an important course for most of the students of computer science domain. Concepts in CG are visual in nature and sometimes involve third dimension. Understanding basic CG concepts (like transformations) is important for working on advanced CG problems. However, many students who study this subject face the difficulty in understanding the basic CG concepts (He & Zhao, 2010). Major difficulty is in visualizing the concepts, such as three dimensional transformations.

Methodology for teaching CG concepts varies from teacher to teacher. Traditional strategies like drawings, verbal explanations and supportive hand gestures are commonly used for teaching these CG concepts. However, new age teachers have tried using videos and software tools for the same (Divjak, 2004).

If such content is created using proprietary software, its reach is limited. Use of open source software enables wider reach and nurtures collaboration between the users. (Kadam et al. 2012) has shown that a workshop on Blender (open source 3D animation and interactive content creation suite) is useful in improving the mental rotation (MR) ability of the students. Participants also showed a marked preference for Blender as a tool to facilitate MR ability.

In this paper, we take a step ahead, and study the usefulness of Blender workshop to augment teaching CG concepts of transformations. For this study we have following research questions:
1. How do students use Blender to visualize transformation concept in CG?
2. Does Blender motivate students to learn computer graphics concepts?

The treatment comprised of a four hour Blender workshop, and a problem solving test. The focus was to teach Transformations topic from basic CG course. We trained first year masters students to perform 2D as well as 3D transformations in Blender such as, translation, scaling and rotation along different axis and from different views. Various Blender features were used to perform these transformations were 3D viewport, Keyboard shortcuts, multiple views and transform properties. After training we administered a post-test, based on composition of 3D transformations problem, that student had to solve using Blender.

The objective of this study was to investigate the problem solving trends of students, rather than the correct/incorrect answer to the problem. In order to observe this, think aloud protocol (Ericsson & Simon, 1993) was used in this study, and data was gathered for six students. In this method, two observers studied the events of the actions performed by the students. The students were asked to constantly narrate their thoughts, while the events were being performed. The entire proceedings were

audio-video taped. Additionally, the computer screens of the students were captured to support the student narratives.

Qualitative method of think aloud protocol was chosen to bring out the details of the trends and the patterns of students' behavior. After the post test, a survey was administered to get students' perception / feedback on whether the treatment (Blender workshop) was found interesting by the students. Both forms of the data qualitative (think-aloud protocol & screen capture) and quantitative (survey) show reflections of Blender being found useful by the students to solve transformation problems. The results suggest features available in Blender are found engaging by the students based on the time spent of these features and also the occurrences to perform actions, compare visuals and recheck solutions. The results also endorse the methodology used to create Blender training module for courses in computer science domain which require visualization

2. Related Work

2.1 Challenges in teaching Computer Graphics course

Majority of the students opting to take the subject of Computer Graphics (CG) are primarily motivated by the digital imagery and special effects regularly seen in advertisements, movies and computer games. Some of students are familiar with various graphic softwares like Adobe Flash, 3D Max and Maya prior to the formal training of CG. These students are curious to know the science and art behind making such imagery. However, they are surprised to know that CG courses deal primarily with basic mathematical theories. It is also seen that students lose their interest owing to the difficulty in understanding the abstract algorithms, their derivations and optimizations. Faculty members have found it challenging to teach CG course/s in an active mode (He & Zhao, 2010). Teachers agree that sound skills of programming, basic math and geometry knowledge for matrix manipulations are necessary pre-requisites for CG courses. However, they also recommend understanding of algorithms for visualization in three dimensional worlds as another pre-requisite (John, 2000; Wolfe 1999, 2000). The first two skills can be verified, however, third is often assumed based on perception of objects in the physical world. This assumption may not be true, as we have observed that students face difficulty in formulating transformation matrices because they are not intuitive.

2.2 Range of solutions used

Apart from the traditional strategies of using *chalk and talk*, teachers have attempted including digital resources. Various platforms and programming tools like JAVA 3D, Opel GL and other tools have been used in CG courses (Yuan, 2010; Divjak, 2004, Luiz, 2002). All of them recommend having software resources facilitating visualization options in CG courses. However, barring few studies (BoChen, 2005) there is less availability of published methodologies of creating such type of teaching material. This makes it difficult for teachers to adapt proven guidelines and methodologies for creating active learning content for CG courses.

There is a need not only for studies showing the effectiveness of using software tools for explaining visualization in CG, but also for methodologies of creating and implementing such content. Use of open source software would facilitate larger scope for dissemination of these.

3. Our solution

In order to address the gap mentioned in the section 2, we created a workshop for explaining 3D transformations (a concept in computer graphics), using Blender software. This tutorial has steps and features which help the students to visualize, solve, compare and check while solving the 3D transformation problems. In this section, we explain our solution in detail:

3.1 Features of Blender software
Blender is a free open source 3D content creation suite, available for all major operating systems under the GNU General Public License (Blender website, 2013). It supports a variety of geometric primitives including polygon meshes and fast subdivision surface modeling. The user interface of Blender offers

options to see the object in multiple viewing angles, concurrently. Apart from this, Blender offers options to apply different textures and materials to the objects and also to manipulate the lights. These features are found comparable to the proprietary software's in 3D animation, and therefore, Blender is used in different entertainment domains like animated movies, short films, television commercials, and gaming. (Blender website, 2013)

Blender has also been used for the educational purposes, primarily because it is open source and offers high quality of graphics (Gumster, 2003). Domains like biology (Callieri, Marco, et al. 2010) and computer science (Mustaro, 2011) have used Blender to create 3D educational content. Blender has also been used for creating repositories for chemical and physics lab experiments (Sahasrabudhe, 2009, Dere, 2010). Our study shows that Blender features such as 3D space, quad-view, hotkey utilization and transform properties played an important role in performing mental rotation transformations (Kadam, et al. 2012).

3.2 Details of Blender workshop

The objective of this workshop was to develop understanding for the CG concept of transformations. Additionally, it was important that students develop the skill to operate Blender in order to achieve desired results. To address this objective, we used the theory of drill and practice in addition to the live demonstration of Blender features.

In each part of the workshop, students had to do: (i) watch instructor manipulating an object in Blender (demonstration), (ii) perform the same manipulation of the same object in-tandem with the instructor by following step-by-step actions (drill), and (iii) repeat the actions on their own for the same object (practice). Teaching assistants were present to help students during practice.

3.2.1 Presentation outline and slides

Outline of the workshop was based on drill and practice theory along with demonstration. Table 1 shows the outline of the workshop and also the actual activities, Blender features, and the corresponding CG concept it addresses.

Table 1: Outline of Blender Workshop.

Blender training activities	Blender Features used to perform the activity	Rationale for the Blender training activity	CG Concept related to Blender training activity
Introduction to Blender user interface	User interface and panels	To get acquainted with Blender UI	Introduction to 3D tool
Interaction in 3D	3D space, 3D viewport	To provide easy interaction with 3D space.	3D space
	Coordinate system	To provide easy interaction with 3D coordinate systems	3D coordinate system
Views	Multiple views separately (Top / Front / Side / 3D)	To provide familiarity with various views as a basis for visualizing transformations from different angles separately.	Viewing object from various directions.
	Quad view (all views at once, Top / Front / Side / 3D)	To provide familiarity with various views is a basis for visualizing transformations from different angles at once..	Viewing object from various directions.
	Camera view	Cameras View can be used to virtually compose shots and preview how the scene will look when rendered.	Synthetic camera
3D cursor	3D cursor	All rotation and scaling	Relative coordinate

		transformations are relative to the location of the 3D cursor.	for transformations
Transformations (2D and 3D)	Basics	To provide 3D interactive environment to support concept development of Translation, Rotation and Scaling	Transformations
	Transform Control	To provide with the facility to modify and control the effects of the available transformations.	Transformations
	Numeric Transformations	For precise control over transformation, to enter numeric values. This can be done by: after pressing G, R or S, type a number to indicate the magnitude of the transformation. Negative numbers and decimals can be entered.	Performing transformations using interactive features of Blender.
	Transform Properties	To provide user to view and manually/ numerically control the position, rotation of an object, in Object mode. In Edit mode, it mainly allows user to enter precise coordinates for a vertex, or median position for a group of vertices	Performing transformations using interactive features of Blender
	Transformation center	This is a point in space around which all rotations and scaling are centered.	Center for transformations.

3.2.2 Presentation outline and slides

In order to explain the transformation concepts, custom 3D files (.blend format) were created for the workshop. As seen on Figure 1 a) default Blender UI has a cube in the centre, default panels and a standard background shown in gray shades.

For the workshop, we created a customized blend file Figure 1 b) which shows one instance of 3D transformation of a cube. The cube is seen in four different views i.e. top, (two) sides and an orthographic view and has a white background to facilitate clarity of view. Transform properties panel is opened in the right, so that the students can see the values easily. We created various such files for each of the activity of demonstration to be given.

3.2.3 Handouts with clear instructions
During the training we provided students with the handouts for the instructions given during the demonstration sessions. The handouts had stepwise instructions and the corresponding keyboard actions to support the students. Additionally, a sheet listing important Blender keyboard shortcuts and feature was also distributed.
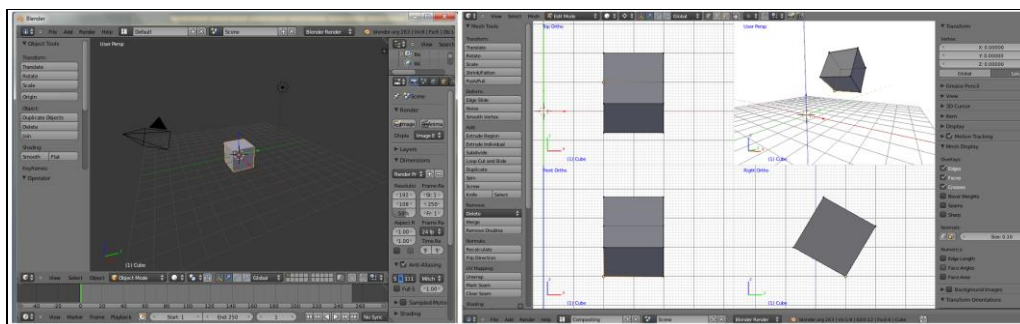

Figure 1. a) Default Blender user interface   b) customized Blender user interface

4. Treatment

In this section we present details of the actual conduct of the Blender workshop. These details would facilitate replication of our treatment.

4.1 Icebreaker (10 minutes)

We started with an activity to highlight the importance visualization skills. In the beginning, a top and a side view of an object was displayed. We asked students to draw (on paper) all possible options for 3D view of the object displayed. Students were seen trying with various objects to satisfy the clauses mentioned. This activity helped not only to engage the students but also underlined the importance visualization skills. This was followed by introduction of Blender 3D software.

4.2 CG Instructions + Blender training (3 hours 30 minutes)

Our previous study where Blender training was used for improvement of mental rotation skills was referred for planning this section (Kadam et. Al., 2012). The training was planned with the focus on Blender features relevant for visualizing CG concepts, as listed in Table 1. The 5-part training was as follows (brackets have the minutes spent on demo + drill + practice):

      (i) Introduction to Blender User Interface, (10+10+10)
      (ii) 3D cursor, 3D space and coordinate system (10+10+10)
      (iii) Multiple views of an object in 3-D space, (10+10+10)
      (iv) 2D transformations, and (15+15+15+15)
      (v) 3D transformations. (15+15+15+15)

4.3 Think aloud for CG problem solving using Blender

After the workshop, students were given a problem to be solved using Blender. The problem has a set of three 3D transformations (translate1, translate2 and scale) with two different compositions to be performed on a cube. Students were expected to perform two compositions and had to find out whether these two were commutative or not using Blender. For this, they were expected to use the procedures learnt during the workshop. This step was being captured using Think-aloud method, and the students were asked to say their thoughts loudly while the researchers recorded and observed the students.

4.4 Survey

Finally, we administered a survey for getting students' perception about the Blender tutorial. The survey questionnaire (having 8 statements) focused on getting students' perception on Blender usefulness for solving transformation problem and the impact of tutorial on their motivation towards learning CG course.

5. Research Methodology

In this section we explain the research methodology used for the study including the details of the sample selected for the course and the instruments. We also explain the data collection and data analysis procedures followed in this study.

5.1 Sample

Sample consisted of 22 undergraduate students (13 who took CG as an elective and rest took HCI as an elective) from second year masters course from a college in Goa University in India. Out of 13 who took CG course, we selected 6 students through convenient sampling for the think-aloud method.

5.2 Instruments

The instruments in this study were chosen to provide data for the research questions formed. Since the nature of the questions was about understanding the thought process and application of skills, qualitative data type was chosen for the study. Think-aloud was the main data collection method, and

was supported by a screen capture (of the students solving the problems and participating in the think-aloud). A questionnaire based survey was also administered to get quantitative data to augment the qualitative data of think-aloud and screen capture.

5.2.1 Audio transcripts of think aloud method

Since the research question 1 is to know the process student uses to use Blender, it is important to have data of the thought process of the student. It is important to have that information 'on the fly', that is, 'as it happens' rather than getting it through an interview (later). In order to capture this, think-aloud method was administered when the students were solving the transformation problem. Think-aloud method is a process, where there is a 'concurrent verbalization' by the participant about the thoughts and actions coming to his/her mind (Jaaskelainen, 2010, Ericsson & Simon, 1993). Think-aloud also helps in inferring from the reasoning processes that were used during the problem-solving task by the users (Fonteyn, 1993) which was a crucial point in this study.

5.2.2 Screen capture

To strengthen the data collected through the think-aloud method, screen capture was done for the same six students participating in the study. Free utility (camstudio) was used on the computers to capture the screen movement. This was matched with the timing of the think-aloud data, which became an additional resource for the researchers to cross check the actions performed by the students during solving the problems. Advantage of the screen capture data was that it was able to record the mouse movement and the time spent on a particular step, which at times the student had failed to narrate. This aspect was particularly useful while analyzing the data.

5.2.3 Survey questionnaire

The survey questionnaire having eight questions was administered online primarily to obtain responses for the research question 2. It had 3 questions (each) pertaining to the constructs of (i) student perception of visualizing CG concepts in Blender and (ii) user experience about Blender software. Last two questions were aimed at getting students feedback about motivation for using Blender in CG course. The answers were in the form of 5 point likert scale having response range between 'Strongly disagree' to 'Strongly agree'.

5.3 Data collection procedure

In the think-aloud method, two observers studied the events of the actions performed by the students. The students were asked to constantly narrate their thoughts, while the events were being performed. In order to ensure clarity about the think-aloud method, we demonstrated students how to think-aloud. Students were asked to repeat it with a different example (mock think-aloud). In the mock think-aloud students solved a puzzle, where they said EVERY thought coming to their mind loudly. The entire proceedings were audio-video taped. Additionally, the computer screens of the students were captured to support the student narratives. The questionnaire was administered using free online survey utility. The users were mailed to fill it up and submit online

5.4 Date analysis procedure

Qualitative data of the think aloud method was analyzed by categorizing it in terms of time, occurrences, and individual performance of the students. Coding scheme was created to separate the actions and behaviours from the overall events of occurrence. Patterns were created and represented in graphs, for further analysis. Data from the screen capture was referred mostly on need basis, in situations where cross check was required to understand the action/behaviour of a student. Quantitative data collected from the survey was collated and means were calculated to get feedback about the questions asked in the questionnaire.

5.4.1 Coding scheme for think aloud data

Transcripts of the think aloud data for six students were created. The chronology of events was reported along the time line. These events which were categorized in two major types:
1. Actions: events/facts of doing something
2. Behaviors: thoughtful conduct of oneself

Both the categories were important from the point of view of the study. Actions were of importance in understanding effectiveness of the chronology of procedures taught in Blender training. Behaviors helped to draw conclusions whether students reflected Blender training in solving transformation related problems.

5.4.2 Behavioral variables in this study

The four events which we shortlisted as behavioral variables were based on the research question 1, 'how do students use Blender to visualization of the transformation problem?' Using the think aloud protocol data, we wanted to study, if the students reflect the features of Blender while solving transformation problems in a CG course. Further, we wanted to investigate, which features of Blender were used by the students, and at what point of time in the overall timeline. The shortlisted behavioral variables were as follows:
1. Perform sequence of transformations: In this the sequence was important, since a wrong sequence led to incorrect answer in the end.
2. Observe final state: This behavior was important as it helped in finalizing the answer.
3. Compare two compositions: This behavior helped in understanding the student's behaviour of checking in between the process. This can avoid time wastage on wrong steps.
4. Perform recheck: This behavior could help the users to avoid wrong answer being submitted as right answer, and save time.

6. Results

We have compared and collated the results in three formats as presented below. The primary source of data was the transcripts of think-aloud method and the screen capture during the problem solving session. The representation is of three main aspects: (i) occurrences of actions/behaviours across time for individual student, (ii) average time spent by all the students on each of the behaviour, and (iii) percentage time spent by each participant on different behaviours.

6.1 Occurrences of actions / behaviours across time

Figure 2 shows the sequence of occurrences of students' behavior observed across the timeline while solving the transformation problem using Blender. The X axis shows the timeline, while the students are placed on the Y axis. From the timeline it can be seen that, longest time taken to solve complete the task is approximately 18 min and shortest duration taken is approximately 7 min. First three from the top are the students who got correct answer, next three got it wrong. Final row shows the instructor's sequence of solving the same problem.

Sequence diagram shows the solution approach, time taken to solve the problem, time spent on each behavior and the differences in pattern of successful and unsuccessful students. We show how parts of the instructor's sequence are followed by students who are successful and not followed by the unsuccessful students. For example the 'observe final state' is seen always after 'perform transformations' behaviour, in the instructor's solution.

For 'perform transformation sequence' behavior (blue), S1 and S2 has spent less time, S3 and S4 has spent more time; where in S5 and S6 has spent approximately the same time, as compared to the instructor.

For 'observe final state' behavior (red) only S6 has spent exactly the same amount of time as that of instructor, wherein S1 has spent very less time and other spent more time; and the pattern of occurrences for this behavior of S2, S3 and S4 matches with the occurrence of pattern of instructor's solution.

For 'compare two compositions' behavior S2 and S6 has spent same amount of time as spent by instructor, where in S3 spent less time and other spent more time. The 'perform recheck' behavior can be seen only in S1 and S4 sequence.
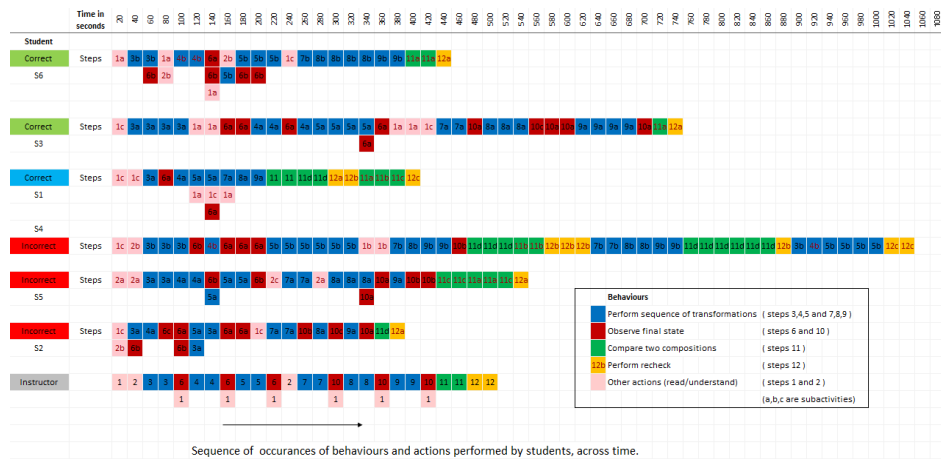

Figure 2. Sequence of occurrences of behaviours and actions performed by students, across time.

6.2 *Average time spent on each of the behaviour*

Figure 3 a) shows combined average time of all the students for each behaviour. The red line shows the time taken by the students who got incorrect answers, while the blue line shows the time taken by the students who got the correct answer. The black line denotes the time taken by the instructor. We found that the average time taken by both groups of students (successful and unsuccessful) is more than the time taken by the instructor. The graph shows comparison between the successful students and unsuccessful students over particular behavior.

Successful students have spent very less time for 'perform recheck' behaviour, because, they have spent more time in the two behaviours of 'observe final state' and 'compare two compositions'. This has enabled them to get to the answer faster.

Two of the behaviours, 'observe final state' and 'compare two compositions' expects the students to observe the coordinate values of current state of the object from various angles. We found that both the groups have spent considerably more amount of time than instructor. After collating the corresponding screen capture data, we found that they were keen on utilizing Blender features.
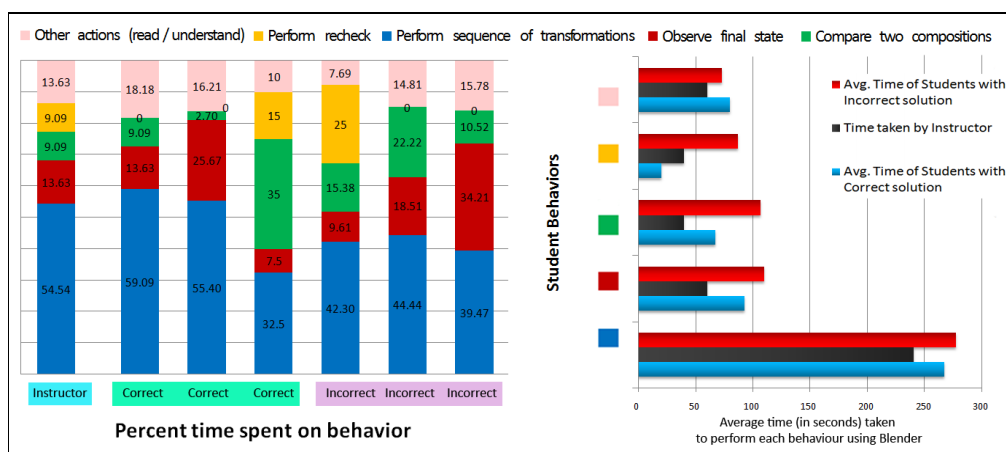

Figure 3. a) Percentage time spent by each student on each of the behavior
b) Average time spent on each of the behavior of the students and the instructor.

6.3 *Percentage time spent on each of the behaviour*

Figure 3 b) shows a graph of percent time spent by each of the student, on each of the behaviours. The first three bars from left are for the students getting the correct answer, while the next three denote the

unsuccessful students. The last bar shows the percent time taken by the instructor for each of the behavior. This graph shows the pattern of comparison for the time spent on a particular behaviour by each student.

We found that students spending similar time for each of the behaviour, as instructor, have got the correct answer. Students who have spent less time on the 'perform sequence of transformation' behavior, had to spend more time on the 'compare' behaviour but got the answers wrong in the end.

6.4 Survey analysis

Results of the survey show that, successful students strongly agree that Blender was very useful for performing transformations, compared to the unsuccessful students. Overall analysis shows that, student found Blender useful in performing and visualizing transformations, they also feel that Blender will be useful in learning computer graphics concepts.

7. Discussion and conclusion

The students participating in the study presented multiple ways of solving the CG problem. A student (S6) got the correct answer by following behavior pattern identical to the instructor. He compared by observing coordinate values in transform properties as well as in 3D view, which led to the correct answer. Another student (S2) did not follow the correct chronology of sequence for performing transformations. He used inappropriate strategy for comparison and the comparison was done only by observing the view and not by observing the coordinate values. Interestingly, yet another student (S1) spent less time on performing transformation, with irregular and less observation of the final state of an object. She also used an inappropriate strategy for comparison, which led to an incorrect answer. However, she performed the recheck step and checked coordinate values in transform to get the correct answer. It is interesting to note that she took less time than that of the instructor solution.

We found that students use Blender for following appropriate chronological sequence of transformations along with observations at regular intervals. This has led to solving the CG problems correctly. We have also found that students intend to spend more time on Blender and explore the options available while solving the CG.

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