# Visual Perception in Computer Graphics Education

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**Abstract**

Computer graphics education is increasingly important to supply the growing needs of the film, games and virtual reality industries. These industries are demanding ever more realistic computer generated environments. Despite the ready availability of modern high performance graphics cards, the complexity of the scenes being modelled and the high fidelity required of the images means that synthesising such scenes is still simply not possible in a reasonable, let alone real time on a computer. One field of computer graphics, visual perception, does appear to offer the possibility of helping achieve high fidelity virtual environments in reasonable time. By taking into account that it is the human who will ultimately be looking at the resultant images, visual perception is able to exploit knowledge of the human visual system to save significant rendering time by simply not computing those parts of a scene which the human will fail to notice.

This paper illustrates the importance of having visual perception as a key component of computer graphics education and considers whether there is a relationship between a student's ability to draw and his/her understanding of perception. If this is the case then drawing too should form an integral part of a modern computer graphics course.

**Keywords**

*Computer graphics, visual perception , drawing, teaching examples.*

## 1. INTRODUCTION

*"The first question we ask anyone applying for a job at Pixar is: Can you draw?"*

[Ed Catmull, President of Pixar]

Significant effort is currently devoted in Computer Graphics education to background mathematics and programming skills. Students thus spend a substantial portion of their time learning such things as matrix manipulation and OpenGL or Java3D programming. The rest of the Computer Graphics courses are typically taken up with teaching fundamental algorithms such as clipping, shading and perhaps some more advanced techniques including raytracing and radiosity.

Very little, if any, time is devoted to helping students acquire the basic perceptual skills they need to put together their 3D models and then appreciate how accurately their resultant synthetic image matches the real scene they are trying to portray. At the University of Bristol we have introduced two new parts to our Computer Graphics course, "visual perception" and "drawing". Even a few lectures on the basics of drawing teaches students a significant amount about the perception of edges, spaces, relationship between objects and light and shadows. Visual perception ensures students are aware of the strength and limitations of the human visual system and how they may go about quantifying the realism of the images they subsequently compute.

## 2. DRAWING

While only a few will go onto become "artists of renown", drawing is a skill that can be learned by everyone [3]. The key is to learn how to see in the right way, that is, how to process the information reaching the eyes correctly and transfer that to the hands.

Neuroscience research has shown that drawing an object that you can see is largely a function of the right-hemisphere of the brain. The left-hemisphere of brain is largely for drawing symbolic shapes from memory [6]. To achieve an accurate drawing of the object that is seen it is important, therefore, that the left side of the brain is "suppressed" and only the right side used [3]. Learning this key to drawing enables the student to develop important perceptual skills, such as the perception of edges, spaces, relationship between objects and lighting, including shadows. All these are crucial components for creating realistic computer models.

## 3. VISUAL PERCEPTION

Recent developments in image synthesis techniques allow us to simulate the distribution of light energy in a scene with great precision. Unfortunately, this does not

ensure that the resultant virtual environment will accurately represent the real scene it is trying to portray. Reasons for this include:

- Modern computer displays are only able to achieve intensities of about 100 cd/m2 giving a practical ratio between maximum and minimum pixel intensity of approximately 100:1. The range of the luminances in the real world can vary from $10^{-4}$ cd/m$^2$ (for starlight) to $10^5$ cd/m$^2$ (for a daylight scene).
- All rendering and modelling techniques are currently only approximations of the physical manifestation of the real scene and thus the perceived fidelity of the resultant image depends on the extent to which human vision encodes such approximations from perfect physical realism.

Conversely, along many parameters, the human visual system (HVS) has strong limitations, and ignoring these may lead to an over specification of accuracy beyond what can be seen on a given display system. This may give rise to unnecessary computational expenses.

### 3.1 Image Quality Metrics

Image quality metrics can be used to evaluate the realistic image synthesis algorithms. Typically the quality of an image synthesis method is evaluated using numerical techniques that attempt to quantify fidelity using image-to-image comparisons (often comparisons are made with a photograph of the scene that the image is intended to depict). Several image quality metrics have been developed whose goals are to predict the visible differences between a pair of images. It is well established that simple approaches, such as Mean Squared Error (MSE), do not provide meaningful measures of image.

More advanced image quality metrics, such as the Visual Difference Predictor [5], which incorporates modeled features of the Human Visual System, provide more meaningful assessments of image quality, but these are still only between the photograph and the rendered image, rather that the real scene and the rendered image.

Psychophysics, that is the study of the response (*psycho*) to an image that is of known composition (*physics*), can be used to measure perception [4]. We can thus compare human performance both in an original scene and on the computer screen. If the response is similar in both cases then we have a perceptually accurate scene. The psychophysical tasks have to be carefully chosen to reflect deficiencies in the display system. Any error of rendition, whether of luminosity or the 3-D structure of the perceived scene, would be expected to lead to errors of psychophysical matching. Thus, the measures of perception serve as a measure of the general perceptual fidelity of the represented scene.

Teaching computer graphics students about visual perception, image quality metrics and the need for including the human observer in any process involving the recreation of real scenes using computer graphics ensures they will be able to evaluate the perceptual fidelity of their virtual environments.

## 4. COURSEWORK

The coursework component of the Computer Graphics unit of the university of Bristol reinforces what the students have been taught about drawing (which was only 1 lecture), visual perception and high fidelity graphics. All students on the course have to participate in the psychophysical experiments that are conducted as on going research within the department, for example [1]. Completion of the experiment provides insight to the students about how to conduct such experiments, the experimental framework that is required and how the results should be interpreted.

Having completed the experiment, the students are asked to construct their own real environment. Using this environment they then:

- Take a series of photographs of the environment
- Draw the environment by hand
- Model and render the environment using Radiance [7]
- Use a Mean Square Error (MSE) image quality metric to evaluate the fidelity of the synthetic image compared with the photographs of the real scene (Note: the view points need to be the same)
- Evaluate the fidelity of the images and photographs compared to the real scene using their own eyes
- Produce a written report of 3-4 pages describing which of the comparison methods they found the most useful, are there situations in which the metrics would fail, how realistic do *they* think the rendered images are, etc? Also included with the report submission are the drawing and all the images produced (these don't have to be in colour)

Students create their models either using either Maya or directly in Radiance. All rendering is done using Radiance which is a state-of-the-art lighting simulation package and which has been shown to produce perceptually high fidelity images [4].

Figure 1 shows the coursework from one student, Howard Lush who had previous drawing experience. This student produced a high quality sketch and a detailed computer model. In contrast, figure 2 shows the course work of David Yiangou whose drawing knowledge came from the single lecture given as part of the Computer Graphics course. In general it was noted that students with previous drawing knowledge considered far more detailed models than those without. Furthermore, again in general, the students with drawing experience submit-

ted more detailed reports that considered perceptual aspects of the scene which other students failed to consider.

Figure 1(a): Photograph of scene

Figure 1(b): Scene rendered with Radiance

Figure 1(c): Sketch of scene

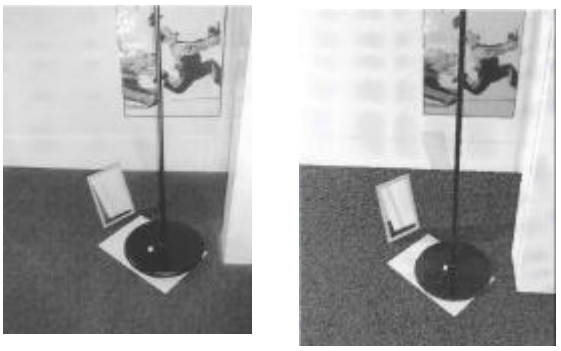

Figure 2(a) Photograph (b) Rendered image

Figure 2(s) Sketch of scene

## 5. CONCLUSIONS

Traditional Computer Graphics courses teach graphics algorithms, APIs and the mathematics that computer graphics requires. At the University of Bristol, based on Ed Catmull's statement, we experimented with teaching drawing to complement the material already being taught on visual perception. Only one lecture was given on this topic. Despite initial resistance from the students, all felt that even this one lecture had helped them when creating their computer models. Furthermore, it was noted that, in general, those students who already had previous drawing experience attempted more difficult computer models for their coursework and considered interesting perceptual aspects of the scene which the other students failed to notice.

Next year four lectures will be given on drawing and a scientific study will be carried out to investigate the relationship between the greater understanding of perception by (a) those students who have significant previous drawing experience, (b) those students with no previous experience who are given the four lectures on drawing, and (c) those students with no previous experience who will not be taught drawing (until after the coursework is due in).

The sophistication of readily available computer graphics software is rapidly increasing. Modelling packages, such as Maya, and lighting simulation software such as Radiance are removing the need for graphics practitioners to develop accurately rendered virtual environments from first principles. If computer graphics is to continue to grow and be widely adopted across many disciplines, it is now the responsibility of computer graphics educators to produce students who are more creative and who have the necessary skills to appreciate the environments they are trying to capture, in order that they might recreate them efficiently and accurately on a computer.

## 6. REFERENCES


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