Visual eye disease simulator

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ABSTRACT

Visually impaired people have a very different view of the world such that seemingly simple environments as viewed by a 'normally' sighted people can be difficult for people with visual impairments to access and move around. This is a problem that can be hard to fully comprehend by people with 'normal vision' even when guidelines for inclusive design are available. This paper investigates ways in which image processing techniques can be used to simulate the characteristics of a number of common visual impairments in order to provide, planners, designers and architects, with a visual representation of how people with visual impairments view their environment, thereby promoting greater understanding of the issues, the creation of more accessible buildings and public spaces and increased accessibility for visually impaired people in everyday situations.

1. INTRODUCTION

It is very difficult to understand and appreciate visual deficiencies from simply a description or static image. It is much easier to see how vision is affected through an actual visual simulation of the situation (Addison and Thiebaux, 1998). One area in which this is of particular significance is in the design of homes, buildings and public spaces. This is an important area of consideration for reasons of social inclusion, legislation and increased personal safety. By providing architects and designers with a tool that enables them to 'see' their designs through the eyes of a visually impaired user, they should be able to produce more accessible designs that will allow people with visual problems to access buildings/public spaces more easily thereby improving their quality of life.

To date most of the work in this area has focused on simulating eye diseases/conditions to give an insight into how a person's vision might be affected by them (Ai et al, 2000). For example, Webb et al (2003) used an immersive environment to display in 3-D the anatomy of the eye to illustrate, for training purposes, the progression and effects of different eye diseases as well as demonstrations of corrective procedures that could be undertaken. Jin et al (2005) created a virtual apartment, and applied masks to this image to simulate various eye diseases. This application was designed as an aid to student doctors, to allow them to experience visual impairments, so that they may be able to recognise these symptoms in patients. The researchers also hoped that it would help in convincing non-compliant patients how serious their particular disease was.

Other earlier work in this area has been based around individual eye conditions, and has used less technological methods. One project (Zuckerman et al, 1973) investigating cataracts used petroleum jelly spotted onto a glass lens to simulate the effect of the cataract on the incident light reaching the eye. Work has also been carried out by Eliott et al. (1996) and Crabb et al. (1998). The website for the Royal National Institute of Blind People (RNIB, 2007), offers a large number of products and services for good design of websites, literature and products, as well as the ability to use them as a consultancy service for help with accessible building designs. The inclusive design toolkit (Clarkson et al, 2007) supplies a range of resources, information and help to designers. The tools they supply include both physical (e.g. sets of glasses with damage applied to them for eye disease simulation) and software (e.g. adjusting the contrast of a photo). The University of Reading also undertook Project Rainbow (Bright and Cook, 1996), which produced two advisory papers, looking at good and bad design practice, along with other aspects of the internal building environment. The Vision 2005 conference (Various 2005) covered a large number of different issues relating

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to people with visual impairments. Amongst these were several papers looking at good design for the internal environment. These were all in the form of good practice guidelines, as with Project Rainbow.

However, despite the initiatives described above, architects still generally only have guidelines to work with, rather than the ability to visually represent their designs as they will be perceived by people with visual impairments. The ability to combine the use of traditional CAD (Computer Aided Design) files etc. with software designed to simulate eye diseases, should make accessible design easier and the resultant buildings and public spaces more effective (Kellas, 2004; Manning, 2006).

2. EYE DISEASES

The eye is a very complex and delicate structure, which can be damaged in many different ways. Some damage can occur with little to no effect on vision, whilst other forms of damage have a significant detrimental effect. The effects of many different eye diseases were researched in order to find those most suitable for simulation as well as those which most commonly affect people's vision (NEI, 2007). From the collated information the following were chosen to be simulated in the early prototypes.

2.1 Macular Degeneration

Macular degeneration is a disease of the eye most commonly found in elderly adults where the centre of the eye (the macular) becomes damaged resulting in the loss of central vision and an inability to see finer details. There are two types of macular degeneration, wet and dry (RNIB, 2007; St Luke's, 2007). Visual symptoms of macular degeneration include:

- Loss of central vision
- Distorted vision (e.g. straight lines appear wavy)
- Blurring of the vision.

2.2 Glaucoma

Glaucoma is a group of eye diseases caused by damage to the optic nerve. The diseases fall into two main categories (Glaucoma Org, 2007); open and closed angle glaucoma. In both cases the pressure in the eye rises and causes damage. Visual symptoms of Glaucoma include:

- Vision becomes misty
- Loss of peripheral vision.

2.3 Cataracts

Cataracts are most common in older people and are a condition of the eye whereby the lens becomes clouded. This clouding can affect only a small part of the lens or the entire lens (NHS, 2007). Cataracts tend to form slowly and many people do not notice they have them. Visual symptoms of cataracts include:

- Blurring of the vision
- Double vision in one eye
- Spots in vision
- Halos around bright lights

2.4 Diabetic Retinopathy

Diabetic Retinopathy is the most common cause of blindness in the UK. It is caused by damage to the blood vessels in the back of the retina (NHS, 2007). Visual symptoms of Diabetic Retinopathy include:

- Tiny dots appearing in vision
- Dark streaks across vision that can sometimes obstruct it
- Blurred vision
- Poor night vision

2.5 Colour Blindness

Colour blindness is a deficiency in colour vision normally attributed to genetic factors; however it can also be brought about by damage to the eye or brain (Wikipedia, 2007). Those affected find it hard to distinguish between two or more colours (Vischeck, 2007).

3. SIMULATING DISEASES

After studying the characteristics of the common diseases outlined above, a number of types of eye effects were identified as needing to be simulated in order to model diseases effectively. These included:

- Colour Effect – changes the colour of the image
- Twist Effect – applies a pinch/twist effect to the image.
- Dots Effect – adds a number of random dots to the image
- Fade Effect – fades the image out
- Texture Effect – applies a texture to the image
- Blur Effect – applies a blur to the image
- Double Vision – applies a double vision effect to the image
- Darken Effect – darkens the image

These effects were implemented using image processing techniques to manipulate the images and produce the simulations. The system uses Microsoft DirectX and C#. The image processing was carried out on the graphics card using HLSL (High Level Shader Language) which dramatically speeds up the image processing, an important consideration if complex scenes are to be modelled and/or if real time processing is to be undertaken (e.g. during actual walkthroughs of buildings). Individual effects were implemented as follows:

3.1 Blur

The obvious type of blur to use is a Gaussian blur which provides a good realistic image that is easily adjusted. However due to limitations of HLSL, the number of samples required to model the impairment (49 samples for a typical example) exceeded the maximum that HLSL can handle and therefore in order to deal with the shortcomings of HLSL, a two pass blur technique was used instead.

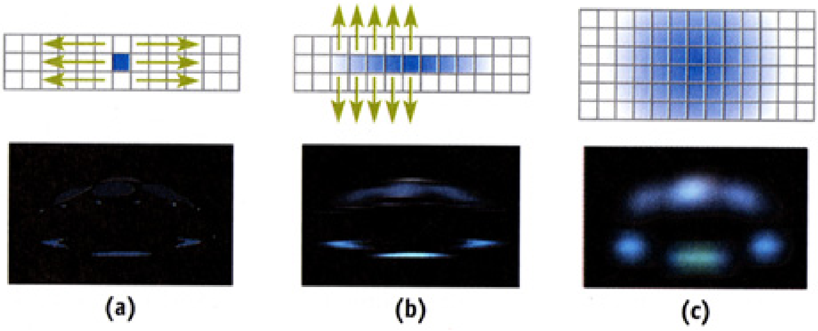

Figure 1. *How the 2 pass blur works. (a) Initial image. (b) Result of horizontal blur. (c) Final result. [16]*

Initially a horizontal pass causes blur to occur along the horizontal axis see Fig. 1 (b). Once this has occurred, a second pass is carried out this time on the vertical axis see Fig. 1 (c). This completes the effect and produces results that are close to that of a Gaussian blur as well as being very much quicker when calculated in real time (James and O'Rouke, 2004).

3.2 Texture

Some eye effects required a texture to be drawn over part of the image as shown in Figure 2. This allows for damage to be shown and areas of the image to be blocked. This was carried out by overlaying an image on top of the original image and has the advantage that different textures can be applied for different conditions, severity of condition or specific symptoms of the disease occurring for a particular individual.

3.3 Brightness and tint

The brightness of the image can also be altered or a colour tint applied to allow a number of eye conditions to be simulated, such as macular degeneration where the image appears to be washed out (brightness increased). Brightness is implemented in a similar way to applying a colour tint. An increase in brightness can be brought about by a white tint (red, green and blue increased by the same amount) and a decrease in brightness by a black tint (decrease in red, green and blue by the same amount). In order to calculate the new colour of a pixel, the tint percentage for red, green and blue are used. The pixel's red value is multiplied by the tint percentage of red. The same is done with green and blue. The result is an image with a tint defined by the percentages given. If the percentages range from 0 to 200, the amount of each colour in the image can be increased and decreased. Colour draining, whereby colours are filtered out to black and white can be used to simulate colour blindness and general colour loss. It can also be used to place a smoked haze over an image by increasing the yellow content of the image, an effect described by some glaucoma sufferers who likened the effect to the tobacco filters used in photography.

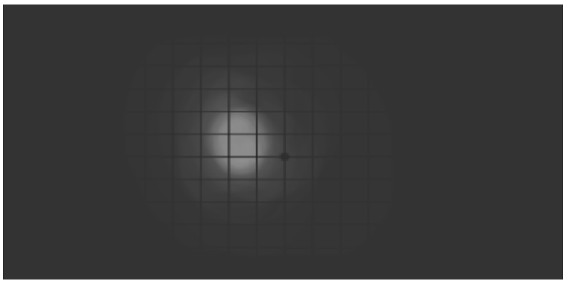

Figure 2. *Example of texture being drawn on top of a grid. Part of the Glaucoma effect.*

3.4 Line Distortion or Pitch

Some of the eye effects involved the area of damage to have a twisted pinch like distortion see Figure 4. This effect requires adjustment through vector mathematics. An initial point can be specified for the centre of the damage as shown in Figure 3.

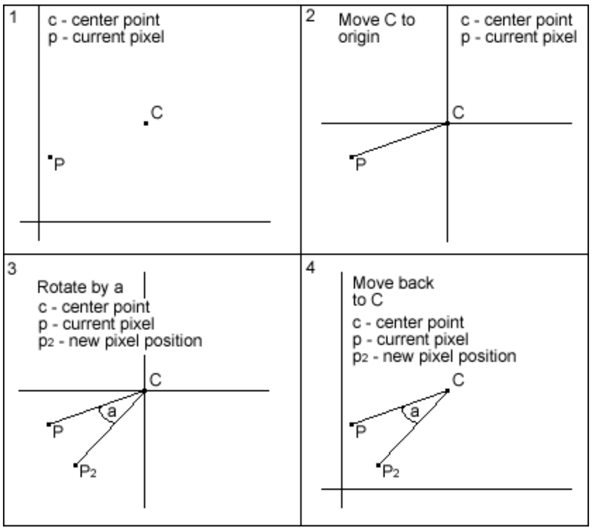

Figure 3. *Rotation calculation - vector is found between P and C in 1 ands moved to the origin in 2; rotated by the angle (related to distance from C) in 3 and finally moved back to C in 4.*

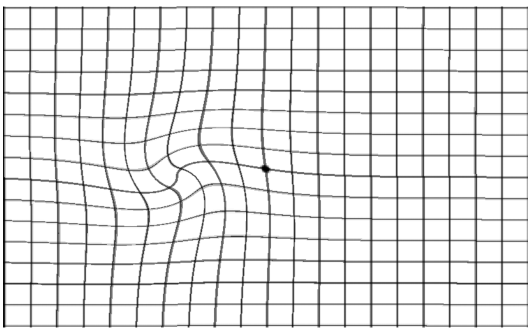

Figure 4. *Example of the Pinch/Twist effect on a grid.*

With this centre point, each pixel can be tested to see if it is within the specified radius of damage. If it is, the vector from the pixel to the centre of damage, is moved to the origin, rotated and then returned to the centre of damage. This causes a rotation of a ring of pixels. If this rotation is varied with distance from centre of damage, it is possible to simulate a pinch distortion effect. This was found to be most effective when using an exponential function.

3.5 Double Vision

Double vision is simulated by drawing the same image twice as shown in Figure 5. The second drawing is offset by a small amount and is made partially transparent through the use of the alpha channel.

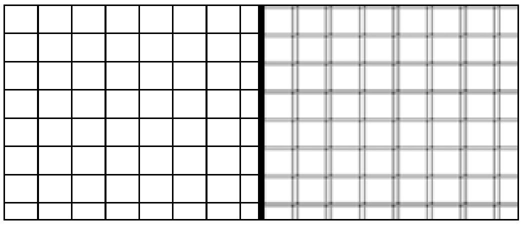

Figure 5. *Example of double vision. Left side is a normal grid. Right side is the same grid with the double vision effect applied.*

4. IMPLEMENTATION

The aforementioned effects allow for individual aspects of eye diseases to be simulated, but in order to complete the full simulation for a particular disease, they need to be combined together. This is achieved by employing an image post-processing framework. In this case, there are scenes for input type (e.g. Image or 3D model), eye diseases (collections of eye effects) and eye effects.

The post processing framework allows the effects to be applied to the scene no matter how complicated it is. The scene is initially drawn to a texture which the post processing framework imports and subsequently manipulates. This allows the effects to appear in real time even in 3D moving scenes.

4.1 Scenes

The two types of scene that have been implemented are an image scene and a 3D scene as shown in Figure 6. The image scene loads in an image of varying formats and this is used as the basis of the simulation. The 3D scene allows a 3D model to be loaded into the program. The mouse and keyboard are used to navigate the scene. For the effects to be implemented, the 3D scene once drawn, is rendered to a texture allowing it to then be treated the same as the image scene. The Video scene is currently under development.

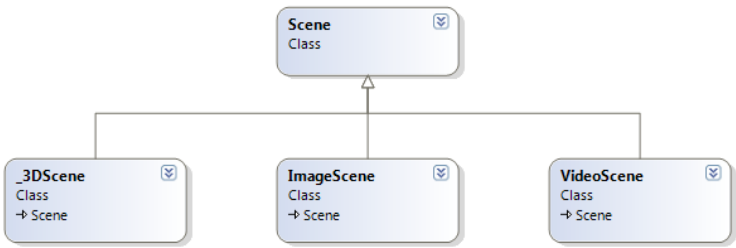

Figure 6. *Hierarchical class diagram of the scene classes.*

4.2 Eye Diseases

The main purpose of the structure shown in Figure 7 is to hold the collection of eye effects. It provides a way of building up diseases by adding and ordering the individual effects. Each of the effects loaded into the program is processed and the resultant image is drawn to the screen.

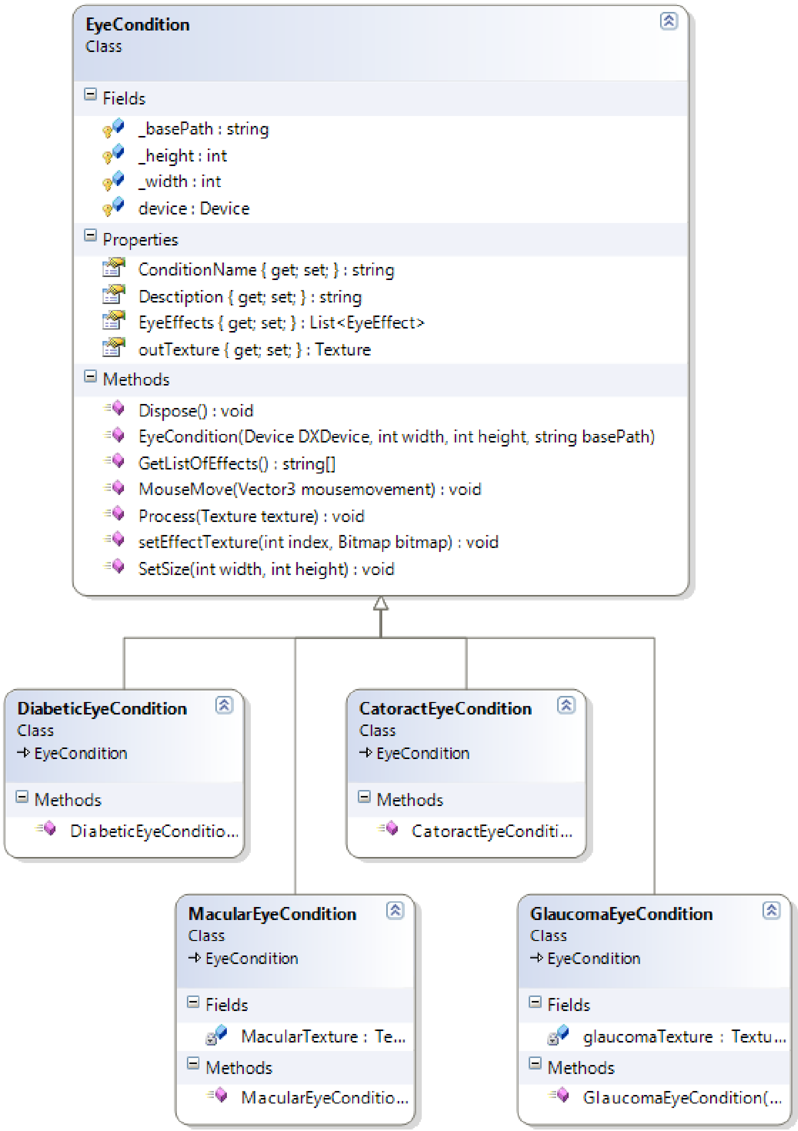

Figure 7. *Hierarchical class diagram of eye conditions.*

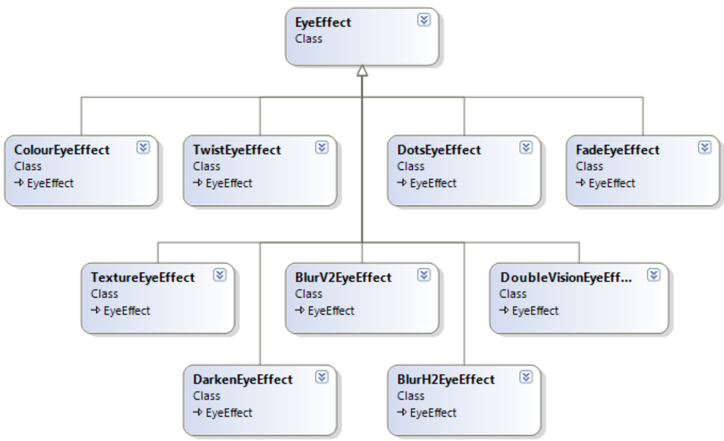

Figure 8. *Hierarchical class diagram showing the eye effects.*

4.3 Eye Effects

The eye effects (Figure 8) are the key to the whole simulation. Each contains a varying way of manipulating the image. As explained earlier most employ pixel shaders which allows direct access to the graphics card, dramatically speeding up the manipulation of the image, allowing for real time simulation.

4.4 System Implementation

The system combines the above component parts with the user interface and the input and output functions. The ability to load in eye conditions and edit them "live", allows for easier building of simulations. Effects can be added and removed to/from conditions and the parameters changed. Once a new condition or a customised one is complete it can then be saved out to an XML file. The system also allows for the image on the screen to be saved as a bitmap image. This can be useful for sharing information with others. With regards to the user interface the menu bar along the top of the program is used for loading and saving data, whilst the editor bar on the right is used for selecting and controlling the eye conditions and effects (Figures 9 and 10).

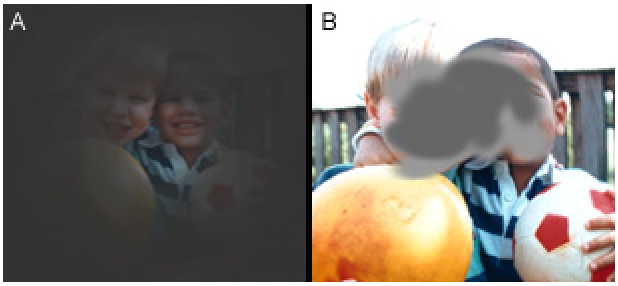

Figure 9. *Output of the simulations from the program. (A) Glaucoma (B) Macular Degeneration.*

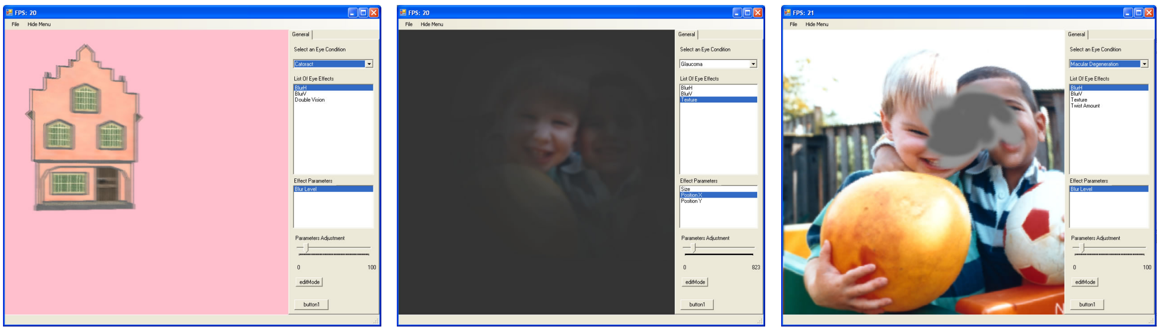

Figure 10. *Output within the context of the user interface*

5. CONCLUSIONS AND FURTHER WORK

Accessibility plays an important role in the design of public buildings and spaces as well as for individual homes. This paper has investigated ways in which eye diseases can be simulated in order to improve the potential for rooms and buildings to be designed with visual impairments in mind. Using the simulator to enable building designs to be viewed through the eyes of a visually impaired user will greatly enhance the potential for better access to and navigation within public buildings and spaces as well as for homes designed with an individual's requirements in mind. The system could also be used to train designers and architects in aspects of inclusive design and accessibility particularly when linked to the good design principles that are already available.

Work is currently underway to increase the complexities of the models that can be imported into the system and to process real-time video data as a designer walks around an actual building. Moving the system into a CAVE-like environment is also under consideration as is the use of object detection algorithms to automatically highlight to designers potential hazards associated with their designs as they progress. We are also in consultation with our construction management colleagues with regard to further features that should be implemented to ensure practical use and value of the system.

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