Design Perception: Individual Bodies, Individual Eyes, Individual Perceptions

Mike Bennett
Stanford Center for Image
Systems Engineering,
Dept of Psychology,
Stanford University

mikemb@stanford.edu

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Abstract

Our bodies shape our experience of the world, and our bodies influence what we design. How important are the physical differences between people? Can we model the physiological differences and use the models to adapt and personalize designs, user interfaces and artifacts? Within many disciplines Digital Human Models and Standard Observer Models are widely used and have proven to be very useful for modeling users and simulating humans [2]. In this paper, we briefly present a personalized digital human model of perception, particularly focused on how humans see. Our model simulates how light travels through the human eye, and accounts for individual differences in human vision / visual acuity. Elsewhere, we have used the model to simulate 3600 biologically valid human eyes. An evaluation of the simulated eyes found that they *see* eye charts and other visual designs the same as humans. The ability to model individual human eyes gives us the ability to measure how individual eyes transform visual information. We can take a visual design, pass it through a virtual eye, then capture the visual design as it is seen at the back of the virtual eye.

Keywords

design perception, physiology modeling, virtual humans, human vision, individual differences

Example 1 Pelli-Robson eyechart which virtual eyes *see* the same as humans.

Introduction

Our bodies shape our experience of the world, and our bodies influence what we design. For example clothes are not designed for people with three arms because designers implicitly model standard human physiology. Yet, human bodies differ, some people are born with small bodies, others with bodies that see colors differently (colorblindness).

Many domains, such as medicine, health, sports science, and car safety are creating digital human models [2]. These digital human models are very useful for identifying and evaluating the strengths and weakness in prototype artifacts and novel tools. Initially, the majority of the digital human models were primarily concerned with modeling humans' physical bodies and biomechanics. Recently, there has been a move to richer and multifaceted digital human models, which are capable of modeling many aspects of being human, including modeling aspects of cognition, simulating affect (emotion), modeling group and social dynamics, and simulating aesthetics and taste. Numerous challenges and research opportunities exist for creating and integrating biomechanical models with cognitive and perceptual models.

Individual differences in human bodies often cause differences in how humans perceive and experience the world, e.g. colorblindness, contrast sensitivity [3]. We briefly describe our model of human eyesight, which models individual bodies and perceptions. The model captures how our bodies shape our perceptions. Models of physiological function are useful for adapting and personalizing user interfaces to suit individual users' bodies and perceptions (Figure 1).

Modeling & Creating Individual Virtual Eyes

To build the individual model of human eyesight we created a simplified optical model of how the human eye works. The model has parameters for controlling the amount of individual differences in eyesight. The eyesight model is built on research from vision science, optometry and ophthalmology [4, 5]. Fortunately, modeling individual differences in eyesight is extensively studied in optometry and ophthalmology research [7, 5].

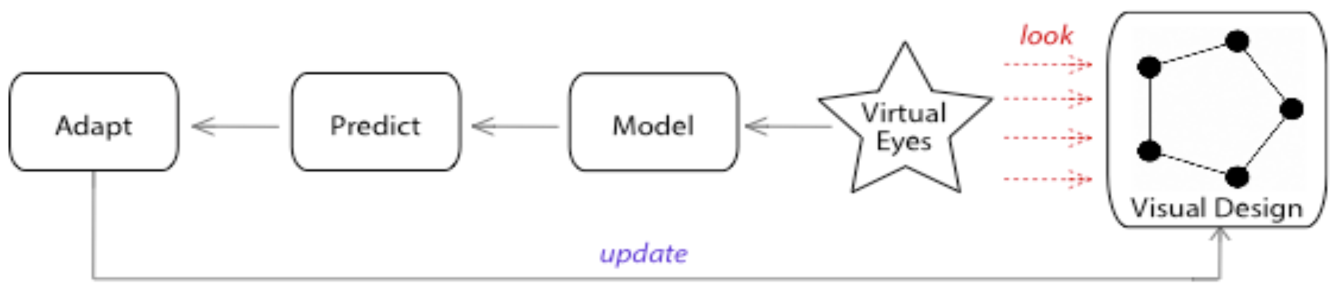
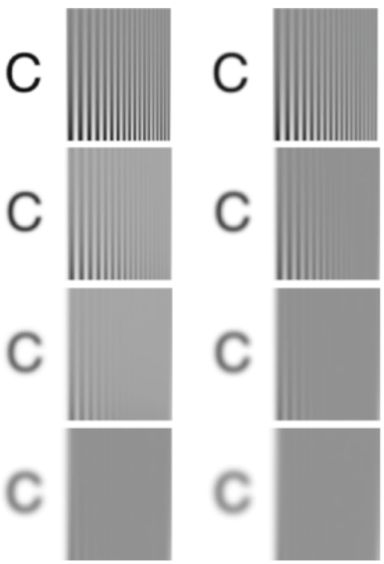


Figure 1 Individual Observer Model for personalizing designs to suit individual perceptions (more in [1]).



Example 2 Demonstration of how different designs are effected by same amount of aberration. Defocus increases from upper left to lower right.

Individual differences between peoples' eyes are accounted for by modeling individual differences in the physical structure of human eyes. Depending on the physical structure of eyes, some peoples' eyes are very good at focusing light on the back of the eye, while in other cases the eyes are bad at focusing light. This difference in how well the eye does or does not focus light is due to the amount of aberrations in the eyes. People with eyes that have high amounts of aberrations usually have worse eyesight than those with low amounts of eye aberrations. Nobody has aberration free eyesight, but there are normal amounts and types of aberrations [7].

Differences in the amount of eye aberrations have a large impact on how easily people can or cannot see visual information. In particular, modeling eye aberrations is good for predicting the amount of visual detail people can see. The ability to see visual detail is called visual acuity. Good visual acuity commonly implies low amounts of eye aberrations, or that an eye has been corrected to reduce the impact of the aberrations. Correction is done either with eyeglasses, or with various kinds of eye surgery. Visual acuity is known to significantly differ between people [5].

Our eye model accounts for how rays of light travel through the human eye. Looking at Figure 2 you can see that multiple rays of light are entering a lens (eye). After the rays of light pass through the lens they are not aligned with each other, and in some cases mistakenly cross. In a perfect eye the rays of light are focused on a single spot (fovea), while in an aberrated eye the light rays are imperfectly focused. Depending on the location at which a ray of light passes through the lens, it will get aberrated in different ways and by

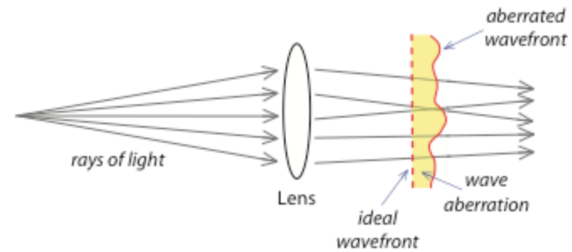


Figure 2 Example of how light rays and wavefront is aberrated when traveling through a human eye.

different amounts. In order to model how different parts of the lens affect light rays, we use wavefronts. Wavefronts describe how numerous light rays simultaneously behave over many points of a lens. A wavefront is perpendicular to the light ray paths.

For example, in Figure 2 we have an ideal wavefront and an aberrated wavefront. The ideal wavefront is the dotted line, and it represents all the light rays emerging from the lens in parallel. Unfortunately, all the light rays are not parallel so the wavefront is distorted and aberrated. Wavefronts are widely used by ophthalmologists when planning eye surgery to correct human vision, such as LASIK eye surgery. Wavefronts enable us to model individual eyes, because we can create and simulate wavefronts based on measures of individual eyes, then use the wavefronts to transform a visual design into what is seen at the back of the human eye. Provided in [1,4] is the wavefront

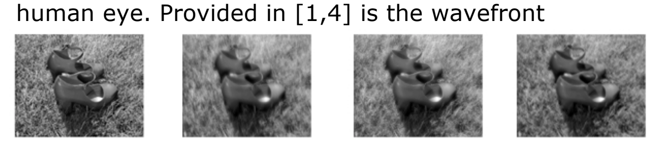
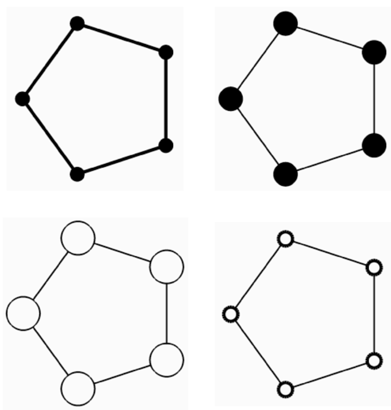
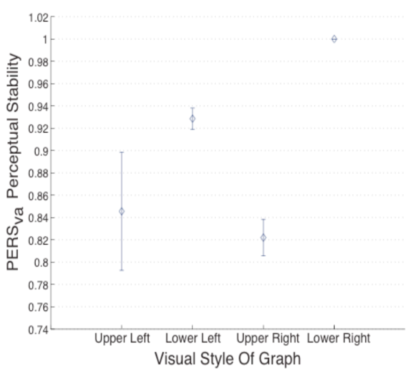


Figure 3 How three different eyes *see* the same photo (original on left). Slight amount of aberration is present.



Example 4 Visual designs that were evaluated with simulated eyes.



Example 3 Example results, where a lower score tells us that a visual design is easier to see (analyzed Example 3). Deviation indicates how differently the design is see by different people.

aberration function for modeling wavefronts.

Shown in Figure 3 are examples of how a photograph of a pair of shoes on grass is seen by three different eyes. The amount of individual differences between the eyes is small. A limitation of our current eye simulation is that it is restricted to grayscale images. This restriction exists because in vision science it is not yet known what the normal aberration amounts are for color eyesight.

Predicting What Users Can Or Cannot See

To predict what a user can or cannot see, we use the virtual eyes in a predictor (Figure 1). The predictor quantifies how differently individual eyes see the same visual information. Quantifying the impact of individual differences in eyesight enables us to improve the layout and presentation of visual information, by adapting it to suit individual eyes and groups of eyes.
The predictor works by looking at the original visual design through a virtual eye, and then it compares the original design against the design as seen at the back of the eye. The difference between the original design and the perceived design gives a measure of how individual differences in peoples' eyesight impacts upon the perception of visual information [1].

Closing

In this extended abstract we briefly touched on our model of human vision and its application to evaluating and adapting visual designs. Our model is focused on individual's low-level early stage human vision and provides a biologically valid model of human eyesight, while accounting for how individual differences in physiology effect design perception. Many more details of our model, its evaluation and its application to evaluating visual designs (including graph layouts and text styles) can be found in [1].

We believe one of the significant challenges and research opportunities for Dynamic Accessibility is to create richer and more diverse individual models of human perception, e.g. [6]. These models should be easy for designers to use and understand, while also being capable of automatically adapting designs to suit individual differences in perception.

Citations

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