# Measurement of Perceived Objects

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## 1 ABSTRACT

We describe an experimental prototype system in which a virtual protractor is used to measure three dimensional relationships between objects. The objects being measured are not modeled explicitly using surface or procedural geometric definitions in the traditional sense, but rather are perceived by a viewer who looks at stereo image pairs. In contrast, the virtual instrument itself is represented using traditional geometric models. A stereo imaging model that is consistent across image-based and geometric-based model viewing is required for successful stereo perception (fusion) and belief that geometry and image-based objects are part of the same scene. Control of inter-image registration as well as placement of geometry are the independent variables of the system. The qualitative lessons from this experiment lead us to conclude that stereo imaging combined with motion parallax allow a researcher to measure three dimensional relationships in data acquired from an electron microscope.

**KEYWORDS**: stereoscopy, visualization, medical imaging, virtual reality, image-based rendering

## 2 INTRODUCTION

Much of contemporary visualization research focuses upon algorithms that create images from data. An implicit assumption underpinning algorithmic research is that a human observer is on the receiving end of the rendering pipeline to view images. Visualization algorithms that focus on the display of information through data reduction or representation, either direct or indirect, generate images that depict abstract data in a form more readily comprehensible than data in its raw form, such as in a tabular or “spreadsheet” format, or seek to depict features within data. A complement to research of this type could focus on leveraging the cognitive processes (perception) that humans use to derive or extract meaning from images. Improvements in understanding how humans extract meaning from images will lead to better visualization algorithms. For example, we know that motion parallax and stereoscopic presentation can measurably improve perception of three dimensional structure [Ware96].

In this paper, the fundamental question we explore is whether or not a human observer can successfully perform a three dimensional point measurement upon objects perceived as being three dimensional from stereo image pairs. In other words, given a stereo pair of images, can a person perform three dimensional measurement operations upon the perceived objects? We present our discussion within the context of a medical research study that generates stereo images from a scanning electron microscope (SEM).

We begin with a discussion of the basic scientific research, with the intent of providing contextual background information. Following, we discuss our approach used in designing a prototype, experimental system used to perform a single operational task: the measurement of angles between objects perceived when viewing stereo image pairs with a *virtual protractor.* One of the central themes of our design is to ensure a consistent imaging model between the data acquisition and visualization/rendering steps. While this system has proven useful to discipline scientists, a number of issues are raised, and remain to be answered.

### 2.1 SCIENTIFIC BACKGROUND

Measuring surface tension at the air/liquid interface along the airways in the lung helps us understand how natural surfactant acts to lower surface tension and prevent collapse of the tiny branching tubes and outpouchings that are the bronchial tree. This is accomplished by depositing micrometer sized droplets of an indicator liquid on the surface of the airway, imaging droplet shape with the scanning electron microscope, measuring droplet shape from pairs of images, and calculating surface tension [Lee95, Strohman96]. These droplets are asymmetrical with unknown orientation. Our scientific research focuses on understanding how surfactant works in the airways, how it is spread and how it is cleared in order to better formulate and administer new therapeutic surfactants. Surfactant therapy has dramatically improved the survival rate of premature babies.

Surface tension of the surface of the airway can be inferred from the contact angle between the indicator droplet and the surface upon which it rests or by other measures of the shape of the droplet and its tendency to flatten due to surface tension of the airway. These would include, for example, droplet height to diameter ratio. The SEM provides images of the surface of three dimensional objects (Figure 1). These specimens can be tilted, rotated, or translated between successive images, and the magnification varied from 10X to 500,000X.

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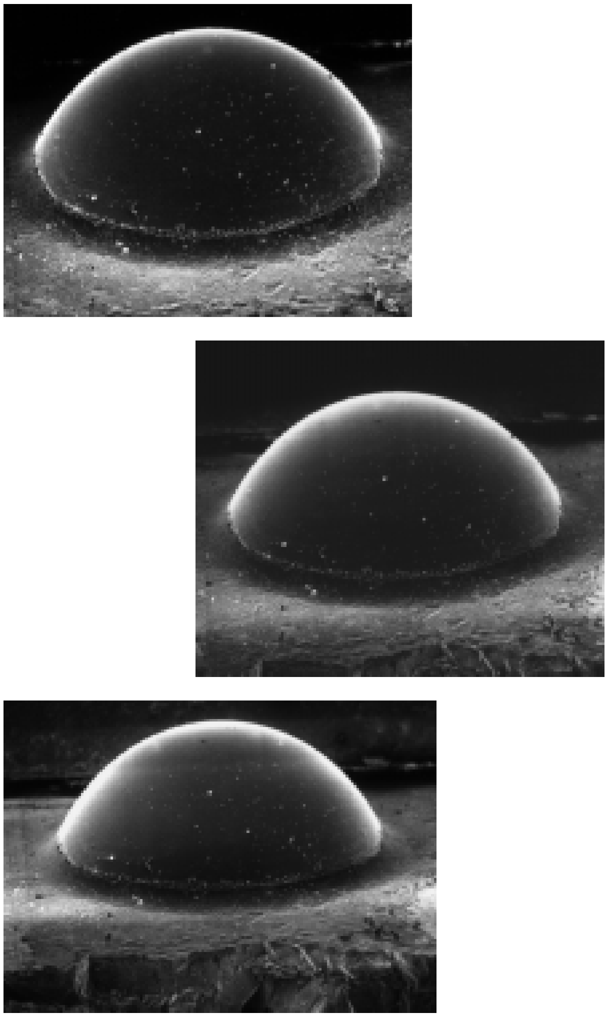

**Figure 1**. Images from the scanning electron microscope.

### 2.2 Approach for Visualization

The fundamental operational objective for the virtual protractor system to provide the means to take point measurements of the angle formed between the surface of the lung and droplets of a liquid deposited upon the surface. Unfortunately, the data from the SEM consists of a set of two-dimensional images; there are no explicit geometric models from which one can obtain measurements. Point measurements will be performed using a model represented with a geometric model (the virtual protractor). Measurements will be taken from three dimensional objects perceived in stereo image pairs.

Human observers are capable of perceiving three dimensional depth relationships when presented with stereo image pairs that reflect a binocular viewing geometry of the form described in [Deering92] and [Grinberg94]. The question that follows is whether or not the “stereo effect” is “sufficiently additive” to make possible the task of taking limited spatial measurements of three dimensional objects perceived in stereo image pairs using an instrument represented with surface geometry but rendered in stereo. Note that this is a different problem than the work of [Ferneau95] in which a “virtual tape measure” is used to “read off” distances in a three dimensional world between objects modeled with geometry. Our work focuses upon taking measurements of perceived objects rather than from models. The crucial element of our system is the observer’s ability to “see stereo” from stereo image pairs, and to place an object represented with geometry in this scene.

The basic thesis of our work is that, within a reasonable scope, the human perception system is capable of formulating a sufficiently meaningful impression of three dimensional shape information from limited information for the purpose of measuring angles between perceived (not modeled) objects. Images from “different viewpoints” can be obtained from the SEM by transforming the sample with respect to the electron beam. Two such images (a stereo pair) can be viewed in a stereoscopic format, such as anaglyph or multibuffered, with the result being that the observer has the impression of viewing objects in three, rather than two dimensions. Using an imaging model consistent with that used to obtain multiple views from the SEM, a geometric model of a measuring device can be rendered in the same “scene” as the stereo image pairs. The result is an overall impression that the measuring device is “in the data,” thereby creating the possibility of measurements.

## 3 Imaging Models

A fundamental issue in the design and evaluation of our virtual protractor system is the rectification of the two participating imaging models. One model results when rendering surface geometry from viewpoints slightly offset from one another. Another model is formed during data acquisition by moving the sample inside the SEM.

The imaging model formed during data acquisition is binocular, but the stereopsis is formed by a rotation about a central point. The rotational model is correct only when the objects being viewed are “at infinity,” as is the case with orthographic projection [Deering92]. With sufficiently large angles of displacement, the rotational model can result in a visual artifact known as the “keystone effect” [Weismman95]. The preferred model for computer graphics based stereo binocular viewing models is to position the eyepoints so that they are offset along a line parallel to the view plane, where each view matrix includes a shear component ([Deering92], [Grinberg94]). The following figure shows binocular imaging models based upon rotational displacement, translational displacement only and translation with shear. According to [Weissman95], the translation-only model fulfills the requirements for orthostereoscopic views.

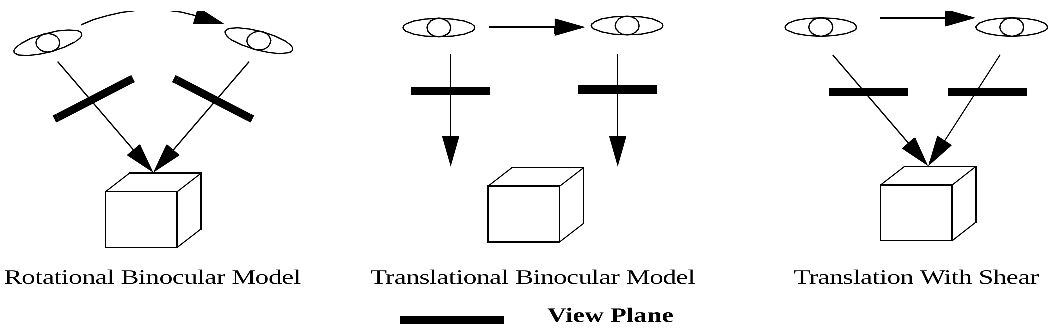


**Figure 2**. Rotational and Translational Imaging Models

## 4 The Virtual Protractor

Our experimental system is constructed from a multipass- and stereo-capable scene graph rendering infrastructure [RMSG99]. This infrastructure provides for simultaneous display of image-based data and geometries in stereo. Either a mouse-based interface, or a wand-based input device may be used to select and manipulate scene geometry or image data. Users may interactively modify registration of the stereo image pairs. Like other aspects of human vision, stereo perception is not constant across the population. It is our experience that most observers prefer to manipulate the registration between stereo images, thereby “fine tuning” the relationship between images and geometry. We found that it is possible for a stereo view of the geometry to be “disrupted” when the images are misregistered. This leads us to believe that a consistent imaging model is required as a first approximation, and that users subsequently fine tune registration to suit their own perceptive abilities.

We have experimented with both rotation-based and translation-based viewing geometries. For small angles of eye separation, we have found them to be largely indistinguishable. In order to preserve consistency between the view geometry dictated by the data acquisition phase (a rotational model), we have chosen to propagate that model into the display of geometry.

With this system, one of the authors successfully performed several point measurements of the angle formed between droplet and the lung wall with relative ease. These measurements will provide solid data for surfactant studies. It is important to emphasize that the system we describe is one of many tools brought to bear on the study of surfactant. Figure 3 is an anaglyph stereo image created by the virtual protractor system; the left eye sees the red image.

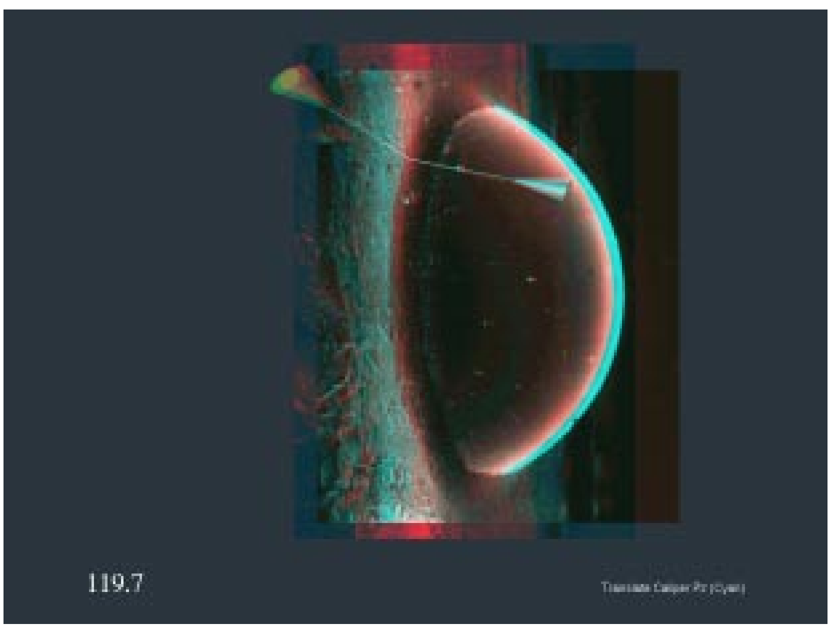


**Figure 3**. The Virtual Protractor (using anaglyph stereo)

## 5 DISCUSSION

The raw microscope images that are displayed in a stereo format do not have any associated depth information. Because these images are displayed in a manner analogous to “billboarding,” when the virtual measurement device passes through the plane containing the images, it appears to be clipped against a plane rather than appearing to be clipped against complex geometry (more precisely, there is no complex interpenetration shown by pixel-wise depth comparisons performed in the z-buffer). One would expect that the conflict between appearance (complex geometry perceived in the stereo pairs) and behavior (protractor clips to a plane) would be unsettling. We can report informally that this conflict of information does not present a significant problem to the user. Many users were not even aware of this inconsistency. For images containing more complex geometries, this artifact will become more of a problem. For example, the images we use contain objects that could be called two-and-a-half dimensional. For complex three dimensional structures, such as those produced by molecular modeling, this method may not prove as useful.

Image based rendering (IBR) techniques, such as those described in [McMillan95], provide the means to “navigate” through a scene composed of image data. A useful extension to our work would be to explore application of IBR techniques for the purpose of adding another degree of freedom to the virtual protractor system. IBR techniques would provide additional motion parallax, thereby allowing users to alter the viewpoint with respect to the acquired image data. The additional cues provided by IBR motion parallax could further enhance the ability of the viewer to resolve depth relationships in the scene. The addition of depth in the acquired image data would be of benefit to both IBR extensions and a vision-based approach.

The conclusions we draw about the usefulness of combining image and geometry based stereoscopy are based upon a single case study. Further work that focuses on quantitative issues would be appropriate. For example, it is possible to obtain images from the SEM with a number of inter-frame displacement methods (rotation or translation). Similarly, it is possible to specify stereo cameras for rendering using a number of different binocular geometry models. Comparison of usability between various imaging models would aid in planning data acquisition for future scientific studies.

## 6 CONCLUSION

We have described an experimental system used to take point measurements between three dimensional objects perceived in stereo image pairs using a virtual protractor. The fundamental leap of faith that makes this system functional is the ability of a human observer to “see stereo” to such a degree as to successfully place a virtual object represented as surface geometry “into” a scene consisting of perceived three dimensional objects. We conclude that while this system is useful, it does have operational limits that can be explored and resolved with further work. This work has reinforced our belief that the human perception system is a powerful but underutilized resource that can be leveraged to aid in solving challenging visualization and analysis problems.

## 7 ACKNOWLEDGMENT

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