

Design Description Document

Historical Manuscript Imaging

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Historical Manuscript Imaging Design Description Document

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Vision Statement

The project team shall produce methods for the design and manufacture of an imaging system for “tightly bound” manuscripts which cannot be opened past a 30 degree limit.

Project Scope

We are responsible for a design study of an imaging system for very fragile, ancient manuscripts which cannot be opened more than 30 degrees. The design study includes both a design that meets the specifications provided, and an explanation as to which different design factors are relevant and how they affect image quality. It is desirable that this imaging system does not make any contact with the manuscripts and that we produce a manufacturing plan for proof of concept devices. We are not responsible for the design of the book holder which will turn over the books automatically, any sort of industrial scale manufacturing plan, or any devices on a larger than necessary scale for proof of concept.

Current Design Advancements

The figures below are a result of a prism that was built from plexiglass ($n=1.48$), the book dimensions are slightly larger than the rare books we are interested in imaging. The light source is a 6” light bar and the angle of incidence was varied across the open face of the prism with the best location, in terms of the image produced, is parallel to and right against the side.

A polarizer was used in contact with one side of the book on the outside of the prism to remove some of the reflection from the respective side of the book. This is helpful in removing the reflection however the customer wants a system that will image both pages simultaneously.

When the prism walls are secured properly and are able to hold up to the pressure of a liquid, the prism can be filled with liquid materials of varying index to test the imaging characteristics.

Professor Hayworth is interested in pursuing an off axis imaging system for this project that utilizes the Scheimpflug condition. There is the possibility that a colleague of Hayworth will be bringing a camera already set up to meet the Scheimpflug condition, however this is only a maybe. An attempt has been made in the lab to set up a system

to model the Scheimpflug condition, this was done with a backlit tilted resolution target, a telecentric lens system on a rotary stage, and a ccd on a rotary stage.

System Overview

Our current prototype system is composed of a light source and a prism. The light source is parallel to the prism. For the prototype, the prism is made of plexiglass, filled with silicone oil. This is due to our project budget. For our final design, the prism is made of environmentally friendly, sustainable N-BK7, by the suggestion from Professor Knox.

Current Design Limitation

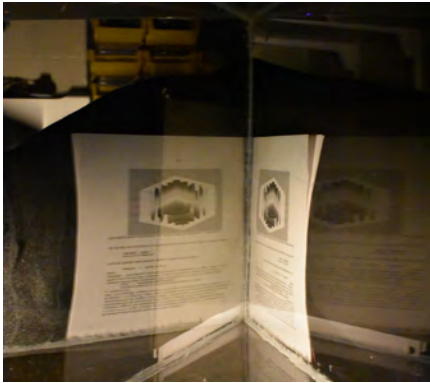
The current prism design is limited by the number of reflections, resulting in a loss in the image resolution. The scheimpflug design is limited by the resources available, they include a telephoto lens and an angled ccd in a single enclosed system.

Design Modifications

We will continue experimenting with polarized light to see the effects on the image quality; there is the possibility of filling the prism with different materials to see how the index change affects the imaging quality. Because the customer wants limited image processing we will need to figure out a way to have the prism present both pages with higher resolution than the that shown in the photographs. Removed SILICONE and now using liquid cement to hold prism together, this improves the imaging of the binding by not obstructing the object as much. With the addition of a mirror to the interior of one side of the prism the distortion of the image is decreased by removing multiple reflections on the opposing side of the book page.

We have filled the prism at different times with liquid silicone ($n=1.48$) and water ($n=1.33$) to observe the change in the imaging quality. Silicones refractive index ($n=1.48$) is very close to that of the current prism material plexiglass.

Before

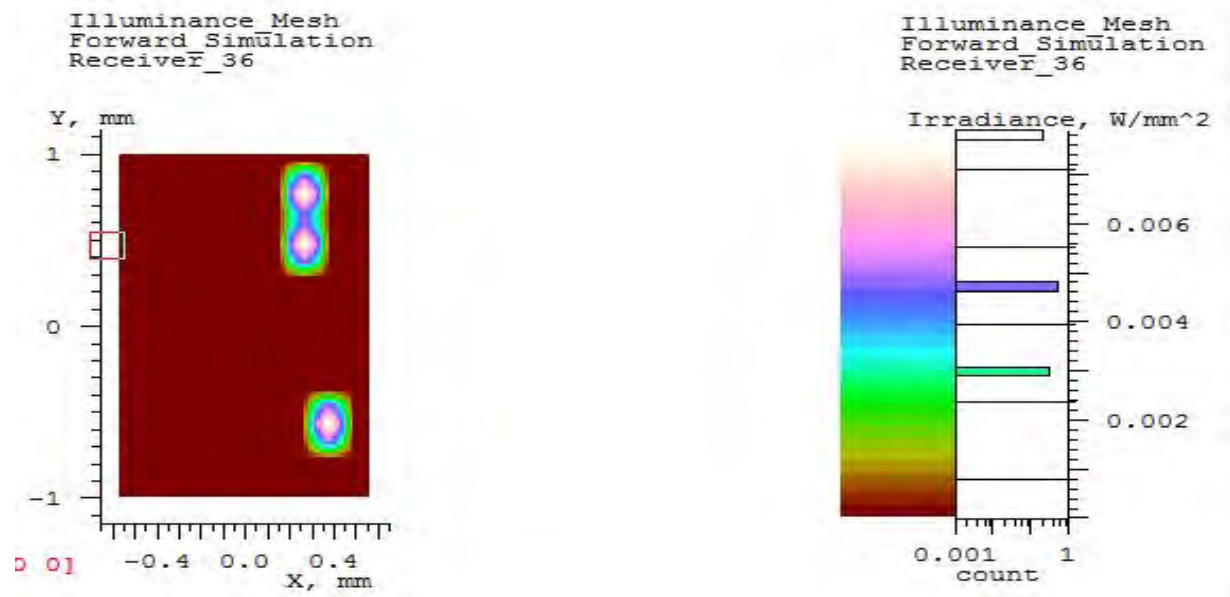


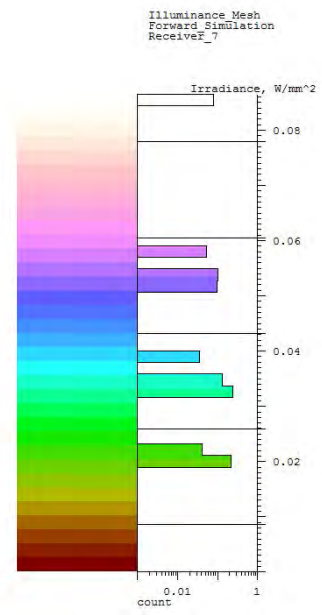
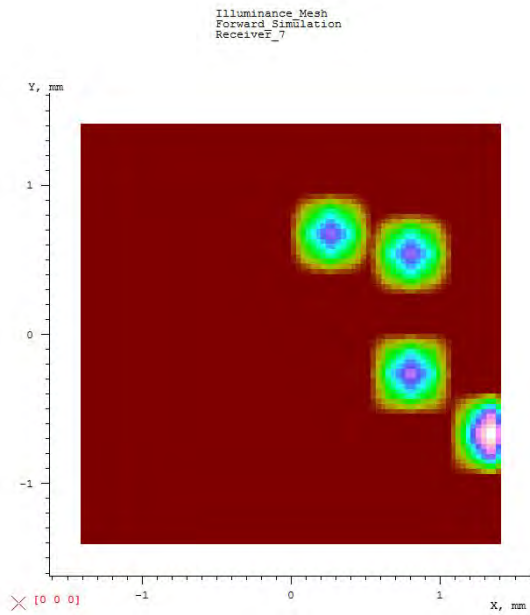
Original image

After

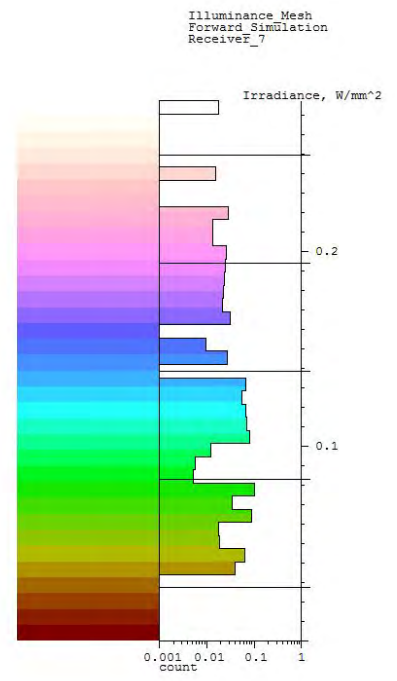
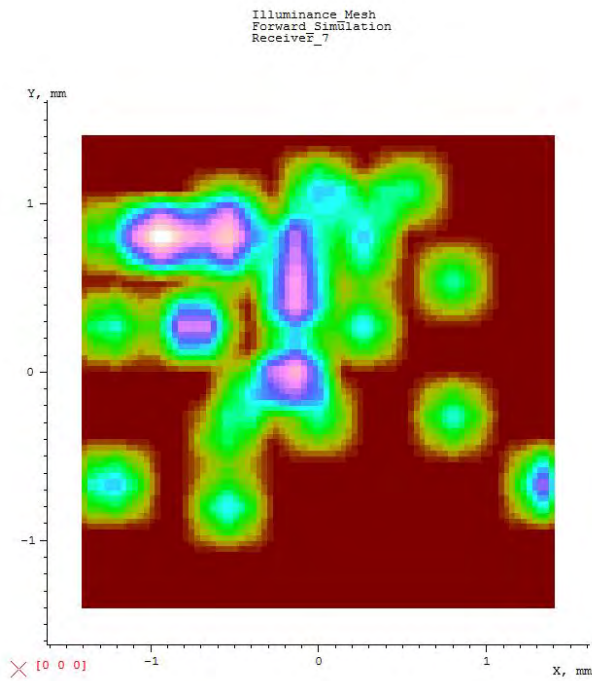


Manipulation of images through
PhotoShop Macro: By using
Transform-Perspective



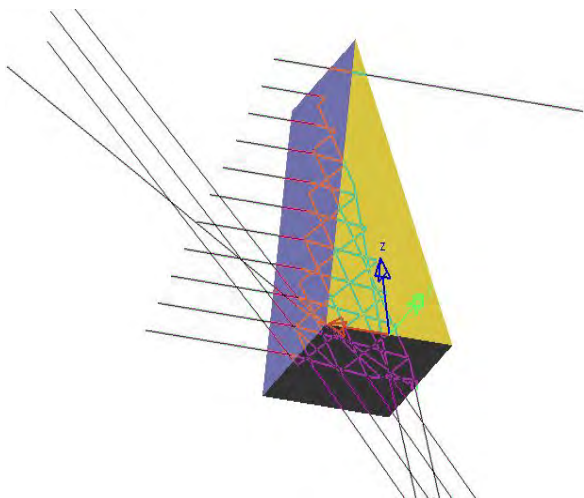


Lambertian Source Irradiance Linear polarization

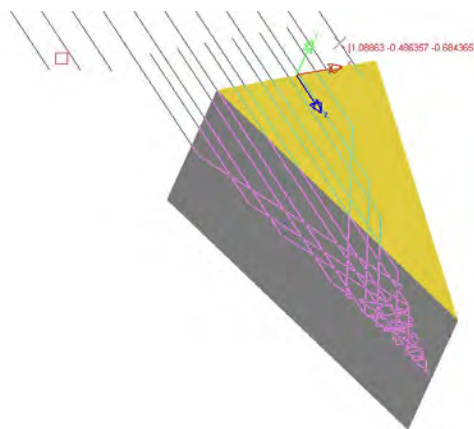


Lambertian Source Irradiance No Polarization

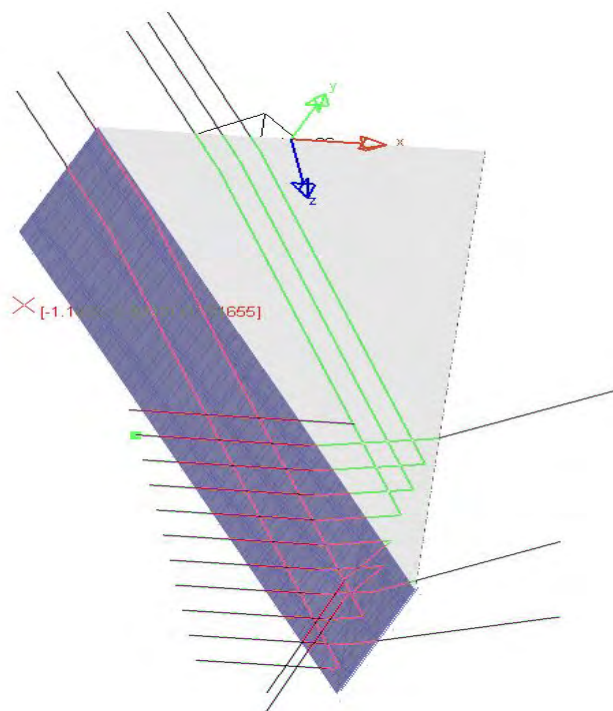
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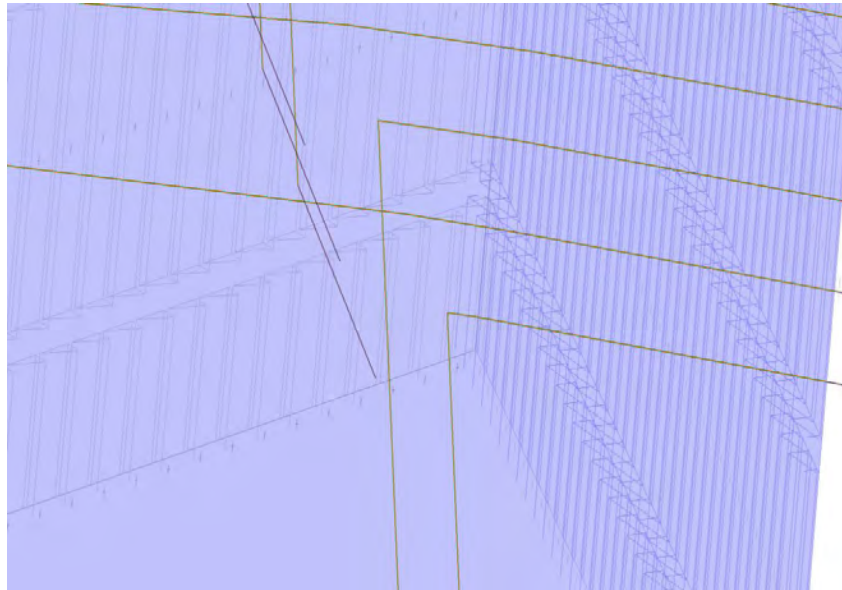
Rays from the page being imaged strike the prism surface at a 15 degree angle of incidence.



Rays from the light source strike the top prism surface at 0 degree angle of incidence.



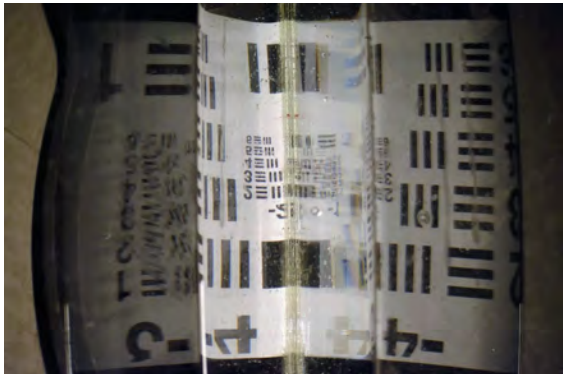

Microlens array to reduce number of reflections



Close up of array and reflecting rays

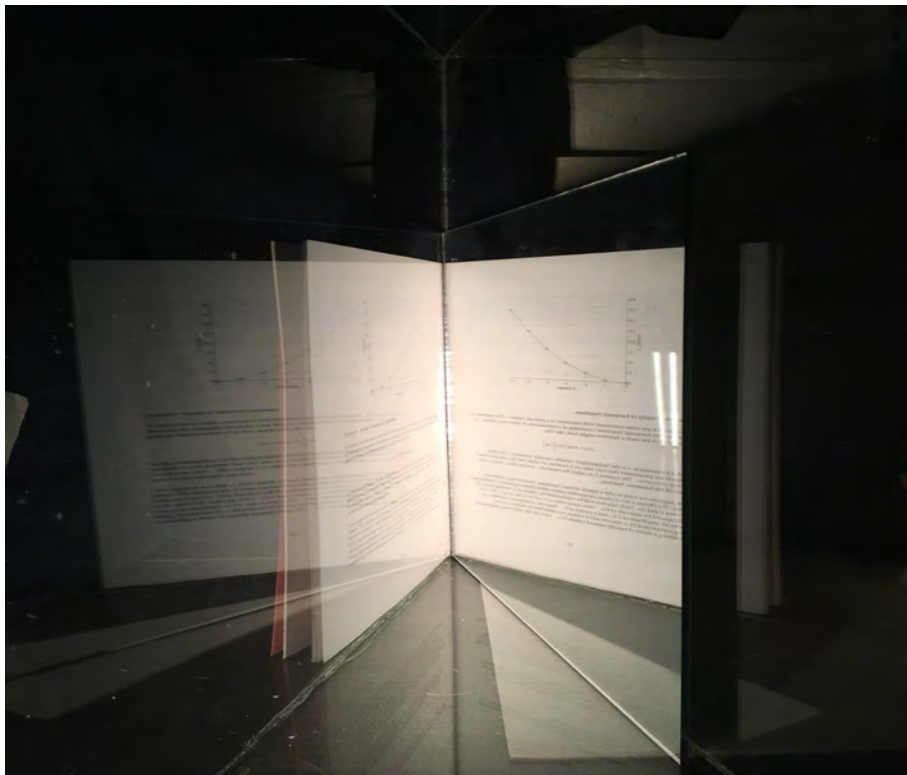
Filling liquid

In order to achieve maximum image quality, we experimented with filling our prism with different liquids with varying refractive indices. In conclusion, we found that better image quality was achieved when the prism was filled with silicone oil with $n=1.393-1.403$. As a result of this finding, we decided to use BK7 glass as our final prism design material.

 A photograph showing a prism filled with silicone oil. The prism is placed on a surface with a grid pattern. The image shows the prism's internal structure and the liquid filling it.	 A photograph showing a prism filled with water. The prism is placed on a surface with a grid pattern. The image shows the prism's internal structure and the liquid filling it.
<p>Prism filled with silicone oil, $n=1.393-1.403$.</p>	<p>Prism filled with water $n=1.33$</p>

Addition of Interior Mirror

In order to reduce the number of reflections within the prism, which was a large contributor to noise in the image quality, we decide to add an interior mirror on one side of the prism. Though this only allows us to image on page at a time instead of two pages simultaneously, the image quality is vastly improved and allows for very clear, readable images of the pages.



Addition of interior mirror

Specifications Table

Size of the Prism

Length of base	37cm
Height	68.5cm
Prism angle	30 degree

Material of the prism	<ol style="list-style-type: none"> 1. The final design will be made of N-BK7. 2. For our current prototype, the prism is made of plexiglass with thickness 2 mm, filled with silicone oil.
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*Note: due to the limit of the budget, we decided to build a prototype with plexiglass to test our project.

Scheimpflug Condition

Professor Hayworth is interested in pursuing an off axis imaging system for this project that utilizes the Scheimpflug condition.

Scheimpflug Condition applies when the object plane is non parallel with the image and lens planes, resulting in much of the image being defocused. By rotating the lens plane to the image (sensor) plane and vice versa the plane of focus(DoF) can be oriented to the object plane. The object is now utilizing less of the sensor, thus reducing the pixel count, as a result of this there will be a drop in resolution of the image.

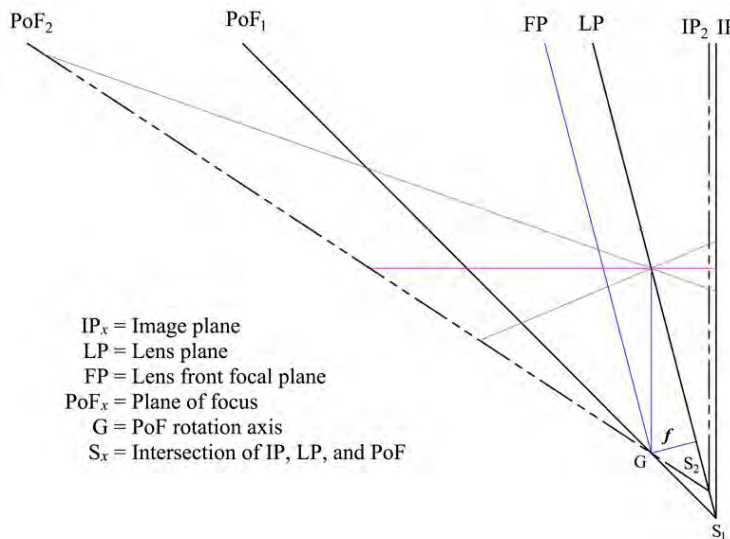
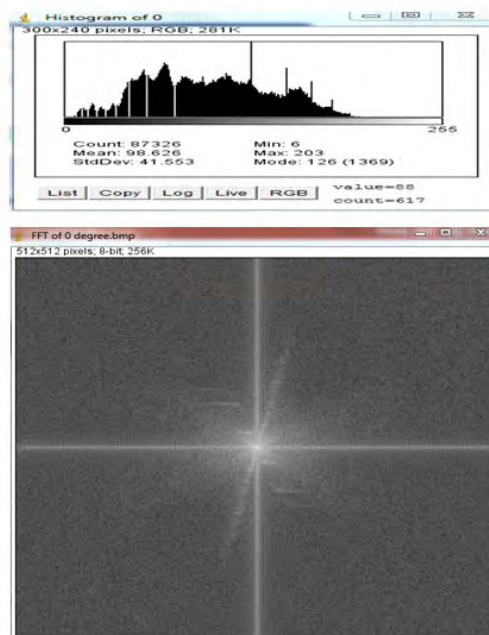
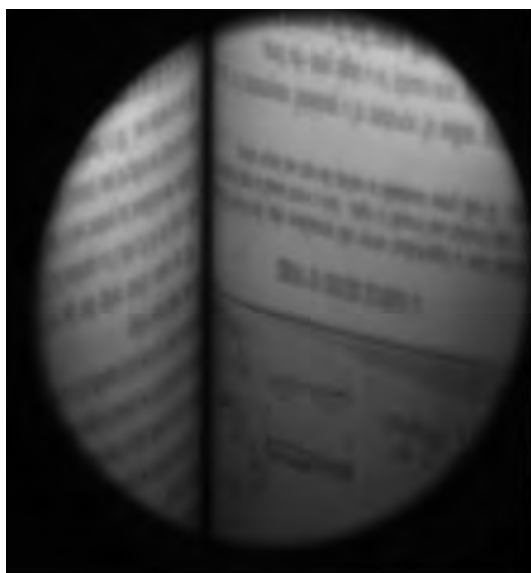


Figure 3.1 Simplified diagram; rotation-axis distance and PoF angle moved to another diagram.
By Jeff Conrad April 2007

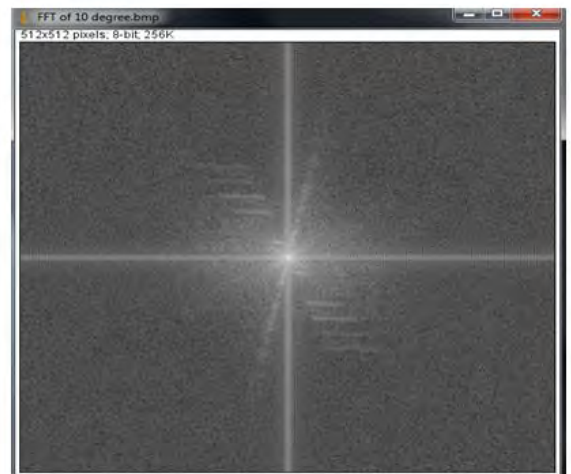
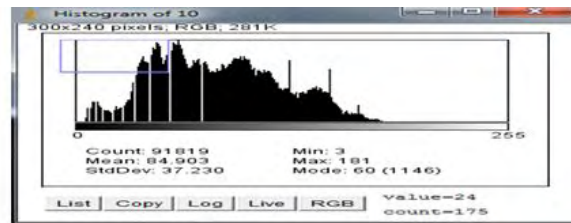
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In our design, we plan to apply scheimpflug condition to increase the depth of focus, in order to decrease the distortion of the image. We have obtained a telephoto camera lens and will begin the process of duplicating the scheimpflug condition using this lens, a resolution target at 15 degrees from normal of the lens plane, and a ccd rotated from parallel to the lens, to the angle of the highest imaging quality, about 7 degrees at 2x magnification

A system was setup to mimic the scheimpflug parameters, first with a resolution target at 15 degrees and then with a 6x8" book open 30 degrees. The Nikkor telephoto lens is coupled with a ccd which for now has a 2x mag lens. An improvement can be seen in the contrast of the image after sensor rotation. The illuminating source is a fiber light located above and just behind the telephoto lens, incident at a slight downward angle as to try and illuminate the exact points of interest.



0 degree Sensor Angle



10 degree sensor angle

We can rotate the sensor plane to intersect with the object and lens plane, projecting focal plane (DoF) parallel to an angled object. A system can be designed so that it utilizes this condition specifically for a 6x8 inch book. The periodicity of the FFT after the rotation of the image plane confirms an increase in image resolution.

In meeting with our advisor, he has suggested the use of a handheld laser scanner with the addition of a small prism to accommodate imaging closer to the binding, because of its ability to accurately and conveniently record information. All of the handheld scanners we have found require direct contact with the page of a book which is usually open 180 degrees flat. We would like to obtain a laser wand scanner to see how well it is able to scan through a thin piece of glass or a prism. The idea is that the book be brought to two pieces of thin glass that are connected at the apex, and in this apex there is a small, removable, prism that projects to image of the binding, and the entire glass surface is scannable by the laser wand with no moving parts contacting the book.

Deep Learning

To explore more possibilities to get better resolution of the binding part of the book, we worked with deep learning team to de-noise the binding part.

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Theory:

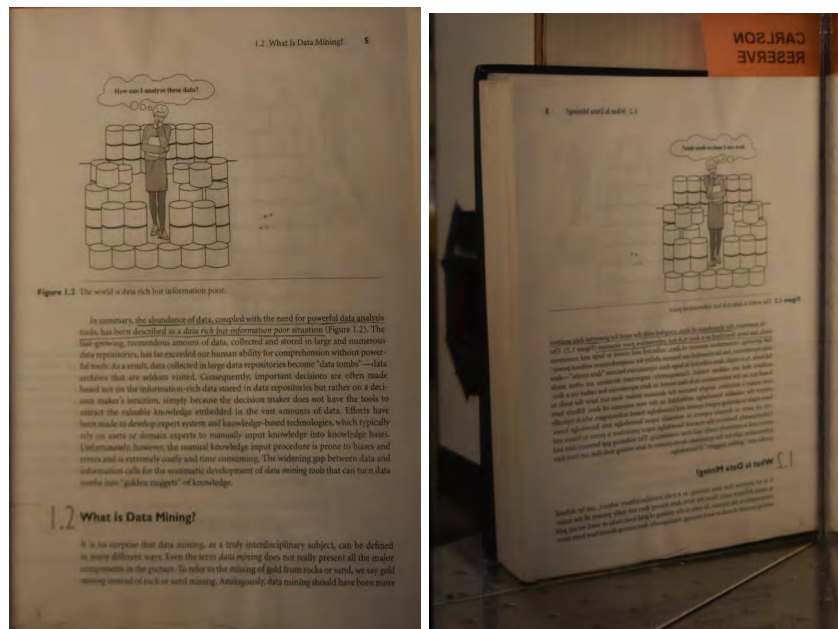
1. Mapping.
2. Simulation.

Method:

1. The image of the book in the prism needs to be taken under very specific conditions, there could be no avoidable noise in the image and only the image of the page with a clear boundary could be in the camera field. The data team will then compare the images of a book open at 30 degrees with the images of the same book in e-book edition (or the images of the same book in flat form). Then by applying the knowledge of deep learning, they will denoise the binding part of the book and achieve higher resolution.
2. The noise in the angled image is compared to the same image when flat. The deep learning team hopes to establish a relationship, through their algorithm, between these two scenarios that can then be applied to angled books with no 'base' image.

What we are responsible for: Take as many images of the book open at 30 degrees, under the same conditions and the same angle, and the image of the same book open in the flat form.

What Deep Learning Team responsible for: Apply the knowledge of deep learning to denoise the binding part of the book.



Left: image of the book open in the flat form. Right: image of the book open at 30 degrees.

Result

The following image is the image transformed by the deep learning system.



Figure 1.1. The world is data rich but information poor.

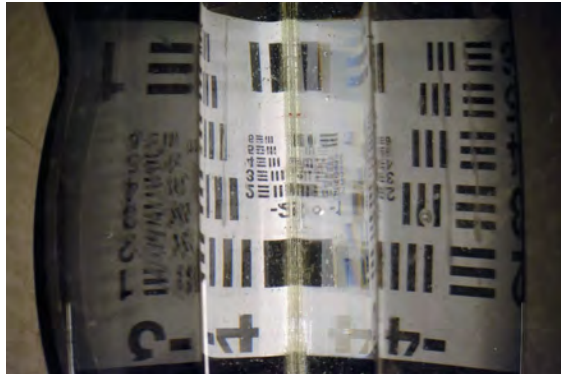
In summary, the abundance of data, coupled with the need for powerful data analysis tools, has been described as a *data rich but information poor* situation (Figure 1.2). The fast-growing, tremendous amount of data, collected and stored in large and numerous data repositories, has far exceeded our human ability for comprehension without powerful tools. As a result, data collected in large data repositories become "data tombs"—data archives that are seldom visited. Consequently, important decisions are often made based not on the information-rich data stored in data repositories but rather on a decision maker's intuition, simply because the decision maker does not have the tools to extract the valuable knowledge embedded in the vast amounts of data. Efforts have been made to develop expert system and knowledge-based technologies, which typically rely on users or domain experts to manually input knowledge into knowledge bases. Unfortunately, however, the manual knowledge input procedure is prone to biases and errors and is extremely costly and time consuming. The widening gap between data and information calls for the systematic development of *data mining tools* that can turn data tombs into "golden nuggets" of knowledge.

1.2 What is Data Mining?

It is no surprise that data mining, as a truly interdisciplinary subject, can be defined in many different ways. Even the term *data mining* does not really present all the major components in the picture. To refer to the mining of gold from rocks or sand, we say *gold mining* instead of *rock or sand mining*. Analogously, data mining should have been more

Result

For our current design, we decide to use imaging system with geometrical optics, which is composed of a light source and a prism made of N-BK7 .



Risk Assessment

Our current prism design prototype is made with plexiglass and filled with silicone oil. The main issue with the plexiglass material is that the imaging system is not stable. The current prism design is prone to leaking of the silicone. To reduce this risk, we designed a image system made of BK7. Using this material in place of plexiglass will give a much more structurally sound prism design, but the construction price will be higher.

Additionally, for this system, a light source is required. The wavelength of the light source should be chosen carefully, since some wavelengths could potentially damage the ancient manuscript. For our project, the wavelength of the light should be equal to or greater than 510 nm(green light).

Transition Plan

We will hand our instrument(prototype) and our design documents to our customers, Professor Gregory Heyworth from the English department, and Jessica Lacher-Feldman from River campus library, University of Rochester.

Appendix

A. Project Schedule and History

Fall semester	
By December	<ul style="list-style-type: none"> ● Present final Project Review Document in class ● Calculated dimensions of necessary prism size ● Create schedule for spring semester in order to test/examine all realistic prism imaging possibilities
Spring semester	
January	<ul style="list-style-type: none"> ● Month of testing design prototypes ● First order estimates of systems.
February	<ul style="list-style-type: none"> ● Further design and implementation of systems ● Look further into use of/modeling Scheimpflug condition
March	<ul style="list-style-type: none"> ● Decide on which system to pursue ● Explore Illumination
April	<ul style="list-style-type: none"> ● Work with Deep Learning Team to achieve better resolution for book binding part. ● Finalize System Design ● Build smaller prisms to easily fill with liquid ● Error checking ● Present to customer

B. Recommendations for Future Improvement

In order to get better image quality of the binding part of the book, we could use Thz to scan the binding part of the book, though it will be quite costly.

We could also use knowledge from the Deep Learning system to make the system learn to reduce noise in the image.