Simulating Focal Lenses Using Matlab Matrices

Ryan Kropp   
Electrical and Systems Engineering Department  
Washington UniversitySt. Louis, USA  
kropp.r@wustl.edu  
  
Matthew Walker   
Electrical and Systems Engineering Department  
Washington UniversitySt. Louis, USA  
matthew.r.walker@wustl.edu  
  
Robert Walsh   
Electrical and Systems Engineering Department  
Washington UniversitySt. Louis, USA  
r.j.walsh@wustl.edu

*Abstract*—Your abstract should consist of a single paragraph up to 250 words, with correct grammar and unambiguous terminology. Provide a concise summary of the project. Include the conclusions reached and the potential implications of those conclusions. It should be self-contained -- no abbreviations, footnotes, references, or mathematical equations. It also should highlight what is unique in your work.

# Introduction (*Heading 1*)

Help the reader understand why your project is important and how it could enrich your knowledge of topics in ESE 105. End with a description of the exact goal(s) or outcome(s) that your project aims to achieve.

Make this report as concise as possible -- aim for 2-3 pages. It must be no longer than 4 pages.

# Methods

**Part 1:**

To begin, we wanted to observe how focal matrices operated in **two dimensions**. Sample light rays were produced using matrices containing information on each individual ray’s x-coordinate, y-coordinate, and the angles corresponding to each dimension. The ray matrices equipped were of the following form:

Rays =

In this 2-dimensional example, only the y coordinates were relevant; the ray plots were linear functions of x, so the slope of each line was determined by y final, which depended on . The rays are the columns of the above array, and the transformed “final array” was determined using the following matrix:

M =

When the above is multiplied with the rays, each individual ray has a new x and y coordinate, calculated by adding d\*Ө. This is an approximation according to the assumption that every angle is very small, so sin(Ө) roughly equals Ө. and matrices were constructed as zeroes or d\*ones matrices so we could set all rays to begin at x = 0 and end at x = d. The ray matrices were constructed so one set of rays began at y = 0 and the other at a random point besides the origin on x = 0. The final y coordinates were calculated via matrix transformation, i.e., M\*Rays, and the lines representing the rays were plotted from initial y values to transformed y values, found in row three of the transformed matrix. The following is the result:



Where the blue and red lines represent rays from different points propagating through our 2D space.

**Part 2:**

A focal lens takes in rays like the above, and it changes the *angle* of each ray so they converge on the other side. We simulated this using code by constructing a matrix that inverted Ө depending on its orientation with respect to the x-axis, i.e., a negative Ө would be made positive. The amount by which every angle is altered depends on its distance from the center of the lens, so with a lens centered on y = 0, the transformed y coordinate derived above would be this distance. Sin(Ө2) = -y/f, and once again we use the small-angle approximation to set Ө2 = -y/f. This is the transformation matrix for this process:

Mf =

We changed the ray angles according to position and focal length f, which we set according to the equation:

Where d1 is the object’s distance to the lens, and d2 is the image’s distance to the lens. We chose f with the goal of d2 equaling d1. However, setting f equal to d1/2 did not give us an image d1 away from the lens. Instead, guess and check near this value was used to get a properly oriented image. The following is the transformation equation *after* the same propagation technique from part 1 was performed:

And its result:



In which the lens is in the middle of our object and image at x = 0.2.

**Part 3:**

For this experiment, we were also given a much larger matrix of light rays, following the same format used for our sample rays, only where we had 5 rays with 4 descriptors each, this data contained 5,000,000 rays with 4 descriptors each. In the provided data, we are given the x and y coordinates of the light rays, which describe the rays’ positions after traveling from the object to earth, or *after initial d1 transformation*. This time, both sets of coordinates and angles are important as these rays travel along the z axis towards us, propagating through 3D space.

Our goal with this data was to equip the previously used focal transformation matrices in concert with a provided rays-to-image equation to form a proper image of the light source. Using both of these, the initial image in the following figure



was transformed into this:



The astral body and its ring can now clearly be made out. The focal length of our “telescope’s lens” was initialized at 300 mm, then altered till a satisfactory image was produced. In the following equation:

d1 should be so large that 1/d2 is roughly equal to 1/f, though this is not the case. Once f was set, d2 was adjusted until image quality was satisfactory.

## Some Common Mistakes

Delete this subsection once you read it.

* The word “data” is plural, not singular.
* The subscript for the permeability of vacuum **0, and other common scientific constants, is zero with subscript formatting, not a lowercase letter “o”.
* In American English, commas, semicolons, periods, question and exclamation marks are located within quotation marks only when a complete thought or name is cited, such as a title or full quotation. When quotation marks are used, instead of a bold or italic typeface, to highlight a word or phrase, punctuation should appear outside of the quotation marks. A parenthetical phrase or statement at the end of a sentence is punctuated outside of the closing parenthesis (like this). (A parenthetical sentence is punctuated within the parentheses.)
* A graph within a graph is an “inset”, not an “insert”. The word alternatively is preferred to the word “alternately” (unless you really mean something that alternates).
* Do not use the word “essentially” to mean “approximately” or “effectively”.
* In your paper title, if the words “that uses” can accurately replace the word “using”, capitalize the “u”; if not, keep using lower-cased.
* Be aware of the different meanings of the homophones “affect” and “effect”, “complement” and “compliment”, “discreet” and “discrete”, “principal” and “principle”.
* Do not confuse “imply” and “infer”.
* The prefix “non” is not a word; it should be joined to the word it modifies, usually without a hyphen.
* There is no period after the “et” in the Latin abbreviation “et al.”.
* The abbreviation “i.e.” means “that is”, and the abbreviation “e.g.” means “for example”.

An excellent style manual for science writers is [7].

## Figures and Tables

Delete this subsection once you read it.

#### Positioning Figures and Tables: Place figures and tables at the top and bottom of columns. Avoid placing them in the middle of columns. Large figures and tables may span across both columns. Figure captions should be below the figures; table heads should appear above the tables. Insert figures and tables after they are cited in the text. Use the abbreviation “Fig. 1”, even at the beginning of a sentence.

1. Table Type Styles

| Table Head | Table Column Head | | |
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1. Sample of a Table footnote. (*Table footnote*)
2. Example of a figure caption. (*figure caption*)

Figure Labels: Use 8 point Times New Roman for Figure labels. Use words rather than symbols or abbreviations when writing Figure axis labels to avoid confusing the reader. As an example, write the quantity “Magnetization”, or “Magnetization, M”, not just “M”. If including units in the label, present them within parentheses. Do not label axes only with units. In the example, write “Magnetization (A/m)” or “Magnetization {A[m(1)]}”, not just “A/m”. Do not label axes with a ratio of quantities and units. For example, write “Temperature (K)”, not “Temperature/K”.

# Results and Discussion

Show the results that you achieved in your work and offer an interpretation of those results. Acknowledge any limitations of your work and avoid exaggerating the importance of the results.

# Conclusion

Summarize your key findings. Include important conclusions that can be drawn. Discuss benefits or shortcomings of your work and suggest future related project ideas you might like to explore in the future.

##### References

Provide citation information for all the previous publications referred to in your paper. Cite only those references that directly support your work.

The template will number citations consecutively within brackets [1]. The sentence punctuation follows the bracket [2]. Refer simply to the reference number, as in [3]—do not use “Ref. [3]” or “reference [3]” except at the beginning of a sentence: “Reference [3] was the first ...”

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