Student Preferences of Ray Tracing Methods for Understanding Geometrical Optics
Samuel Steven, Sarah Walters, and Anthony Yee, University of Rochester

1 Introduction

Optical engineering students at the University of Rochester are taught ray tracing, or calculating the path of light rays through an optical system, in the Geometrical Optics course. The method traditionally used to teach ray tracing employs what is known as a Brick Diagram. This visual tool is a table with a column representing each surface in the optical system. One can quickly calculate the path of light through the optical system by simple mathematical operations between quantities in the table. Alternatively, the student can choose to recursively apply the ray trace equations to each surface by hand without using the visual aid.

Methods of Ray Tracing
- Ray Trace equations by hand
- Brick Diagram
- Matrices
- Optical Design Software

The ray tracing equations can also be represented in matrix form. The matrix method is more practical in today’s world as computer based ray-trace programs, including optical design software, are programmed to trace rays using matrices. Although linear algebra is not a prerequisite for Geometrical Optics, only basic matrix operations are needed to calculate the path of light rays through the system. However, matrix math can be daunting for students that are unfamiliar with it.

The aim of this research is to determine whether matrices should be taught as the primary method for tracing rays. In Fall 2012, the matrix method was incorporated into the curriculum, but the Brick Diagram was still taught as the primary method for ray tracing. This research focuses specifically on determining the students’ comfort level with basic matrix math, their understanding of using matrices for ray tracing problems, and whether the students feel they could achieve the same level of understanding Geometrical Optics if they had learned how to ray trace using only the matrix method.

2 Methodology

The subjects used for our study were 40 students in the Fall 2012 Geometrical Optics course. The majority of students were sophomores, although a few freshman were taking the course a year early, and a small number of upperclassmen were taking the course as an engineering elective. We gathered data by giving two sets of surveys and a ray tracing problem which required the students to use only the matrix method.

Survey 1: Background
- Demographics
- Previous exposure to matrix math
- Comfort level with matrices

Survey 2: Preferences
- Preferred method of ray-tracing
- Method which led to greatest understanding
- Ray trace problem using matrices
- Self-evaluation of ability to solve problem
- Perceived understanding of geometrical optics using only matrix method

3 Results

The matrix math education for students in the class was varied. The graph on the left shows previous experience with matrices for students who felt comfortable using matrices (29 students) and the graph on the right shows the same for those who didn’t feel comfortable (11 students).

The students reported using the brick diagram and ray tracing by hand as their preferred method with regard to helping them understand geometrical ray tracing and reported preferring the matrix method and the optical design software least.

Most preferred method
- Ray tracing by hand: 73%
- Brick Diagram: 27%

Least preferred method
- Matrix Method: 39%
- Design Software: 56%

4 Conclusions

The majority of students felt that they would be able to sufficiently understand geometrical optics if taught only the matrix method. Nonetheless, a non-negligible amount of students were not confident that they would reach the same level of understanding geometrical optics. Students’ preferred ray trace method did not tend to correlate with previous education in matrix math, so requiring a linear algebra course as a prerequisite would likely not increase students’ preference for the matrix method. Therefore, we conclude that the use of Brick Diagrams to teach ray tracing should be continued; however, the matrix method should be taught alongside this method and given more emphasis in order to expand students’ understanding of geometrical optics by using both methods.