

Commonality Analysis for Family of Lighting Models

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1 Revision History

Date	Version	Notes
October 1, 2019	1.0	Original draft

2 Reference Material

This section records information for easy reference.

2.1 Table of Units

Throughout this document SI (Système International d’Unités) is employed as the unit system. In addition to the basic units, several derived units are used as described below. For each unit, the symbol is given followed by a description of the unit and the SI name.

symbol	unit	SI
m	length	metre
kg	mass	kilogram
s	time	second
°C	temperature	centigrade
J	energy	Joule
W	power	Watt ($W = J s^{-1}$)

2.2 Table of Symbols

The table that follows summarizes the symbols used in this document along with their units. The choice of symbols was made to be consistent with the heat transfer literature and with existing documentation for solar water heating systems. The symbols are listed in alphabetical order.

symbol	unit	description
A_C	m^2	coil surface area
A_{in}	m^2	surface area over which heat is transferred in

[Use your problems actual symbols. The si package is a good idea to use for units. —TPLT] [For the case of a generic numerical library, units will likely not be included. For instance, a linear ODE solver will not know the units of its coefficients. —TPLT]

2.3 Abbreviations and Acronyms

symbol	description
A	Assumption
DD	Data Definition
GD	General Definition
GS	Goal Statement
IM	Instance Model
LC	Likely Change
PS	Physical System Description
R	Requirement
SRS	Software Requirements Specification
Family of Lighting Models	[put your famram name here —TPLT]
T	Theoretical Model

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3 Introduction

An important part of computer graphics is modeling the lighting of objects in a virtual environment. Understanding and modeling how light interacts with objects of different materials is necessary to provide realistic lighting to virtual environments. Having an open source lighting model library that is reliable and robust would allow for new computer graphics programmers to more efficiently create scenes.

The following section provides an overview of the Commonality Analysis for a family of lighting models. This section explains the purpose of the document, scope of the family, characteristics of the intended reader, and organization of the document.

3.1 Purpose of Document

This document describes a family of lighting models to be used for computer graphics. This document is intended to be used as a reference to provide the necessary information to verify the family of models, and implement the different family members.

This document captures the problem domain, theoretical models used to address the problem, the commonalities and variabilities between members of the family, and the requirements common to those members. It serves as a starting point to the design and implementation of a library of lighting models, and will be referenced in the creation of a verification and validation plan.

3.2 Scope of the Family

The scope of the family includes the geometrical optics simulation of light interacting with material objects.

3.3 Characteristics of Intended Reader

The intended readers of this document should have understanding of Grade 12 Physics (particularly Optics) and a undergraduate Level 2 understanding of Linear Algebra and Matrix operations.

3.4 Organization of Document

This document is organized in accordance with the CA template for scientific computing software provided by Dr. Smith for CAS 741. These templates are based on work by [Smith \(2006\)](#).

4 General System Description

This section identifies the interfaces between the system and its environment, describes the potential user characteristics and lists the potential system constraints.

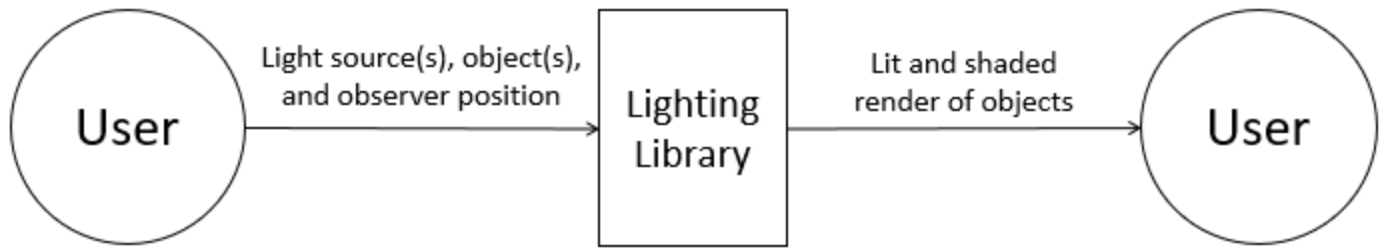


Figure 1: High level system context for Family of Lighting Models

4.1 Potential System Contexts

Figure 1 shows the high level system context. The circle represents the system user. The box is the library of lighting models system. Arrows are used to show the flow of data between the system and its environment.

- User Responsibilities:
 - Ensure that problem they are looking to solve matches the assumptions made for this family.
 - Provide information on the light source(s), object(s) in scene, and observer position.
 - Declare shading model to use from preset options.
 - Declare lighting model to use from present options.
 - Ensure application programming interface use complies with the user guide.
- Family of Lighting Models Responsibilities:
 - Calculate the reflections of all light rays coming from the light source(s).
 - Determine which light rays (reflected or from source) reach the observer.
 - Render a lit environment based on selected shading and lighting model.
 - Update the calculations and render in response to changes in the input data.
 - Detect data type mismatch, such as a string of characters instead of a floating point number.

4.2 Potential User Characteristics

The end user of Family of Lighting Models should have an Computer Science/Software Engineering Undergraduate Level 3 understanding of Computer Graphics (such as through completing the SFWR ENG/CS 3GC3) and moderate experience with programming.

4.3 Potential System Constraints

There are no system constraints.

5 Commonalities

This section presents a high-level view of the problem. It captures terminology and definitions relevant to the problem, theoretical models that are common to all members of the family, goal statements of the family, data definitions that will be used to solve these problems, as well as commonalities in inputs, calculations, and outputs.

This section also provides a background overview which explains the motivation for this work.

5.1 Background Overview

5.2 Terminology and Definitions

This subsection provides a list of terms that are used in the subsequent sections and their meaning, with the purpose of reducing ambiguity and making it easier to correctly understand the requirements:

- Geometrical Optics: The study of lights as rays.
- Reflection:
- Specular reflection:
- Diffuse reflection:
- Refraction:
- Lighting model:
- Global illumination:
- Emissive illumination:
- Ambient light: Light with no identifiable source or direction.
- Directional light: Light defined only by direction; light travels infinitely in that single direction.
- Point light: Light defined only by a point; light travels uniformly in every direction from that point, with intensity decreasing with square of distance from source.
- Spotlight: Light defined by a point and direction; light travels infinitely in a single direction from the defined source point.

- Shading model:
- OpenGL:

5.3 Data Definitions

This section collects and defines all the data needed to build the instance models. The dimension of each quantity is also given. [Modify the examples below for your problem, and add additional definitions as appropriate. —TPLT]

Number	DD1
Label	Heat flux out of coil
Symbol	q_C
SI Units	W m^{-2}
Equation	$q_C(t) = h_C(T_C - T_W(t))$, over area A_C
Description	T_C is the temperature of the coil ($^{\circ}\text{C}$). T_W is the temperature of the water ($^{\circ}\text{C}$). The heat flux out of the coil, q_C (W m^{-2}), is found by assuming that Newton's Law of Cooling applies (A??). This law (GD??) is used on the surface of the coil, which has area A_C (m^2) and heat transfer coefficient h_C ($\text{W m}^{-2} ^{\circ}\text{C}^{-1}$). This equation assumes that the temperature of the coil is constant over time (A??) and that it does not vary along the length of the coil (A??).
Sources	Citation here
Ref. By	IM??

5.4 Goal Statements

Given some light source(s), some object(s) and their respective material properties, and an observer the goal statements are:

GS1: Predict the angle of reflection of light ray(s) off the object(s).

GS2: Predict the vector(s) of reflected light ray(s) between the object and observer.

GS3: Predict the vector(s) of reflected light ray(s) between objects.

GS4: Render a fully lit and shaded scene of the objects based on the observer location.

5.5 Theoretical Models

This section focuses on the general equations and laws that Family of Lighting Models is based on.

Number	T1
Label	Law of Specular Reflection
Equation	
Description	The above equations gives the linear algebra form for the Law of Reflection. Given an incident direction \vec{d}_s
Source	http://www.efunda.com/formulae/heat_transfer/conduction/overview_cond.cfm
Ref. By	GD??

6 Variabilities

[The variabilities are summarized in the following subsections. They may each be summarized separately, like in Smith et al. (2017), or in a table, as in Smith (2006). —TPLT]

[For each variability, a description should be given, along with the parameters of variation and the binding time. The parameters of variation give the type that defines possible values. The binding time is when the variability is set. The possible values are specification time (scope time), build time and run time. —TPLT]

6.1 Assumptions

A1: All object materials are non-refractive.

A2: Light sources will all be a point light.

6.2 Calculation

- Abstract Variabilities:

—

- Data Structure Variabilities:

—

- Algorithmic Variabilities:

—

6.3 Output

7 Requirements

This section provides the functional requirements, the business tasks that the software is expected to complete, and the nonfunctional requirements, the qualities that the software is expected to exhibit.

7.1 Family of Functional Requirements

[Since the CA will often be applied to a library, the functionality will not be a single use case. Therefore, this section should summarize the family of potential requirements. A good way to provide an overview of the functional requirements would be to provide multiple use cases on how the library will be employed. —TPLT]

- R1: [Requirements for the inputs that are supplied by the user. This information has to be explicit. —TPLT]
- R2: [It isn't always required, but often echoing the inputs as part of the output is a good idea. —TPLT]
- R3: [Calculation related requirements. —TPLT]
- R4: [Verification related requirements. —TPLT]
- R5: [Output related requirements. —TPLT]

7.2 Nonfunctional Requirements

[To allow the Non-Functional Requirements (NFRs) to vary between family members, try to parameterize them. The value of the parameter is than a variability. —TPLT]

[An important variability between family members it the relative importance of the NFRs. [Smith \(2006\)](#) shows how pairwise comparisons can be used to rank the importance of NFRs. —TPLT]

[List your nonfunctional requirements. You may consider using a fit criterion to make them verifiable. —TPLT]

8 Likely Changes

- LC1: [If there is a ranking of variabilities, or combinations of variabilities, that are more likely, this information can be included here. —TPLT]

9 Traceability Matrices and Graphs

[You will have to add tables. —TPLT]

References

- W. Spencer Smith. Systematic development of requirements documentation for general purpose scientific computing software. In *Proceedings of the 14th IEEE International Requirements Engineering Conference, RE 2006*, pages 209–218, Minneapolis / St. Paul, Minnesota, 2006. URL <http://www.ifi.unizh.ch/req/events/RE06/>.
- W. Spencer Smith, John McCutchan, and Jacques Carette. Commonality analysis for a family of material models. Technical Report CAS-17-01-SS, McMaster University, Department of Computing and Software, 2017.

10 Appendix

[Your report may require an appendix. For instance, this is a good point to show the values of the symbolic parameters introduced in the report. —TPLT]

10.1 Symbolic Parameters

[The definition of the requirements will likely call for SYMBOLIC_CONSTANTS. Their values are defined in this section for easy maintenance. —TPLT]

[Advice on using the template:

- Assumptions have to be invoked somewhere
- “Referenced by” implies that there is an explicit reference
- Think of traceability matrix, list of assumption invocations and list of reference by fields as automatically generatable
- If you say the format of the output (plot, table etc), then your requirement could be more abstract
- For families the notion of binding time should be introduced
- Think of families as a library, not as a single program

—TPLT]