Software Requirements Specification for : Double Pendulum

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Contents

Revision History

Date	Version	Notes
Oct.02	1.0	Initial Draft

1 Reference Material

This section records information for easy reference.

1.1 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	**Description**	**SI Name**
kg	mass	kilogram
s	time	second
$^\circ$	angle	degree
m	length	metre
N	force	newton

Table 1: Table of Units

1.2 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
x_1	m	horizontal position of the top pendulum
x_2	m	horizontal position of the top pendulum
y_1	m	vertical position of the bottom pendulum
y_2	m	vertical position of the bottom pendulum
${x_1}'$	m/s	horizontal velocity of the top pendulum
${x_2}'$	m/s	horizontal velocity of the bottom pendulum
${y_1}'$	m/s	vertical velocity of the top pendulum
${y_2}'$	m/s	vertical velocity of the bottom pendulum
${x_1}''$	m/s^2	horizontal acceleration of the top pendulum
${x_2}''$	m/s^2	horizontal acceleration of the bottom pendulum
${y_1}''$	m/s^2	vertical acceleration of the top pendulum
${y_1}''$	m/s^2	vertical acceleration of the bottom pendulum
θ_1	$^\circ$	angle of the top pendulum(0 = vertical downwards, counter-clockwise is positive)
θ_2	$^\circ$	angle of the bottom pendulum(0 = vertical downwards, counter-clockwise is positive)
${\theta_1}'$	m/s	angular velocity of the top rod
${\theta_2}'$	m/s	angular velocity of the bottom rod
${\theta_1}''$	m/s	angular acceleration of the top rod
${\theta_2}''$	m/s	angular acceleration of the bottom rod
L_1	m	length of the top rod
L_2	m	length of the bottom rod
T_1	N	tension in the top rod
T_2	N	tension in the bottom rod
g	N/kg	gravitational constant
F_a	N	air drag force
v_air	m/s	air speed
ρ	kg/m^3	density of the air
A	m^2	cross-sectional area of the object perpendicular to ts direction of motion
C_D		drag coefficient of air
t	s	time of the motion

Table 2: Table of Symbols

1.3 Abbreviations and Acronyms

symbol	**description**
2D	Two-Dimensional
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
TM	Theoretical Model

Table 3: Abbreviations and Acronyms

2 Introduction

A double pendulum consists of two pendulums attached end to end, it's moving curve is highly sensitive to initial conditions. Therefore, it is useful to have a program to simulate the motion of double pendulum to exhibit the chaotic characteristics of it. The program documented here is called Double Pendulum.

The following section provdies an overview of Software Requirements Specification(SRS) for Double Pendulum. This section explains the purpose of this document, the scope of the requirements, the characteristics of intended reader, and the organization of document.

2.1 Purpose of Document

The purpose of the document is to provide detailed requirements of the Double Pendulum project for co-workers(CAS 741 classmates and Dr.Spencer Smith) to better understand the project, and to provide planning dor the design stage.

2.2 Scope of Requirements

The scope of the requirements includes the analysis of a two-dimentional(2D) double pendulum motion problem with various initial conditions.

2.3 Characteristics of Intended Reader

The intended readers are expected to be knowledgeable about high school physics.

2.4 Organization of Document

The following document are composed of general system description, specific description, solution characteristics specification, functional and nonfunctional requirements, likely and unlikely changes, traceability matrices and graphs, and values of auxiliary constant.

3 General System Description

This section provides general information about the system. It identifies the interfaces between the system and its environment, describes the user characteristicsand lists the system constraints.

3.1 System Context

Figure 1 shows the system context of the software. The program can be viewed abstractly following the design pattern of Inputs → Calculations → Outputs.The user provides inputs, the system does the calculations, and then provides the outputs to the user.

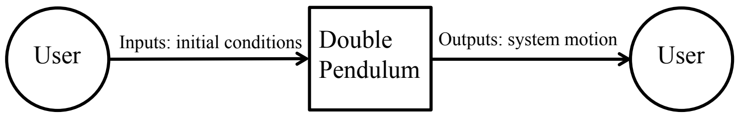


Figure 1: System Context

The responsibilities of each of the entities are listed below:

- User Responsibilities:
  - Ensure the inputs are valid
- Double Pendulum Responsibilities:
  - Detect data type mismatch, such as a string of characters instead of a floating point number
  - Do the corresponding calculations
  - Generate the graphs of angles of the robs
  - Display the graphs to users

3.2 User Characteristics

The end user should have an understanding of high school Calculus and Physics.

3.3 System Constraints

There is no system constraints for this project.

4 Specific System Description

This section first presents the problem description, which gives a high-level view of the problem to be solved. This is followed by the solution characteristics specification, which presents the assumptions, theories, definitions and finally the instance models.

4.1 Problem Description

A system is needed to efficiently and correctly predict the motion of a double pendulum.

4.1.1 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.

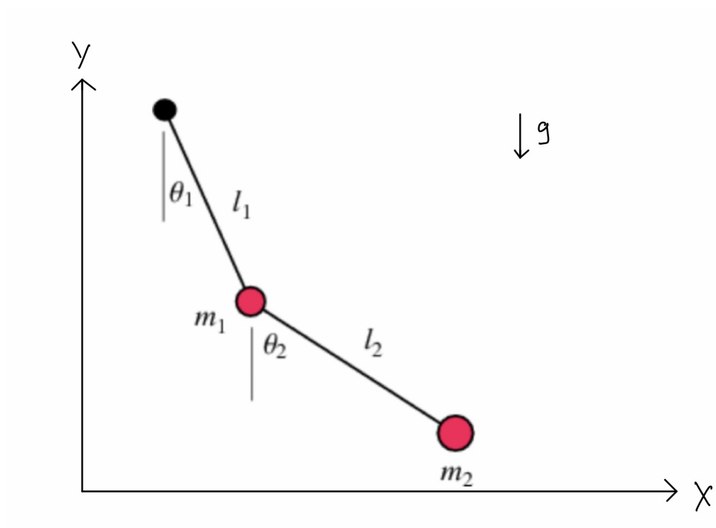


Figure 2: The physics system

- m_1: The top mass
- m_2: The bottom mass
- l_1: The top rob
- l_2: The bottom rob
- θ_1: The initial angle of the top mass
- θ_2: The initial angle of the bottom mass

- g: The gravitational constant
- Cartesian coordinate system: A coordinate system that specifies each point uniquely in a plane by a set of numerical coordinates, which are the signed distances to the point from two fixed perpendicular oriented lines, measured in the same unit of length.

4.1.2 Physical System Description

The physics system of Double Pendulum, as shown in (Section The physics system), includes the following elements:

PS1: The top mass (with initial angle θ_1)

PS2: The bottom mass (with initial angle θ_2)

PS3: The top rob

PS4: The bottom rob

4.1.3 Goal Statement

Given the masses, lengths of robs, initial angles of masses, and the gravitational constant, the goal statements are:

GS1: Show the graphs of motions of the two masses, namely the graphs of θ_1(t) and θ_2(t).

4.2 Solution Characteristics Specification

The instance models that govern Double Pendulum are presented in section Instance Models. The information to understand the meaning of the instance models and their derivation is also presented, so that the instance models can be verified.

4.2.1 Assumptions

This section simplifies the original problem and helps in developing the theoretical models by filling in the missing information for the phisical system. The assumptions refines the scope by providing more detail.

A1: The projectile motion is two-dimensional(2D). (RefBy:)

A2: A Cartesian coordinate system is used. (RefBy:)

A3: The direction of the y-axis is directly opposite to gravity. (RefBy:)

A4: The double pendulum is attached to the origin. (RefBy:)

A5: The motion is small enough that the curvature of the Earth can be neglected. (RefBy:)

A6: Time starts at zero. (RefBy:)

4.2.2 Theoretical Models

This section focuses on the general equations and laws that Double Pendulum is based on.

Refname	TM: Newton's law
Label	**Newton's laws of motion**
Equation	$$F = m * a$$
Description	F is the force(N)) m is the mass(kg) a is the acceleration($\frac{m}{s^2}$)
Source	https://www.grc.nasa.gov/www/k-12/airplane/newton.html
Ref. By	

4.2.3 General Definitions

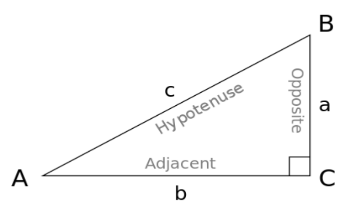
This section collects the laws and equations that will be used to build the instance models.

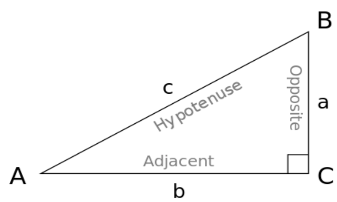
4.2.4 Data Definitions

This section collects and defines all the data needed to build the instance models.

Refname	DD: velocity
Label	**Velocity**
Equation	$$v = \frac{\partial x}{\partial t}$$
Description	v is the velocity($\frac{m}{s}$) t is the time(s) x is the position(m)
Source	http://wearcam.org/absement/Derivatives_of_displacement.htm
Ref. By	

Refname	DD: acceleration
Label	**Acceleration**
Equation	$$a = \frac{\partial v}{\partial t}$$
Description	a is the acceleration($\frac{m}{s^2}$) t is the time(s) v is the velocity($\frac{m}{s}$)
Source	http://wearcam.org/absement/Derivatives_of_displacement.htm
Ref. By	

Refname	DD: sine
Label	**Sine Rule**
Equation	$$\sin\theta = \frac{Opposite}{Hypotenuse}$$
Description	 Opposite is the length of opposite edge(m) Hypotenuse is the length of the hypotenuse edge(m)
Source	https://en.wikipedia.org/wiki/Trigonometry
Ref. By	

Refname	DD: cosine
Label	**Cosine Rule**
Equation	$$\cos\theta = \frac{Adjacent}{Hypotenuse}$$
Description	 Adjacent is the length of adjacent edge(m) Hypotenuse is the length of the hypotenuse edge(m)
Source	https://en.wikipedia.org/wiki/Trigonometry
Ref. By	

4.2.5 Instance Models

This section transforms the problem defined in section Specific System Description into one which is expressed in mathematical terms. It uses concrete symbols defined in section Data Definitions to replace the abstract symbols in the models identified in section Theoretical Models and section General Definitions.

4.2.6 Input Data Constraints

4.2.7 Properties of a Correct Solution

Number	IM1
Label	**Calculation of potential energy**
Input	m_1, g1, The input is constrained so that
Output	T
Description	T_W is the water temperature (°C). T_P is the PCM temperature (°C). T_C is the coil temperature (°C). $\tau_W = \frac{m_W C_W}{h_C A_C}$ is a constant (s). $\eta = \frac{h_P A_P}{h_C A_C}$ is a constant (dimensionless). The above equation applies as long as the water is in liquid form,.
Sources	Citation here

5 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.

5.1 Functional Requirements

This section provides the functional requirements, the tasks and behaviours that the software is expected to complete.

R1: Input the values from

R2: Check the entered input values to ensure that they do not exceed the data constraints mention in section Input Data Constraints

R3: Calculate the equation for the following values: θ_1(t) (from) and θ_1(t) (from).

R4: Output graphs of θ_1(t) (from) and θ_1(t) (from).

5.2 Nonfunctional Requirements

This section provides the non-functional requirements, the qualities that the software is expected to exhibit.

NFR5: The outputs of the code have the properties described in section Properties of a Correct Solution.

NFR6: The code is tested with complete verification and validation plan.

NFR7: The code is modularized.

NFR8: The traceability between requirements, assumptions, theoretical models, general definitions, data definitions, instance models, likely changes, unlikely changes, and modules is completely recorded in traceability matrices in teh SRS and module guide.

NFR9: The code is able to be run in different environments. The code is modularized.

6 Likely Changes

7 Unlikely Changes

8 Traceability Matrices and Graphs

9 Values of Auxiliary Constants