Software Requirements Specification for Pendulum

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Contents

1 Reference Material

This section records information for easy reference.

1.1 Table of Units

The unit system used throughout is SI (Système International d'Unités). In addition to the basic units, several derived units are also used. For each unit, Tab: ToU lists the symbol, a description and the SI name.

Symbol	Description	SI Name
°	angle	degree
kg	mass	kilogram
m	length	metre
N	force	newton
rad	angle	radian
s	time	second

Table 1: Table of Units

1.2 Table of Symbols

The symbols used in this document are summarized in Tab: ToS along with their units. Throughout the document, symbols in bold will represent vectors, and scalars otherwise. The symbols are listed in alphabetical order. For vector quantities, the units shown are for each component of the vector.

Symbol	Description	Units
a_{x}	x-component of acceleration	$\frac{\text{m}}{\text{s}^2}$
a_{y}	y-component of acceleration	$\frac{\text{m}}{\text{s}^2}$
$\mathbf{a}$	Acceleration	$\frac{\text{m}}{\text{s}^2}$
$\mathbf{F}$	Force	N
$\mathbf{g}$	Gravitational acceleration	$\frac{\text{m}}{\text{s}^2}$
$\mathbf{i}$	Unit Vector	–
L_{rod}	Length of rod	m
m	Mass	kg
${p_{\text{x}}}^{\text{i}}$	x-component of initial position	m
${p_{\text{y}}}^{\text{i}}$	y-component of initial position	m
$\mathbf{p}$	Position	m
$\mathbf{T}$	Tension	N
t	Time	s
v_{x}	x-component of velocity	$\frac{\text{m}}{\text{s}}$

Symbol	Description	Units
v_{y}	y-component of velocity	$\frac{\text{m}}{\text{s}}$
$\mathbf{v}$	Velocity	$\frac{\text{m}}{\text{s}}$
α	Angular Acceleration	$\frac{\text{rad}}{\text{s}^2}$
θ	Angle of pendulum	$^\circ$
ω	Angular Velocity	$\frac{\text{rad}}{\text{s}}$

Table 2: Table of Symbols

1.3 Abbreviations and Acronyms

Abbreviation	Full Form
2D	Two-Dimensional
A	Assumption
DD	Data Definition
GD	General Definition
GS	Goal Statement
IM	Instance Model
PS	Physical System Description
R	Requirement
SRS	Software Requirements Specification
TM	Theoretical Model
Uncert.	Typical Uncertainty

Table 3: Abbreviations and Acronyms

2 Introduction

A pendulum consists of mass attached to the end of a rod, its moving curve is highly sensitive to initial conditions Therefore, it is useful to have a program the to simulate the motion of the pendulum to exhibit the chaotic characteristics of it The program documented here is called pendulum.

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

2.1 Scope of Requirements

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

3 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, and definitions that are used.

3.1 Problem Description

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

3.1.1 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.

- Gravity: The force that attracts one physical body with mass to another.
- 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 (from [2]).

3.1.2 Physical System Description

The physical system of Pendulum, as shown in Fig:pendulum, includes the following elements:

PS1: The rod.

PS2: The mass.

3.1.3 Goal Statements

Given the the mass length of the rod, initial angle of the mass and the gravitational constant, the goal statements are:

lotion-of-the-mass: the Calculate the motion of the mass

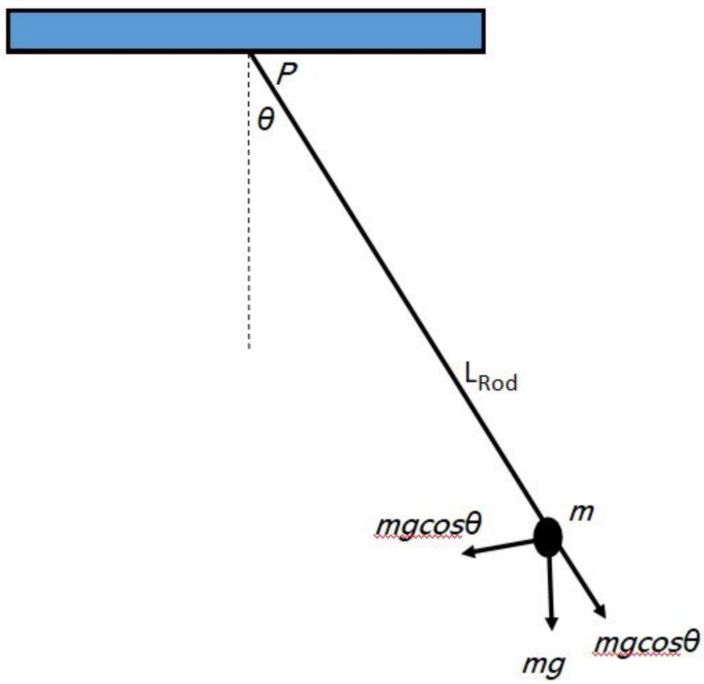

Figure 1: The physical system

3.2 Solution Characteristics Specification

The instance models that govern 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.

3.2.1 Assumptions

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

pend2DMotion: The Pendulum motion is two-dimensional (2D).

cartCoord: A Cartesian coordinate system is used

cartCoordRight: The Cartesian coordinate system is right-handed where positive x-axis. and y-axis point right up

yAxisDir: The The direction of the y-axis is directed opposite to gravity.

startOrigin: The Pendulum is attached to the origin.

3.2.2 Theoretical Models

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

Refname	TM:acceleration
Label	Acceleration
Equation	$$\mathbf{a} = \frac{d\mathbf{v}}{dt}$$
Description	$\mathbf{a}$ is the acceleration ($\frac{\text{m}}{\text{s}^2}$) t is the time (s) $\mathbf{v}$ is the velocity ($\frac{\text{m}}{\text{s}}$)
Source	[1] and [4, (pg. 7)]
RefBy	

Refname	**TM:velocity**
Label	Velocity
Equation	$$\mathbf{v} = \frac{d\mathbf{p}}{dt}$$
Description	$\mathbf{v}$ is the velocity ($\frac{\text{m}}{\text{s}}$) t is the time (s) $\mathbf{p}$ is the position (m)
Source	[3] and [4, (pg. 6)]
RefBy	

Refname	**TM:NewtonSecLawMot**
Label	Newton's second law of motion
Equation	$$\mathbf{F} = m\mathbf{a}$$
Description	$\mathbf{F}$ is the force (N) m is the mass (kg) $\mathbf{a}$ is the acceleration ($\frac{\text{m}}{\text{s}^2}$)
Notes	The net force $\mathbf{F}$ on a body is proportional to the acceleration $\mathbf{a}$ of the body, where m denotes the mass of the body as the constant of proportionality.
Source	–
RefBy	IM: calOfAngularAcceleration

3.2.3 General Definitions

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

Refname	GD:velocityIX
Label	The x-component of velocity of the pendulum
Units	$\frac{\text{m}}{\text{s}}$
Equation	$$v_{\text{x}} = \omega L_{\text{rod}} \cos(\theta)$$
Description	v_{x} is the x-component of velocity ($\frac{\text{m}}{\text{s}}$) ω is the angular velocity ($\frac{\text{rad}}{\text{s}}$) L_{rod} is the length of rod (m) θ is the angle of pendulum ($^{\circ}$)
Source	–
RefBy	

Detailed derivation of x-component velocity:

$$v_{\text{x}} = \omega L_{\text{rod}} \cos(\theta)$$

Refname	**GD:velocityIY**
Label	The y-component of velocity of the pendulum
Units	$\frac{\text{m}}{\text{s}}$
Equation	$$v_{\text{y}} = \omega L_{\text{rod}} \cos\left(\theta\right)$$
Description	v_{y} is the y-component of velocity ($\frac{\text{m}}{\text{s}}$) ω is the angular velocity ($\frac{\text{rad}}{\text{s}}$) L_{rod} is the length of rod (m) θ is the angle of pendulum ($^{\circ}$)
Source	–
RefBy	

Detailed derivation of y-component velocity:

$$v_{\text{y}} = \omega L_{\text{rod}} \cos\left(\theta\right)$$

Refname	**GD:accelerationIX**
Label	The x-component of acceleration of the pendulum
Units	$\frac{\text{m}}{\text{s}^2}$
Equation	$$a_{\text{x}} = -\omega L_{\text{rod}} \sin(\theta) + \alpha L_{\text{rod}} \cos(\theta)$$
Description	a_{x} is the x-component of acceleration ($\frac{\text{m}}{\text{s}^2}$) ω is the angular velocity ($\frac{\text{rad}}{\text{s}}$) L_{rod} is the length of rod (m) θ is the angle of pendulum (°) α is the angular acceleration ($\frac{\text{rad}}{\text{s}^2}$)
Source	–
RefBy	

Detailed derivation of x-component acceleration:

$$a_{\text{x}} = -\omega L_{\text{rod}} \sin(\theta) + \alpha L_{\text{rod}} \cos(\theta)$$

Refname	**GD:accelerationIY**
Label	The y-component of acceleration of the pendulum
Units	$\frac{\text{m}}{\text{s}^2}$
Equation	$$a_{\text{y}} = \omega L_{\text{rod}} \cos(\theta) + \alpha L_{\text{rod}} \sin(\theta)$$
Description	a_{y} is the y-component of acceleration $\left(\frac{\text{m}}{\text{s}^2}\right)$ ω is the angular velocity $\left(\frac{\text{rad}}{\text{s}}\right)$ L_{rod} is the length of rod (m) θ is the angle of pendulum (°) α is the angular acceleration $\left(\frac{\text{rad}}{\text{s}^2}\right)$
Source	–
RefBy	

Detailed derivation of y-component acceleration:

$$a_{\text{y}} = \omega L_{\text{rod}} \cos(\theta) + \alpha L_{\text{rod}} \sin(\theta)$$

Refname	**GD:hForceOnPendulum**
Label	Horizontal force on the pendulum
Units	N
Equation	$$\mathbf{F} = m a_{\text{x}} = -\mathbf{T} \sin(\theta)$$
Description	$\mathbf{F}$ is the force (N) m is the mass (kg) a_{x} is the x-component of acceleration ($\frac{\text{m}}{\text{s}^2}$) $\mathbf{T}$ is the tension (N) θ is the angle of pendulum (°)
Source	–
RefBy	

Detailed derivation of force pendulum:

$$\mathbf{F} = m a_{\text{x}} = -\mathbf{T} \sin(\theta)$$

Refname	**GD:vForceOnPendulum**
Label	Vertical force on the pendulum
Units	N
Equation	$$\mathbf{F}=m a_{\text{y}}=\mathbf{T}\cos\left(\theta\right)-m\mathbf{g}$$
Description	$\mathbf{F}$ is the force (N) m is the mass (kg) a_{y} is the y-component of acceleration ($\frac{\text{m}}{\text{s}^2}$) $\mathbf{T}$ is the tension (N) θ is the angle of pendulum (°) $\mathbf{g}$ is the gravitational acceleration ($\frac{\text{m}}{\text{s}^2}$)
Source	–
RefBy	

Detailed derivation of force pendulum:

$$\mathbf{F}=m a_{\text{y}}=\mathbf{T}\cos\left(\theta\right)-m\mathbf{g}$$

3.2.4 Data Definitions

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

Refname	**DD:positionIX**
Label	x-component of initial position
Symbol	${p_{\text{x}}}^{\text{i}}$
Units	m
Equation	$${p_{\text{x}}}^{\text{i}}=L_{\text{rod}}\sin\left(\theta\right)$$
Description	${p_{\text{x}}}^{\text{i}}$ is the x-component of initial position (m) L_{rod} is the length of rod (m) θ is the angle of pendulum (°)
Notes	${p_{\text{x}}}^{\text{i}}$ is the horizontal position ${p_{\text{x}}}^{\text{i}}$ is shown in Fig:pendulum.
Source	–
RefBy	

Refname	DD:positionIY
Label	y-component of initial position
Symbol	${p_{\text{y}}}^{\text{i}}$
Units	m
Equation	$${p_{\text{y}}}^{\text{i}}=L_{\text{rod}}\cos\left(\theta\right)$$
Description	${p_{\text{y}}}^{\text{i}}$ is the y-component of initial position (m) L_{rod} is the length of rod (m) θ is the angle of pendulum (°)
Notes	${p_{\text{y}}}^{\text{i}}$ is the vertical position ${p_{\text{y}}}^{\text{i}}$ is shown in Fig:pendulum.
Source	–
RefBy	

3.2.5 Instance Models

This section transforms the problem defined in Section: Problem 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.

Refname	**IM:calOfAngularAcceleration**
Label	Calculation of angular acceleration
Input	L_{rod}, θ
Output	α
Input Constraints	$L_{\text{rod}} > 0$ $\theta > 0$
Output Constraints	$\alpha > 0$
Equation	$\alpha = -\frac{\mathbf{g}}{L_{\text{rod}}} \sin(\theta)$
Description	α is the angular acceleration ($\frac{\text{rad}}{\text{s}^2}$) $\mathbf{g}$ is the gravitational acceleration ($\frac{\text{m}}{\text{s}^2}$) L_{rod} is the length of rod (m) θ is the angle of pendulum (°)
Notes	The constraint $\theta > 0$ is required
Source	–
RefBy	FR: Output-Values and FR: Calculate-Angular-Position-Of-Mass

Detailed derivation of angular acceleration: Using the Newton's Law in TM: NewtonSecLawMot, we have:

$$\mathbf{F} = m\mathbf{a}$$

Where $\mathbf{F}$ denotes the force, m denotes the mass and $\mathbf{a}$ denotes the acceleration Therefore:

$$-m\mathbf{g}\sin(\theta) = m\alpha$$

Then we have:

$$-\mathbf{g}\sin(\theta) = \alpha$$

the when the rod makes an θ with the vertical, displacement of the mass is given by.

$$\mathbf{T}\cos(\theta)\,\mathbf{j} - \mathbf{T}\sin(\theta) - m\mathbf{g}\mathbf{j} = mL_{\text{rod}}\left(\alpha\cos(\theta)\,\mathbf{j} - \omega^2\sin(\theta) + \alpha\sin(\theta)\,\mathbf{j} + \omega^2\cos(\theta)\,\mathbf{j}\right)$$

With the trig identity $\cos(\theta) + \sin(\theta) = 1$:

$$\mathbf{T}\cos(\theta)\,\mathbf{j} - \mathbf{T}\sin(\theta) - m\mathbf{g}\mathbf{j} = mL_{\text{rod}}\left(\alpha\cos(\theta)\,\mathbf{j} - \omega^2\sin(\theta) + \alpha\sin(\theta)\,\mathbf{j} + \omega^2\cos(\theta)\,\mathbf{j}\right)$$

3.2.6 Data Constraints

Table:InDataConstraints shows the data constraints on the input variables. The column for physical constraints gives the physical limitations on the range of values that can be taken by the variable. The uncertainty column provides an estimate of the confidence with which the physical quantities can be measured. This information would be part of the input if one were performing an uncertainty quantification exercise. The constraints are conservative, to give the user of the model the flexibility to experiment with unusual situations. The column of typical values is intended to provide a feel for a common scenario.

Var	Physical Constraints	Typical Value	Uncert.
L_{rod}	$L_{\text{rod}} > 0$	44.2 m	10%
θ	$\theta > 0$	2.1 °	10%

Table 4: Input Data Constraints

3.2.7 Properties of a Correct Solution

Table:OutDataConstraints shows the data constraints on the output variables. The column for physical constraints gives the physical limitations on the range of values that can be taken by the variable.

Var	Physical Constraints
α	$\alpha > 0$

Table 5: Output Data Constraints

4 Requirements

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

4.1 Functional Requirements

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

Input-Values: Input the values from Table:ReqInputs.

erify-Input-Values: Check the entered input values to ensure that they do not exceed the data constraints mentioned in Section: Data Constraints. If any of the input values are out of bounds, an error message is displayed and the calculations stop.

-Position-Of-Mass: Calculate the following values: α (from IM: calOfAngularAcceleration) and θ (from IM: calOfAngularAcceleration).

Output-Values: Output L_{rod} (from IM: calOfAngularAcceleration) and L_{rod} (from IM: calOfAngularAcceleration).

Symbol	Description	Units
$\mathbf{F}$	Force	N
L_{rod}	Length of rod	m
α	Angular Acceleration	$\frac{\text{rad}}{\text{s}^2}$
θ	Angle of pendulum	$^\circ$

Table 6: Required Inputs following FR: Input-Values

4.2 Non-Functional Requirements

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

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

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

5 Values of Auxiliary Constants

There are no auxiliary constants.

6 References

[1] Wikipedia Contributors. *Acceleration*. https://en.wikipedia.org/wiki/Acceleration. June 2019.

[2] Wikipedia Contributors. *Cartesian coordinate system*. https://en.wikipedia.org/wiki/Cartesian_coordinate_system. June 2019.

[3] Wikipedia Contributors. *Velocity*. https://en.wikipedia.org/wiki/Velocity. June 2019.

[4] R. C. Hibbeler. *Engineering Mechanics: Dynamics*. Pearson Prentice Hall, 2004.