Software Requirements Specification for Truss

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Revision History

Date	**Version**	**Notes**
October 8, 2020	1.0	Initial version of SRS

Contents

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	**unit**	**SI**
m	length	metre
rad	angle	radian
N	force	newton

1.2 Table of Symbols

The table that follows summarizes the symbols used in this document along with their units. The symbols are listed in alphabetical order.

symbol	**unit**	**description**
F_{Ax}	N	x-component of reaction force on joint A
F_{Ay}	N	y-component of reaction force on joint A
F_{By}	N	y-component of reaction force on joint B
F_{AC}	N	Force on truss member 1
F_{BC}	N	Force on truss member 2
F_{AD}	N	Force on truss member 3
F_{BD}	N	Force on truss member 4
F_{CD}	N	Force on truss member 5
F_{out}	N	All the output forces mentioned in the document.
F_{xi}	N	Force component in the x direction of joint i
F_{yi}	N	Force component in the y direction of joint i
F_1	N	External force
M_{i}	Nm	Moment component of joint i
S_{p}	-	Pin support
S_{r}	-	Roller support
x_1	m	Distance from joint A to joint D
x_2	m	Distance from joint D to joint B

θ_1	rad	Angle between member 1 and 3
θ_2	rad	Angle between member 2 and 4

1.3 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
T	Theoretical Model

2 Introduction

A truss is a framework that could hold something up, supporting bridges, roofs, or other structures. Knowing both motions and forces within the trusses prepares us for a better understanding of how stable the architecture is.

This document describes in detail of the Software Requirements Specification (SRS) for Truss. This section serves to explain the purpose of the document, the scope of the requirements, the characteristics of the intended reader and the organization of the document.

2.1 Purpose of Document

The primary purpose of this document is to record the requirements of the Truss project. Goals, assumptions, theoretical models, definitions, and other model derivation information are specified, allowing the reader to fully understand and verify the purpose and scientific basis of Truss. This SRS will remain abstract, describing what problem is being solved, but not how to solve it.

This document will be used as a starting point for subsequent development phases, including writing the design specification and the software verification and validation plan. The design document will show how the requirements are to be realized, including decisions on the numerical algorithms and programming environment. The verification and validation plan will show the steps that will be used to increase confidence in the software documentation and the implementation. Although the SRS fits in a series of documents that follow the so-called waterfall model, the actual development process is not constrained in any way. Even when the waterfall model is not followed, as Parnas and Clements (1985) point out, the most logical way to present the documentation is still to "fake" a rational design process.

2.2 Scope of Requirements

The scope of the requirements includes solving for unknown forces and find out their stress distribution of a ideal truss sctructure.

2.3 Characteristics of Intended Reader

Reviewers of this documentation should have an understanding of solving equilibrium forces and moments from level 3 mechanical engineering.

2.4 Organization of Document

The organization of this document follows the template for an SRS for scientific computing software proposed by Smith and Lai (2005) and Koothoor (2013). The presentation follows the standard pattern of presenting goals, theories, definitions, and assumptions. For readers that would like a more bottom up approach, they can start reading the instance models in Section 4.2.5 and trace back to find any additional information they require.

The goal statements (Section 4.1.3) are refined to the theoretical models, and the theoretical models (Section 4.2.2) to the instance models (Section 4.2.5). The data definitions (Section 4.2.4) are used to support the definitions of the different models.

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 characteristics and lists the system constraints.

3.1 System Context

Figure 1 shows the system context. A circle represents an external entity outside the software, the user in this case. A rectangle represents the software system itself (Truss). Arrows are used to show the data flow between the system and its environment.

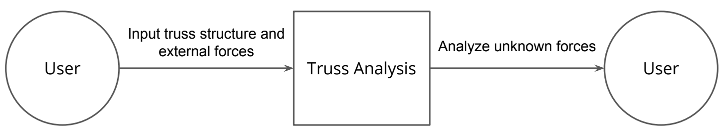


Figure 1: System Context

The interaction between the product and the user is through a user interface. The responsibilities of the user and the system are as follows:

- User Responsibilities:
  - Provide the input data to the system, ensuring no errors in the data entry.
  - Ensure that the input data is sufficient to specify a truss structure that has a unique solution.
- Truss Responsibilities:

- Detect data type mismatch, such as a string of characters instead of a floating point number.
- Determine if the inputs satisfy the required physical and software constraints.
- Solve the equilibrium equations arising from the input data to generate the output data.

3.2 User Characteristics

Level 1 engineering mechanics

The end user of Truss should have an understanding of solving equilibrium forces and moments from level 3 mechanical engineering.

3.3 System Constraints

There are no system constraints.

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 intended to analyze the unknown forces acting on truss members.

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:

- Compression: The force that squeezes materials together.
- Equilibrium: The state of an object in which all the forces acting upon it are balanced.
- Joint: A place where two trusses are connected.
- Method of Joint: A way to find unknown forces in a truss structure. The principle behind this method is that all forces acting on a joint must add to zero.
- Moment: A measure of its tendency to cause a body to rotate about a specific point or axis.

- Pin support: A kind of structural support can have both a horizontal x direction force and a vertical y direction force.
- Reaction force: The force that the support act on the structure to keep it stationary.
- Roller support: A kind of structural support can only have a vertical y direction force.
- Tension: The force that pulls materials apart.

4.1.2 Physical System Description

The physical system of Truss, as shown in Figure 2, includes the following elements:

PS1: The pin support (S_{p}).

PS2: The roller support (S_{r}).

PS3: The joints (A, B, C, and D).

PS4: Truss members (1, 2, 3, and 4).

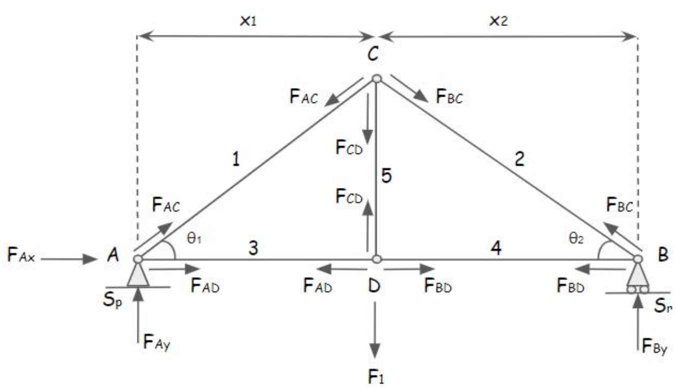


Figure 2: The physical system

4.1.3 Goal Statements

Given the truss structure and external forces, the goal statement is:

GS~~1~~2: Solve the internal forces acting on truss members.

You should also have a goal to solve for the support reactions T GS1

4.2 Solution Characteristics Specification

The instance models that govern Truss are presented in Section 4.2.5. 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 model by filling in the missing information for the physical system. The numbers given in the square brackets refer to the theoretical model [T], general definition [GD], data definition [DD], instance model [IM], or likely change [LC], in which the respective assumption is used.

A1: The structure is statically determinate. [T1, T2]

A2: All joints are connected by frictionless pins. [LC1]

A3: Truss members are connected only at their end.

A4: All the truss members are perfectly straight.

A5: The weight of the members are negligibly small which can be ignored. [LC2]

A6: All the members have only tension or compression forces. [LC3]

A7: All loads and support reactions are applied at the joints only. [T1]

You should invoke the assumptions when you use them

4.2.2 Theoretical Models

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

Number	TM1
Label	**Method of Joint**
Equation	$\sum F_{\text{xi}} = 0$ $\sum F_{\text{yi}} = 0$
Description	F_{xi} is the force component in the x direction of joint i. F_{yi} is the force component in the y direction of joint i.
Source	Wikipedia (2019)
Ref. By	-

Combine TM1 & TM2 into one theoretical model labelled "Static Equilibrium" — follow the beam example — we want to be able to reuse the TMs

Number	TM2
Label	**Equilibrium of moments**
Equation	$\sum M_{\mathrm{i}} = 0$
Description	M_{i} is the moment component of joint i. We will use moments to find the reaction forces at the supports.
Source	Wikipedia (2020)
Ref. By	DD2, DD3

4.2.3 General Definitions

There are no general definitions.

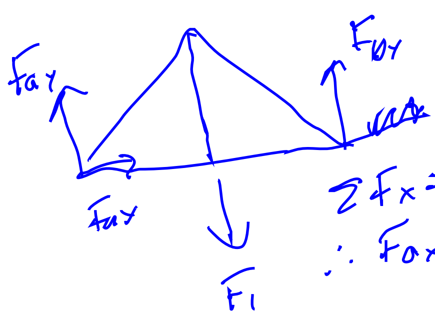
4.2.4 Data Definitions

This section collects and defines all the data needed to build the instance models. The dimension of each quantity is also given.

make this an instance model, ∵ you are adding GS1 for solving the support reactions

Number	~~DD1~~
Label	**Support reaction force on joint A in the x direction**
Symbol	F_{Ax}
Units	N
Equation	$F_{\mathrm{Ax}} = 0$
Description	F_{Ax} is the support reaction force on joint A in the x direction (N).
Notes	Because joint A is pinned, there is a reacting force in the x direction, F_{Ax}. However, there is no other load applied to this truss has x-component and therefore it must be zero.
Sources	-
Ref. By	T1

The result is correct, but the reason is wrong. You apply the equations for static equilib. to the entire truss, not a section



$\Sigma F_x = 0$

$\therefore F_{Ax} = 0$

make an IM

glve the equation isolated to solve for F_{Ay}

Number	DD2
Label	**Support reaction force on joint A in the y direction**
Symbol	F_{Ay}
Units	N
Equation	$\sum M_{\text{B}} = F_1 \cdot x_2 - F_{\text{Ay}} \cdot (x_1 + x_2) = 0$
Description	F_{Ay} is the support reaction force on joint A in the y direction (N). F_1 is the given external force (N). x_1 is the distance between joint A and joint D (m). x_2 is the distance between joint D and joint B (m).
Notes	F_{Ay} contributes a negative moment because it causes a clockwise moment about B. F_1 contributes a positive moment because it causes a counterclockwise moment about B. x_1 and x_2 are shown in figure 2.
Sources	-
Ref. By	T2

say where you are taking your moments about

(pt. B)

Invoke the assumptions as you use them. For instance when you calculate the member reactions you do not need to sum moments because the connections are pin connections (A2)

Same comments as for F_{Ay}

Number	DD3
Label	**Support reaction force on joint B in y direction**
Symbol	F_{By}
Units	N
Equation	$\sum M_{\text{A}} = F_{\text{By}} \cdot (x_1 + x_2) - F_1 \cdot x_1 = 0$
Description	F_{By} is the support reaction force on joint B in the y direction (N). F_1 is the given external force (N). x_1 is the distance between point A and point D (m). x_2 is the distance between point D and point B (m).
Notes	F_{By} contributes a positve moment because it causes a counterclockwise moment about A. F_1 contributes a negative moment because it causes a clockwise moment about B. x_1 and x_2 are shown in figure 2.
Sources	-
Ref. By	T2

4.2.5 Instance Models

This section transforms the problem defined in Section 4.1 into one which is expressed in mathematical terms. It uses concrete symbols defined in Section 4.2.4 to replace the abstract symbols in the models identified in Sections 4.2.2 and 4.2.3.

The goal GS1 is met by IM1, IM2, and IM3.

write in the form that explicitly solves for F_{AC} & F_{AD} ?

same comment for the other

Number	IM1
Label	**Solving for internal forces at point A**
Input	F_{Ay}, θ_1
Output	F_{AC}, F_{AD}
Equation	$\sum F_{\text{y}} = F_{\text{Ay}} + F_{\text{AC}} \cdot \sin\theta_1 = 0$ $\sum F_{\text{x}} = F_{\text{AD}} + F_{\text{AC}} \cdot \cos\theta_1 = 0$
Description	F_{AC} is the force in truss 1 (N). F_{AD} is the force in truss 3 (N). F_{Ay} is the support reaction force at point A in the y direction (N). θ_1 is the angle between truss 1 and truss 3 (rad).
Sources	-
Ref. By	T1, DD2

Number	IM2
Label	**Solving for internal forces at point B**
Input	F_{By}, θ_2
Output	F_{BC}, F_{BD}
Equation	$\sum F_{\text{y}} = F_{\text{By}} + F_{\text{BC}} \cdot \sin\theta_2 = 0$ $\sum F_{\text{x}} = F_{\text{BD}} + F_{\text{BC}} \cdot \cos\theta_2 = 0$
Description	F_{BC} is the force in truss 2 (N). F_{BD} is the force in truss 4 (N). F_{By} is the support reaction force at point B in the y direction (N). θ_2 is the angle between truss 2 and truss 4 (rad).
Sources	-
Ref. By	T1, DD3

Number	IM3
Label	**Solving for internal forces at point D**
Input	F_1
Output	F_{CD}
Equation	$\sum F_{\text{y}} = F_{\text{CD}} - F_1 = 0$
Description	F_{CD} is the force in truss 5 (N). F_1 is the given external force (N).
Sources	-
Ref. By	T1

4.2.6 Data Constraints

Table 1 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 column for software constraints restricts the range of inputs to reasonable values. The software constraints will be helpful in the design stage for picking suitable algorithms. 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. 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.

Table 1: Input Data Constraints

Var	Physical Constraints	Software Constraints	Typical Value	Uncertainty
F_1	$F_1 > 0$	$F_{\text{min}} \leq F_1 \leq F_{\text{max}}$	500 N	10%
x_1	$x_1 > 0$	$d_{\text{min}} \leq x_1 \leq d_{\text{max}}$	3 m	10%
x_2	$x_2 > 0$	$d_{\text{min}} \leq x_2 \leq d_{\text{max}}$	7 m	10%
θ_1	$0 < \theta_1 < \pi$	$0 < \theta_1 < \frac{\pi}{2}$	$\frac{\pi}{6}$ rad	10%
θ_2	$0 < \theta_2 < \pi$	$0 < \theta_2 < \frac{\pi}{2}$	$\frac{\pi}{6}$ rad	10%

4.2.7 Properties of a Correct Solution

Table 2 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.

Table 2: Output Data Constraints

Var	Physical Constraints
F_{out}	$F_{\text{out}} > 0$

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

R1: Input the values from Table 3.

R2: Check the entered input values to ensure that they do not exceed the data constraints mentioned in Section 4.2.6. If any of the input values are out of bounds, an error message is displayed and the calculations stop.

R3: Calculate equilibrium equations on all joints in both the x and y direction.

R4: Output F_{AC} and F_{AD} via IM1, F_{BC} and F_{BD} via IM2, and F_{CD} via IM3.

R5: Analyze what kind of forces those outputs are from Table 4.

5.2 Nonfunctional Requirements

- Correct: The outputs of the code have the properties described in Section 4.2.7.
- Verifiable: The code is tested with complete verification and validation plan.
- Understandable: The code is modularized with complete module guide and module interface specification.
- Reusable: The code is modularized.

These are the things you do to achieve the NFRs, not the requirements themselves

These are not verifiable

Table 3: Required Inputs

Symbol	Description	Units
F_1	External force	N
x_1	Distance from joint A to joint D	m
x_2	Distance from joint D to joint B	m
θ_1	Angle between member 1 and 3	rad
θ_2	Angle between member 2 and 4	rad

I've added some ideas to the SRS template in the blank project that you might find helpful

Table 4: Output Variables

Value	Stress Distribution
$F_{\text{out}} > 0$	Tension
$F_{\text{out}} < 0$	Compression

- Maintainable: 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 the SRS and module guide.
- Portable: The code is able to be run in different environments.

6 Likely Changes

space

This section lists the likely changes to be made to the software.

LC1: Joints may not connected by pins.[A2]

LC2: The software may be changed to consider the weight of the trusses. [A5]

LC3: There are other forces involved in (e.g., shearing and bending). [A6]

7 Unlikely Changes

This section lists the unlikely changes to be made to the software.

UC1: The goal of the system is to find out the internal forces.

UC2: The truss structure is statically determinate.

UC3: The truss members are straight.

8 Traceability Matrices and Graphs

The purpose of the traceability matrices is to provide easy references on what has to be additionally modified if a certain component is changed. Every time a component is changed, the items in the column of that component that are marked with an "X" may have to be modified as well. Table 5 shows the dependencies of theoretical models, general definitions, data definitions, and instance models with each other. Table 6 shows the dependencies of instance models, requirements, and data constraints on each other. Table 7 shows the dependencies of theoretical models, general definitions, data definitions, instance models, and likely changes on the assumptions.

	T1	T2	DD1	DD2	DD3	IM1	IM2	IM3
T1								
T2								
DD1	X							
DD2		X						
DD3		X						
IM1	X			X				
IM2	X				X			
IM3	X							

Table 5: Traceability Matrix Showing the Connections Between Items of Different Sections

	IM1	IM2	IM3	4.2.6
R1				
R2				X
R3				
R4	X	X	X	
R5				

Table 6: Traceability Matrix Showing the Connections Between Requirements and Instance Models

	A1	A2	A3	A4	A5	A6	A7
T1	X						X
T2	X						
DD1	X						X
DD2	X						
DD3	X						
IM1	X						X
IM2	X						X
IM3	X						X
LC1		X					
LC2					X		
LC3						X	

Table 7: Traceability Matrix Showing the Connections Between Assumptions and Other Items

9 Values of Auxiliary Constants

This section contains the standard values that are used for calculations in Truss.

Symbol	Description	Value	Units
π	ratio of circumference to diameter for any circle	3.14159265	-

Table 8: Auxiliary Constants

Pi is defined mathematically, you do not need to give it a value

Fmin etc should be defined

References

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