

# Software Requirements Specification for Truss

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## Revision History

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

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# 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
$d_{\max}$	m	Maximum value for distance
$d_{\min}$	m	Minimum value for distance
$F_{Ax}$	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
$F_{\max}$	N	Maximum value for external force
$F_{\min}$	N	Minimum value for external force
$F_{\text{out}}$	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
$\theta_1$	rad	Angle between member 1 and 3
$\theta_2$	rad	Angle between member 2 and 4
$\theta_{\max}$	rad	Maximum value for angle
$\theta_{\min}$	rad	Minimum value for angle

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### 1.3 Abbreviations and Acronyms

symbol	description
A	Assumption
DD	Data Definition
GD	General Definition
GS	Goal Statement
IM	Instance Model
LC	Likely Change
NFR	Nonfunctional Requirement
PS	Physical System Description
R	Requirement
SRS	Software Requirements Specification
T	Theoretical Model

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## 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.

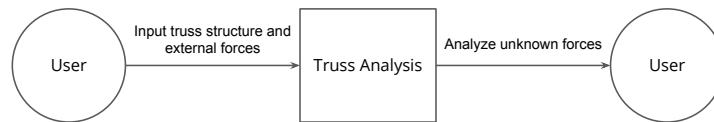


Figure 1: System Context

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

The end user of Truss should have an understanding of solving equilibrium forces and moments from level 1 engineering mechanic.

## 3.3 System Constraints

There are no system constraints.

# 4 Specific System Description

This section first presents the problem description (Section 4.1), which gives a high-level view of the problem to be solved. This is followed by the solution characteristics specification (Section 4.2), 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.
- Force equilibrium: a body is in force equilibrium if the sum of all the forces acting on the body is zero.
- 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: moment of a force, also called *torque*, is the tendency to cause a body to rotate about a specific point or axis.
- Moment equilibrium: a body is in moment equilibrium if the sum of all the moments of all the forces acting on the body is zero.
- Pin support: a kind of structural support can have both a horizontal x direction force and a vertical y direction force.
- Reaction force: an external force on a body which is contributed by its supports or connections.
- 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).

#### 4.1.3 Goal Statements

Given the truss properties and the external force, the goal statement is:

GS1: Solve the support reaction forces.

GS2: Solve the internal forces acting on truss members.

GS3: Determine the stress distribution for each internal force.

## 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.



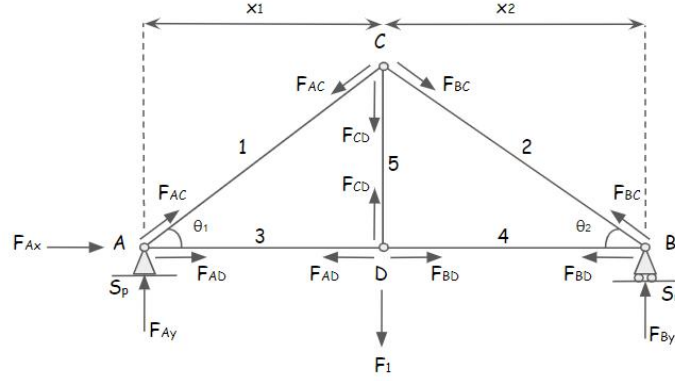


Figure 2: The physical system

#### 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]
- 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.

#### 4.2.2 Theoretical Models

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

Number	TM1
Label	<b>Static equilibrium</b>
Equation	$\sum F_{xi} = 0$ $\sum F_{yi} = 0$ $\sum M_i = 0$
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. $M_i$ is the moment component of joint i.
Source	<a href="#">Wikipedia (2019)</a> , <a href="#">Wikipedia (2020)</a>
Ref. By	A1

#### 4.2.3 General Definitions

There are no general definitions.

#### 4.2.4 Data Definitions

There are no data definitions.

#### 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 GS2 is met by IM4, IM5, and IM6.

Number	IM1
Label	<b>Support reaction force on joint A in the x direction</b>
Input	-
Output	$F_{Ax}$
Equation	$F_{Ax} = 0$
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, $F_{Ax}$ . We apply the static equilibrium to solve the reaction force, since $\sum F_x = 0$ , $F_{Ax} = 0$ .
Sources	-
Ref. By	A2, T1

Number	IM2
Label	<b>Support reaction force on joint A in the y direction</b>
Input	$F_1, x_1, x_2$
Output	$F_{Ay}$
Equation	$F_{Ay} = F_1 \cdot x_2 / (x_1 + x_2)$
Description	<p><math>F_{Ay}</math> is the support reaction force on joint A in the y direction (N).</p> <p><math>F_1</math> is the given external force (N).</p> <p><math>x_1</math> is the distance between joint A and joint D (m).</p> <p><math>x_2</math> is the distance between joint D and joint B (m).</p>
Notes	<p>The equation is from <math>\sum M_B = F_1 \cdot x_2 - F_{Ay} \cdot (x_1 + x_2) = 0</math>.</p> <p><math>F_{Ay}</math> contributes a negative moment because it causes a clockwise moment about B.</p> <p><math>F_1</math> contributes a positive moment because it causes a counterclockwise moment about B.</p> <p><math>x_1</math> and <math>x_2</math> are shown in figure 2.</p>
Sources	-
Ref. By	A2, T1

Number	IM3
Label	<b>Support reaction force on joint B in the y direction</b>
Input	$F_1, x_1, x_2$
Output	$F_{By}$
Equation	$F_{By} = F_1 \cdot x_1 / (x_1 + x_2)$
Description	<p><math>F_{By}</math> is the support reaction force on joint B in the y direction (N).</p> <p><math>F_1</math> is the given external force (N).</p> <p><math>x_1</math> is the distance between point A and point D (m).</p> <p><math>x_2</math> is the distance between point D and point B (m).</p>
Notes	<p>The equation is from <math>\sum M_A = F_{By} \cdot (x_1 + x_2) - F_1 \cdot x_1 = 0</math>.</p> <p><math>F_{By}</math> contributes a positive moment because it causes a counterclockwise moment about A.</p> <p><math>F_1</math> contributes a negative moment because it causes a clockwise moment about B.</p> <p><math>x_1</math> and <math>x_2</math> are shown in figure 2.</p>
Sources	-
Ref. By	A2, T1

Number	IM4
Label	<b>Solving for internal forces at point A</b>
Input	$F_{Ay}, \theta_1$
Output	$F_{AC}, F_{AD}$
Equation	$F_{AC} = -F_{Ay} / \sin \theta_1$ $F_{AD} = -F_{AC} \cdot \cos \theta_1$
Description	<p><math>F_{AC}</math> is the force in truss 1 (N).</p> <p><math>F_{AD}</math> is the force in truss 3 (N).</p> <p><math>F_{Ay}</math> is the support reaction force at point A in the y direction (N).</p> <p><math>\theta_1</math> is the angle between truss 1 and truss 3 (rad).</p>
Notes	$\sum F_y = F_{Ay} + F_{AC} \cdot \sin \theta_1 = 0$ $\sum F_x = F_{AD} + F_{AC} \cdot \cos \theta_1 = 0$
Sources	-
Ref. By	T1

Number	IM5
Label	<b>Solving for internal forces at point B</b>
Input	$F_{By}, \theta_2$
Output	$F_{BC}, F_{BD}$
Equation	$F_{BC} = -F_{By} / \sin \theta_2$ $F_{BD} = -F_{BC} \cdot \cos \theta_2$
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). $\theta_2$ is the angle between truss 2 and truss 4 (rad).
Notes	$\sum F_y = F_{By} + F_{BC} \cdot \sin \theta_2 = 0$ $\sum F_x = F_{BD} + F_{BC} \cdot \cos \theta_2 = 0$
Sources	-
Ref. By	T1

Number	IM6
Label	<b>Solving for internal forces at point D</b>
Input	$F_1$
Output	$F_{CD}$
Equation	$F_{CD} = F_1$
Description	$F_{CD}$ is the force in truss 5 (N). $F_1$ is the given external force (N).
Notes	$\sum F_y = F_{CD} - F_1 = 0$
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
$F_1$	$F_1 > 0$	$F_{\min} \leq F_1 \leq F_{\max}$	500 N	10%
$x_1$	$x_1 > 0$	$d_{\min} < x_1 \leq d_{\max}$	3 m	10%
$x_2$	$x_2 > 0$	$d_{\min} < x_2 \leq d_{\max}$	7 m	10%
$\theta_1$	$0 < \theta_1 < \pi$	$\theta_{\min} < \theta_1 < \theta_{\max}$	$\frac{\pi}{6}$ rad	10%
$\theta_2$	$0 < \theta_2 < \pi$	$\theta_{\min} < \theta_2 < \theta_{\max}$	$\frac{\pi}{6}$ 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
$F_{\text{out}}$	$F_{\text{out}} > 0$

## 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 via IM1, IM2, and IM3.
- R4: Output  $F_{AC}$  and  $F_{AD}$  via IM4,  $F_{BC}$  and  $F_{BD}$  via IM5, and  $F_{CD}$  via IM6.
- R5: Analyze what kind of forces those outputs are from Table 4.

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
$\theta_1$	Angle between member 1 and 3	rad
$\theta_2$	Angle between member 2 and 4	rad

Table 4: Output Variables

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

## 5.2 Nonfunctional Requirements

- NFR1: **Accuracy.** The accuracy of the computed solutions should meet the level needed for structural mechanic and have the properties described in Section 4.2.7.
- NFR2: **Verifiability.** The properties of the software should be able to tested easily through verification and validation plan.



- NFR3: **Understandability.** The source code and the design of the software should be easy to understand by a new developer.
- NFR4: **Portability.** The software is able to run on different environments, such as Windows, MacOS, and Linux.
- NFR5: **Maintainability.** The software can be modified and improved easily.
- NFR6: **Reliability.** The probability of failure-free software operation for required functions for a specified period of time.
- NFR7: **Usability.** The system should be easy to learn and use.

## 6 Likely Changes

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. [GS2]
- UC2: The truss structure is statically determinate. [A1]
- UC3: The truss members are straight. [A4]

## 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	IM1	IM2	IM3	IM4	IM5	IM6
T1							
IM1	X						
IM2	X						
IM3	X						
IM4	X		X				
IM5	X			X			
IM6	X						

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

	IM1	IM2	IM3	IM4	IM5	IM6	4.2.6
R1							
R2							X
R3	X	X	X				
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		
IM1	X	X					
IM2	X	X			X		
IM3	X	X			X		
IM4	X					X	X
IM5	X					X	X
IM6	X					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

Table 8 contains the standard values that are used for calculations in Truss.

Symbol	Description	Value	Units
$F_{\max}$	the maximum value for external force	100000	N
$F_{\min}$	the minimum value for external force	-100000	N
$d_{\max}$	the maximum value for distance	100000	m
$d_{\min}$	the minimum value for distance	0	m
$\theta_{\max}$	the maximum value for angle	90	rad
$\theta_{\min}$	the minimum value for angle	0	rad

Table 8: Auxiliary Constants

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