Program Family Title

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1 Revision History

Date	Version	Notes
Date 1	1.0	Notes
Date 2	1.1	Notes

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 ($\mathrm{W} = \mathrm{J\,s^{-1}}$)

[Only include the units that your CA actually uses. If there are no units for your problem, like for a general purpose library, you should still include the heading, with the content "not applicable" (or similar). —SS]

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. —SS]

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
FamName	[put your famram name here —SS]
T	Theoretical Model

[Add any other abbreviations or acronyms that you add —SS]

Contents

3 Introduction

[This CA template is based on Smith (2006). It will get you started, but you will have to make changes. Any changes to section headings should be approved by the instructor, since that implies a deviation from the template. Although the bits shown below do not include type information, you may need to add this information for your problem. —SS]

[Feel free to change the appearance of the report by modifying the LaTeX commands. —SS]

3.1 Purpose of Document

3.2 Scope of the Family

3.3 Characteristics of Intended Reader

The reader is expected to have some undergraduate STEM background. Ideally, they have been exposed to some calculus and programming courses.

3.4 Organization of Document

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.

4.1 Potential System Contexts

[Your system context will likely include an explicit list of user and system responsibilities —SS]

- User Responsibilities:
  - Provide a non-stiff continuous ODE to FamName for which an accurate solution can be obtained using RK4 (see T2)
  - Correctly process the resulting interpolated spline function
- FamName Responsibilities:
  - Generate (in a type-safe manner) a family member which contains a spline that approximates the given ODE.
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4.2 Potential User Characteristics

The most common user of FamName will be other programs. However, one or more programmers are needed to write the code that calls the function(s) provided by this family.

These programmers therefore should have an understanding of undergraduate Level 1 Calculus.

4.3 Potential System Constraints

The responsibility of generating family members in a type-safe way restricts the system to the MetaOCaml extension of the OCaml programming language.

5 Commonalities

5.1 Background Overview

There are various numerical methods for approximating ordinary differential equation (ODE), such as the Runge-Kutta methods (which include Euler's method).

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:

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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. —SS]

Number	DD1
Label	**Ordinary Differential Equation (ODE)**
Symbol	$\mathbf{f}$
Units	$\mathbb{R} \times \mathbb{C}^n \rightarrow \mathbb{C}^n$
Equation	$\mathbf{x}' = \mathbf{f}(t, \mathbf{x}(t))$
Description	$\mathbf{f}$ is the equation for which we ultimately want to find a numerical approximation.
Sources	**?**
Ref. By	IM**??**

Number	DD2
Label	**Initial values**
Symbol	a, b
Units	$\mathbb{R} \times \mathbb{R}$
Equation	
Description	The interval for which to solve the ODE (see DD1). a represents the beginning of the interval, b the end.
Sources	**?**
Ref. By	IM**??**

Number	DD3
Label	**Interval**
Symbol	$\mathbf{x}_0$
Units	$\mathbb{C}^n$
Equation	$\mathbf{x}(t_0) = \mathbf{x}_0$
Description	Initial values for solving ODE (see DD1).
Sources	**?**
Ref. By	IM**??**

Number	DD4
Label	**Step size**
Symbol	h
Units	$\mathbb{R}$
Equation	
Description	Size of the steps between the opints for which to find approximations using RK4 (T2).
Sources	**?**
Ref. By	IM**??**

5.4 Goal Statements

Given the non-stiff continuous ODE, the goal statements are:

GS1: Given an interval and the desired number of knots, as well as an initial value, calculate a spline and return a function that uses this spline to solve for specific points on the provided interval.

5.5 Theoretical Models

This section focuses on the general equations and laws that FamName is based on. [Modify the examples below for your problem, and add additional models as appropriate. —SS]

Number	T1
Label	**Initial value problem (IVP)**
Equation	$\mathbf{x}' = \mathbf{f}(t, \mathbf{x}(t)), \quad \mathbf{x}(t_0) = \mathbf{x}_0$ where • $\mathbf{x} : \mathbb{R} \to \mathbb{C}^n$ is the vector solution as a function of time • $\mathbf{x}_0 \in \mathbb{C}^n$ is the initial condition (see DD2) • $\mathbf{f} : \mathbb{R} \times \mathbb{C}^n \to \mathbb{C}^n$ is the function describing the vector field (see DD1) Given an initial value $\mathbf{x}_0$, the goal is to find approximations on a given interval $[t_a..t_b]$.
Description	The standard form of an initial value problem is given above. The issue is that many IVPs are difficult to solve manually (or programmatically) and the correct solutions are often unknown. Numerical methods are close enough to be used in most applications.
Source	Corless & Fillion, A Graduate Introduction to Numerical Methods, p. 510,513 [TODO: ref to bib —AS]
Ref. By	GD??

Number	T2
Label	**Fourth order Runge-Kutta method (RK4)**
Equation	• $t_1 = t_0 + h$ • $\mathbf{k}_1 = \mathbf{f}(t_0, \mathbf{x}_0)$ slope at x_0 • $\mathbf{k}_2 = \mathbf{f}(t_0 + \frac{h}{2}, \mathbf{x}_0 + \frac{h}{2}\mathbf{k}_1)$ slope of the point halfway between t_0 and t_1 when extrapolating slope $\mathbf{k}_1$ from point $\mathbf{x}_0$ • $\mathbf{k}_3 = \mathbf{f}(t_0 + \frac{h}{2}, \mathbf{x}_0 + \frac{h}{2}\mathbf{k}_2)$ slope of the point halfway between t_0 and t_1 when extrapolating slope $\mathbf{k}_2$ from point $\mathbf{x}_0$ • $\mathbf{k}_4 = \mathbf{f}(t_0 + h, \mathbf{x}_0 + h\mathbf{k}_3)$ slope of point at t_1 when extrapolating slope $\mathbf{k}_3$ from point $\mathbf{x}_0$ • $\mathbf{x}_1 = \mathbf{x}_0 + \frac{h}{6}(\mathbf{k}_1 + 2\mathbf{k}_2 + 2\mathbf{k}_3 + \mathbf{k}_4)$ new point created when extrapolating from point $\mathbf{x}_0$ using a weighted average of the previously calculated slopes
Description	The above equations can be used to calculate (an approximation of) a new point given the previous or starting point.
Source	Corless & Fillion, A Graduate Introduction to Numerical Methods, p. 618 [TODO: ref to bib —AS]
Ref. By	GD??

6 Variabilities

6.1 Assumptions

A1: [Short description of each assumption. Each assumption should have a meaningful label. Use cross-references to identify the appropriate traceability to T, GD, DD etc., using commands like dref, ddref etc. —SS]

A2: The given initial values (DD2) are for the beginning of the interval (DD3), represented by a.

A3: Initial value vector size is expected to match the ones produced by the ODE (DD1).

A4: $a \leq b$

6.2 Calculation

6.3 Output

7 Traceability Matrices and Graphs

[You will have to add tables. —SS]

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/.

8 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. —SS]

8.1 Symbolic Parameters

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