

Module Interface Specification for FSL

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1 Revision History

Date	Version	Notes
Nov. 26, 2019	0.99	First Draft

2 Symbols, Abbreviations and Acronyms

See SRS Documentation at <https://github.com/caobo1994/FourierSeries/blob/master/docs/SRS/SRS.pdf>. We also define the following acronyms for the scope of this document

Acronym	Full Text
OOB	Out of range

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3 Introduction

The following document details the Module Interface Specifications for Fourier Series Library (FSL).

Complementary documents include the System Requirement Specifications and Module Guide. The full documentation and implementation can be found at <https://github.com/caobo1994/FourierSeries/>.

4 Notation

The structure of the MIS for modules comes from Hoffman and Strooper (1995), with the addition that template modules have been adapted from Ghezzi et al. (2003). The mathematical notation comes from Chapter 3 of Hoffman and Strooper (1995). For instance, the symbol $:=$ is used for a multiple assignment statement and conditional rules follow the form $(c_1 \Rightarrow r_1 | c_2 \Rightarrow r_2 | \dots | c_n \Rightarrow r_n)$.

The following table summarizes the primitive data types used by FSL.

Data Type	Notation	Description
character	char	a single symbol or digit
integer	\mathbb{Z}	a number without a fractional component in $(-\infty, \infty)$
natural number	\mathbb{N}	a number without a fractional component in $[1, \infty)$
real	\mathbb{R}	any number in $(-\infty, \infty)$

The specification of FSL uses some derived data types: sequences, strings, and tuples. Sequences are lists filled with elements of the same data type. Strings are sequences of characters. Tuples contain a list of values, potentially of different types. In addition, FSL uses functions, which are defined by the data types of their inputs and outputs. Local functions are described by giving their type signature followed by their specification. For simplicity, the sequence of type T will be abbreviated as $\text{seq}(T)$, while that with dimensions $[l_1, \dots, l_n]$ as $\text{seq}(T, l_1, \dots, l_n)$.

5 Module Decomposition

The following table is taken directly from the Module Guide document for this project.

Level 1	Level 2
Hardware-Hiding Module	Infrastructure (hardware-related part, external)
Behaviour-Hiding Module	Data definition module
	Conversion module
	Transformation module
	Basic operations module
	Advanced operations module
Software Decision Module	Linear solver (external or partially external)
	Integral (external or partially external)
	Infrastructure (software-related part, external)

Table 1: Module Hierarchy

6 MIS of Infrastructure

6.1 Module

Infrastructure.

6.2 Uses

None.

6.3 Syntax

6.4 Exported Data Type

`FLOAT` a floating point data type used in the library.

sequence the abstract sequence data type.

7 MIS of Data Definition

7.1 Module

Data Definition.

7.2 Uses

Infrastructure.

7.3 Syntax

7.3.1 Exported Constants

None.

7.3.2 Exported Data Type

There is one exported data type, `CFST`, which is the type of a CFS object. (abstract, with one type template `FLOAT`, indicating floating point types)

The structure of `CFST` is

- n : integer
- ω : `FLOAT`
- A : `seq(FLOAT)`

- $B: \text{seq}(\text{FLOAT})$

The mathematical notation is

$$\text{CFST} := \text{tuple of } (n : \mathbb{N}, \omega : \text{FLOAT}, A : \text{TA}, B : \text{TB}) \quad (1)$$

where TA and TB are

$$\begin{aligned} \text{TA} &:= \text{seq}(\text{FLOAT}, n) \\ \text{TB} &:= \text{seq}(\text{FLOAT}, n + 1) \end{aligned} \quad (2)$$

During implementation, it is recommended that the sequence type used above are random accessible.

7.3.3 Exported Access Programs

The exported access programs for this module are mainly getters and setters. For simplicity, we use the following getter and setter rules.

For each variable X, the getters and setters are

Name	In	Out	Exceptions
getX		X: type of X	None.
setX	X: type of X		None.

Furthermore, we design getters and setters for each element of A and B. For each X being A or B, the syntax is

Name	In	Out	Exceptions
getXi		X: type of X	OOR.
setXi	X: type of X		OOR.

7.4 Semantics

7.4.1 Assumptions

7.4.2 Access Routine Semantics

This part follows the most common rules of getters and setters. For simplicity, we do not elaborate on them.

8 MIS of Linear Solver

8.1 Module

Linear Solver.

8.2 Uses

Infrastructure.

8.3 Syntax

8.3.1 Export Access Programs

Name	In	Out	Exceptions
LinSolve	$m: \mathbb{N}$ $A: \text{seq}(\text{FLOAT}, m, m)$ $b: \text{seq}(\text{FLOAT}, m)$	$x: \text{seq}(\text{FLOAT}, m)$	Solution non-exist Solution not unique .

8.4 Semantics

8.4.1 Assumptions

8.4.2 Access Routine Semantics

This part follows the most common semantics of linear solvers, and for simplicity, we do not elaborate on it.

9 MIS of Integral

9.1 Module

Integral.

9.2 Uses

Infrastructure.

9.3 Syntax

9.3.1 Export Access Programs

Name	In	Out	Exceptions
Integral	$f: \text{FLOAT} \rightarrow \text{FLOAT}$ $a, b: \text{FLOAT}$	$\text{res}: \text{FLOAT}$	Integral non-exist or not computable .

9.4 Semantics

9.4.1 Access Routine Semantics

Integral(f, a, b):

- output: $\int_a^b f(t)dt$
- exception: Evident

10 MIS of Conversion

10.1 Module

Conversion.

10.2 Uses

Data Definition.

10.3 Syntax

10.3.1 Export Access Programs

With 0 being short for OUT_OF_BOUNDARY and M being short for MISMATCHED_SIZE,

Name	In	Out	Exceptions
ConvertFrom	$n \in \mathbb{N}$ ω : FLOAT A : sequence of FLOAT B : sequence of FLOAT	CFST CFS	0: $\omega \leq 0$ M: Mismatch between n , (size of A -1), and size of B
ConvertTo	CFST CFS user-acquired space for outputs	Same as inputs of ConvertFrom	None

10.4 Semantics

10.5 Access Routine Semantics

ConvertFrom(n, ω, A, B):

- output: CFS. n , CFS. ω , CFS. A , CFS. $B := n, \omega, A, B$

- exception: $\text{exc} := (\omega \leq 0 \Rightarrow O||A| \neq n + 1 \Rightarrow M||B| \neq n \Rightarrow M)$

The semantics for `ConvertTo` is straightforward, and we do not elaborate on it.

11 MIS for Transformation

11.1 Module

Transformation.

11.2 Uses

Data Definition, Integration.

11.3 Syntax

11.3.1 Export Access Programs

Name	In	Out	Exceptions
TransformTo	$f \in \{\mathbb{R} \rightarrow \mathbb{R}\}$ $n \in \mathbb{N}$ $\omega \in \mathbb{R}^+$	CFST CFS	None.
FunctionValue	CFST CFS $t \in \mathbb{R}$	$V \in \mathbb{R}$	None.

11.4 Semantics

11.5 Access Program Semantics

`TransformTo`(f, n, ω):

- output: $\text{CFS}.n, \text{CFS}.\omega, \text{CFS}.A, \text{CFS}.B := n, \omega, A, B$, where A_i and B_i are computed in accordance with T1 of the SRS.

`FunctionValue`(CFS, t):

- output: $V := \sum_{i=0}^{\text{CFS}.n} \text{CFS}.A(i) \cos(i\omega t) + \sum_{i=1}^{\text{CFS}.n} \text{CFS}.B(i) \sin(i\omega t)$

12 MIS of Basic Operation

12.1 Module

Basic Operations.

12.2 Uses

Data Definition, Linear Solver

12.3 Syntax

12.3.1 Export Access Programs

Name	In	Out	Exceptions
CFSTMatch	CFST CFS1, CFST CFS2	Bool res	None.
Addition	CFST CFS1, CFST CFS2	CFST CFSres	mismatch of n and ω
Subtraction	CFST CFS1, CFST CFS2	CFST CFSres	Same as Addition
Multiplication	CFST CFS1, CFST CFS2	CFST CFSres	Same as Addition
Divison	CFST CFS1, CFST CFS2	CFST CFSres	Same as Addition, plus any exception raised by linear solver and reclassified in Division.
Amplitude	CFST CFS1	FLOAT amp	None.

12.4 Semantics

12.4.1 Access Program Semantics

CFSTMatch(CFST CFS1, CFST CFS2):

- output: $(CFS1.n = CFS2.n) \wedge (CFS1.\omega = CFS2.\omega) \Rightarrow \text{TRUE} | \text{TRUE} \Rightarrow \text{FALSE}$

The semantics of **Addition**, **Subtraction**, and **Multiplication** are similar in structure, and the only difference is the calculation of the A and B variables shown below, which is consistent with the corresponding theories introduced in SRS.

As an example, we give the semantics of the **Addition** function.

Addition(CFST CFS1, CFST CFS2):

- output: $A_i := CFS1.getAi(i) + CFS2.getAi(i)$, $B_i := CFS1.getBi(i) + CFS2.getBi(i)$,
 $A := [A_0, \dots, A_{CFS1.n}]$, $B := [B_0, \dots, B_{CFS1.n}]$,
 $CFSres.n, CFSres.\omega, CFSres.A, CFSres.B := CFS1.n, CFS1.\omega, A, B$
- exception: $exc := (CFSTMatch(CFS1, CFS2) = \text{FALSE}) \Rightarrow \text{MISMATCH_CFS}$

As for **Division**, the difference is much significant. The A and B is computed as follows

$$\begin{aligned}x &:= \textit{LinSolve}(M, y), \\ A &:= x[0, \text{CFS1}.n], \\ B &:= x[\text{CFS1}.n + 1, |x| - 1]\end{aligned}$$

where M and y are constructed in accordance with the theories for division in SRS.

Amplitude(CFS CFS1):

- output: $amp := \sqrt{\text{CFS1}.getAi(0)^2 + (1/2) * \sum_{i=1}^{\text{CFS1}.n} (\text{CFS1}.getAi(i)^2 + \text{CFS1}.getBi(i)^2)}$

13 MIS for Advanced Operation

13.1 Module

Advanced Operation.

13.2 Uses

Name	In	Out	Exceptions
ConvertFrom	n : integer ω : FLOAT A : sequence of FLOAT B : sequence of FLOAT	Constructed CFS	Mismatch between n , (size of $A - 1$), and size of B
ConvertTo	CFS pointers to the space for outputs	Same as inputs of ConvertFrom	None
TransformTo	function f, n, ω	Constructed CFS	Any exception raised by integral module
FunctionValue	CFS, t	Value of $f(t)$, where CFS comes from f	None.
Addition	CFST CFS1, CFST CFS2	CFST, CFSres	mismatch of n and ω
Subtraction	CFST CFS1, CFST CFS2	CFST, CFSres	Same as Addition
Multiplication	CFST CFS1, CFST CFS2	CFST, CFSres	Same as Addition
Divison	CFST CFS1, CFST CFS2	CFST, CFSres	Same as Addition, plus any exception raised by linear solver and reclassified in Division.
ToleratedEquality	CFST CFS1, CFST CFS2, FLOAT tol	Bool res	Same as Addition
Function	CFST CFS, Taylor series type variable	CFST, CFSres	Insufficient length of Taylor series.
Amplitude	CFS	FLOAT amp	None.

13.3 Semantics

13.3.1 State Variables

[Not all modules will have state variables. State variables give the module a memory. —SS]

13.3.2 Environment Variables

[This section is not necessary for all modules. Its purpose is to capture when the module has external interaction with the environment, such as for a device driver, screen interface, keyboard, file, etc. —SS]

13.3.3 Assumptions

[Try to minimize assumptions and anticipate programmer errors via exceptions, but for practical purposes assumptions are sometimes appropriate. —SS]

13.3.4 Access Routine Semantics

[accessProg —SS]():

- transition: [if appropriate —SS]
- output: [if appropriate —SS]
- exception: [if appropriate —SS]

[A module without environment variables or state variables is unlikely to have a state transition. In this case a state transition can only occur if the module is changing the state of another module. —SS]

[Modules rarely have both a transition and an output. In most cases you will have one or the other. —SS]

13.3.5 Local Functions

[As appropriate —SS] [These functions are for the purpose of specification. They are not necessarily something that is going to be implemented explicitly. Even if they are implemented, they are not exported; they only have local scope. —SS]

References

- Carlo Ghezzi, Mehdi Jazayeri, and Dino Mandrioli. *Fundamentals of Software Engineering*. Prentice Hall, Upper Saddle River, NJ, USA, 2nd edition, 2003.
- Daniel M. Hoffman and Paul A. Strooper. *Software Design, Automated Testing, and Maintenance: A Practical Approach*. International Thomson Computer Press, New York, NY, USA, 1995. URL <http://citeseer.ist.psu.edu/428727.html>.

14 Appendix

[Extra information if required —SS]