Module Interface Specification for Time_Freq_Analysis

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1 Revision History

Date	Version	Notes
11.19.2020	1.0	Initial Release

2 Symbols, Abbreviations and Acronyms

See SRS Documentation at https://github.com/liziscool/cas741_project/blob/master/docs/SRS/SRS.pdf

Contents

3 Introduction

The following document details the Module Interface Specifications for Time_Freq_Analysis, a program to compute the time-frequency analysis of a 1 dimensional signal.

Complementary documents include the System Requirement Specifications and Module Guide. The full documentation and implementation can be found at https://github.com/liziscool/cas741_project.

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 $(c_1 \Rightarrow r_1 | c_2 \Rightarrow r_2 | ... | c_n \Rightarrow r_n)$.

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

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 $(-\infty, \infty)$
complex	$\mathbb{C}$	a number with a real part a and an imaginary part b s.t. $a + bi$ where i is the imaginary number

The specification of Time_Freq_Analysis 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, Time_Freq_Analysis 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.

5 Module Decomposition

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

Level 1	Level 2
Hardware-Hiding Module	
Behaviour-Hiding Module	Input Parameter Module
	Specification Param Module
	Read Data Module
	Boundary Configuration Module
	STFT Module
	Wavelet Module
	Output Verification Module
	Output Module
	Compute Transform Module
	Control Module
	Plotting Module
Software Decision Module	Zero-Pad Module
	Matrix Data Structure Module
	Fast Fourier Transform Module

Table 1: Module Hierarchy

6 MIS of Control Module

6.1 Module

main

6.2 Uses

Compute Transform Module 15, Output Module 14, Output Verification Module, Plotting Module 18

6.3 Syntax

6.3.1 Exported Constants

None.

6.3.2 Exported Access Programs

Name	In	Out	Exceptions
main	$argc$: $\mathbb{N}$, $< argv_1, \ldots, argv_{argc} >$ s.t. $argv_n : string$	-	-

6.4 Semantics

6.4.1 State Variables

None.

6.4.2 Environment Variables

None.

6.4.3 Assumptions

- User enters correct inputs for calculation that is expected.

- User enters inputs in correct format.

6.4.4 Access Routine Semantics

main():

- transition: Controls the entire program, transition through the program as follows:

    1. Sets `param` from command line arguments `set_inputs()`.

2. Calls compute transform module with `comp_transform()`.

3. Plots output with `plot_matrix()`

6.4.5 Local Functions

None.

7 MIS of Specification Parameter Module

7.1 Module

spec_param

7.2 Uses

None.

7.3 Syntax

7.3.1 Exported Constants

Name	Type
MIN_FREQ	$\mathbb{R}$
MAX_FREQ	$\mathbb{R}$
MIN_SIG_LEN	$\mathbb{N}$
MAX_SIG_LEN	$\mathbb{N}$
STEP_SIZE	$\mathbb{N}$
WIN_SIZE	$\mathbb{N}$

[handwritten note: What are the values of the constants?]

7.3.2 Exported Access Programs

None.

7.4 Semantics

7.4.1 State Variables

None.

7.4.2 Environment Variables

None.

7.4.3 Assumptions

None.

7.4.4 Access Routine Semantics

None.

7.4.5 Local Functions

None.

7.5 Considerations

This module basically just holds all of the constants.

8 MIS of Input Param Module

8.1 Module

input_param

8.2 Uses

Specification Param Module 7, Hardware Hiding Module

8.3 Syntax

8.3.1 Exported Constants

None.

8.3.2 Exported Access Programs

Name	In	Out	Exceptions
set_input	$argc$: $\mathbb{N}$, $<$ $argv_1, \ldots, argv_{argc} >$ s.t. $argv_n$: $string$	-	bad_arguments, bad_min_time, bad_max_time, bad_time_range, bad_min_freq, bad_max_freq, bad_freq_range , bad_transform_type
param.N	-	$\mathbb{N}$	
f_1	-	$\mathbb{R}$	
f_2	-	$\mathbb{R}$	
n_1	-	$\mathbb{R}$	
n_2	-	$\mathbb{R}$	
transform_type	-	$\{`W', `S'\}$	
param.time_res	-	$\mathbb{N}$	
param.freq_res	-	$\mathbb{N}$	
param.sig_file	-	string	

[handwritten: ~ Rather than a set of strings, you could use an enumerated type]

[handwritten: {W, S}]

8.4 Semantics

8.4.1 State Variables

None.

[handwritten: Don't you want a state variable for each of the input params?]

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8.4.2 Environment Variables

None.

8.4.3 Assumptions
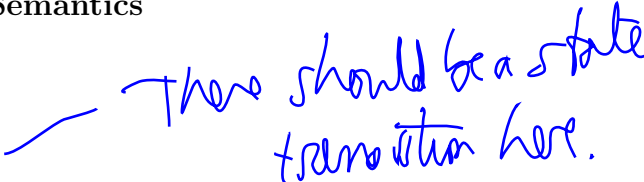
While there will be measures in place to check that the input values comply with the ability of the program, some additional assumptions are listed below

1. The user inputs the correct file path.

2. The bounds are appropriate for the signal.

3. The input parameters must be set (initialized) before they are accessed.

8.4.4 Access Routine Semantics

set_input():

- output: None.

[handwritten: — There should be a state transition here.]

- exception: exc:=

$$
\begin{cases}
bad\_arguments & \text{if any of the arguments are incorrectly flagged (i.e. using a flag that doesnt} \\
bad\_min\_time & \text{if } n_1 \geq n_2 \\
bad\_max\_time & \text{if } n_2 > N \\
bad\_time\_range & \text{if } (n_2 - n_1) > MAX\_SIG\_LEN \text{ or } (n_2 - n_1) < MIN\_SIG\_LEN \\
bad\_min\_freq & \text{if } f_1 < MIN\_FREQ \\
bad\_max\_freq & \text{if } f_2 < MAX\_FREQ \\
bad\_freq\_range & \text{if } (f_2 - f_1) > MAX\_FREQ\_R\cancel{/}ANGE \text{ or } (f_2 - f_1) < MIN\_FREQ\_RAN \\
bad\_transform\_type & \text{if T is not 'W' or 'S'}
\end{cases}
$$

[handwritten: ?]

param.N :

- output: $out := N$

[handwritten: — Your outputting values, but where are the values coming from? I think state variables are missing.]

- exception: none

param.f1 :

- output: $out := f_1$

- exception: none

param.f2 :

- output: $out := f_2$

[handwritten: spacing]

8

- exception: none

param.n1 :

- output: $out := n_1$

- exception: none

param.n2 :

- output: $out := n_2$

- exception: none

param.time_div :

- output: $out := time\_div$

- exception: none

param.freq_div :

- output: $out := freq\_div$

- exception: none

param.time_res :

- output: $out := time\_res$

- exception: none

param.freq_res :

- output: $out := freq\_res$

- exception: none

param.sig_filename :

- output: $out := sig\_filename$

- exception: none

8.4.5 Local Functions

None.

9 MIS of Read Data Module

9.1 Module

read_data

9.2 Uses

Input Param Module 8

[handwritten: — You say this module is used, but you don't actually invoke it]

9.3 Syntax

9.3.1 Exported Constants

None.

9.3.2 Exported Access Programs

Name	In	Out	Exceptions
read_sig	sig_filename: string	$\ldots, x_N > x_n : \mathbb{R}$	bad_path, empty_file, file_wrong_format

9.4 Semantics

9.4.1 State Variables

None.

9.4.2 Environment Variables

None.

[handwritten: shouldn't you have a file as an environment variable?]

9.4.3 Assumptions

1. File should be in correct format.

9.4.4 Access Routine Semantics

read_sig():

- output: out := $< x_1, \ldots, x_N >$

[handwritten: It isn't clear what this module does? Is its role to change the state of the input parameters module?]

- exception: exc :=

$$\begin{cases} bad\_file & \text{if the file or a directory on the path does not exist} \\ empty\_file & \text{if the file has no data in it} \\ file\_format\_wrong & \text{if data in the folder is not in } \mathbb{R} \text{ or uses incorrect delimter} \end{cases}$$

9.4.5 Local Functions

None.

10 MIS of Boundary Configuration Module

10.1 Module

bound_config

10.2 Uses

Specification Param Module 7

[handwritten: I don't see this invoked anywhere?]

10.3 Syntax

10.3.1 Exported Constants

None.

10.3.2 Exported Access Programs

Name	In	Out	Exceptions
calc_freq_res	$f_1 : \mathbb{R}, f_2 : \mathbb{R}$, win_size $: \mathbb{N}$	$\mathbb{R}$	-
calc_time_res	$n_1 : \mathbb{N}, n_2 : \mathbb{R}$, step_size $: \mathbb{N}$	$\mathbb{N}$	-

10.4 Semantics

10.4.1 State Variables

None.

10.4.2 Environment Variables

None.

10.4.3 Assumptions

None.

[handwritten: show your arguments]

10.4.4 Access Routine Semantics

calc_freq_res():

- output: out $:= (f_2 - f_1) * win\_size$

calc_time_res():

- output: out $:= \dfrac{(n_2 - n_1)}{\frac{win\_size}{step\_size}}$

10.4.5   Local Functions

None.

10.5   Considerations

At the time this document was written, the writer is not totally confident in the methods to calculate time_res or freq_res. The equations provided above are sufficient to communicate the point, but in execution it may be more complicated, and at that time this section of the document will be updated to reflect that.

11 MIS of STFT Module

11.1 Module

STFT

11.2 Uses

FFT Module, Boundary Configuration Module 10 Matrix Data Structure Module 17

11.3 Syntax

11.3.1 Exported Constants

None.

11.3.2 Exported Access Programs

Name	In	Out	Exceptions
comp_stft	$< x_1, \ldots, x_N >$ where $x_n : \mathbb{R}$, $N : \mathbb{N}$, time_res: $\mathbb{N}$, freq_res: $\mathbb{N}$	$< X_{0,0}, X_{0,1}, \ldots, X_{1,0}, X_{1,1}, \ldots, X_{I,J} >$ where $x_{i,j} : \mathbb{C}$	-

11.4 Semantics

11.4.1 State Variables

None.

11.4.2 Environment Variables

None.

11.4.3 Assumptions

None.

show arguments

11.4.4 Access Routine Semantics

comp_stft():

- output: out := $< X_{0,0}, X_{0,1}, \ldots, X_{1,0}, X_{1,1}, \ldots, X_{I,J} >$ where $X_{i,j} : \mathbb{C}$ s.t.

$$X(i,j) = \sum_{i=0}^{WIN\_SIZE} x_i w_i e^{-\hat{i}\omega j} \tag{1}$$

how is this value obtained? Is this an argument?

and $I[0, time\_res]$ and $J[0, freq\_res]$ and $\hat{i}$ is the imaginary number.

- This routine will utilize the fast Fourier transform.

11.4.5 Local Functions

argument

window_function():

- output: out $:= < w_0, \ldots, w_{WIN\_SIZE} >$ where

?

$$w_n = (\sin \frac{\pi * n}{WIN\_SIZE})^2 \tag{2}$$

local functions are used in the spec of the module. This local function is not finished.

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12 MIS of Wavelet

12.1 Module

wavelet

12.2 Uses

FFT Module, Boundrey Configuration Module 10, Matrix Data Structure Module 17

12.3 Syntax

12.3.1 Exported Constants

None.

12.3.2 Exported Access Programs

Name	In	Out	Exceptions
comp_waveletT	$< x_1, \ldots, x_N >$ where x_n : $\mathbb{R}$, N : $\mathbb{N}$, time_res: $\mathbb{N}$, freq_res : $\mathbb{N}$	$< X_{0,0}, X_{0,1}, \ldots, X_{1,0}, X_{1,1}, \ldots, X_{I,J} >$ where $x_{i,j} : \mathbb{C}$	-

12.4 Semantics

12.4.1 State Variables

None.

12.4.2 Environment Variables

None.

12.4.3 Assumptions

None.

names of arguments

12.4.4 Access Routine Semantics

comp_waveletT():

- output: out := $< X_{0,0}, X_{0,1}, \ldots, X_{1,0}, X_{1,1}, \ldots, X_{I,J} >$ s.t.

$$X(a,b) = \frac{1}{\sqrt{a}} \Sigma_{n=0}^{wav\_scale\_a} \Psi_{a,b,n} x_n \qquad (3)$$

where $\Psi_{a,b,n}$ represents the wavelet scaled by a and shifted by b.

12.4.5   Local Functions

(handwritten annotation: never involved)

wavelet_function():

- output: out $:= \, < w_0, \ldots, w_{wav\_scale\_a} >$ where

$$w_n = c_\sigma \pi^{-\frac{1}{4}} e^{-\frac{1}{2}t} \left(e^{i\sigma n} - \kappa_\sigma \right) \tag{4}$$

and where $\kappa_\sigma = e^{1\frac{1}{2}\sigma^2}$ and $c_\sigma = (1 + e^{-\sigma^2} - 2e^{-\frac{3}{4}\sigma^2})^{\frac{1}{2}}$, a.k.a. a Morlet Wavelet.

13 MIS of Output Verification Module

13.1 Module

output_verify

13.2 Uses

Matrix Data Module

13.3 Syntax

13.3.1 Exported Constants

None.

13.3.2 Exported Access Programs

Name	In	Out	Exceptions
verify_output	$< X_{0,0}, X_{0,1}, \ldots, X_{1,0}, X_{1,1}, \ldots, X_{I,J} >$ where $x_{i,j} : \mathbb{R}$	$b : \mathbb{B}$	-

13.4 Semantics

13.4.1 State Variables

None.

13.4.2 Environment Variables

None.

13.4.3 Assumptions

None.

13.4.4 Access Routine Semantics

verify_output():

- output: out :=
$$\begin{cases} T & \text{if transform passes verification} \\ F & \text{if transform fails verification} \end{cases}$$

To pass the verification the output matrix must pass the following conditions:

$$\sum_{j=0}^{freq\_res} X_{i,j} \leq \Sigma x_n \tag{5}$$

where Σx_n and corresponds to the portion of the signal represented by i in $X_{i,j}$.

13.4.5   Local Functions

None.

14 MIS of Output Module

14.1 Module

output

14.2 Uses

Hardware Hiding Module

14.3 Syntax

14.3.1 Exported Constants

14.3.2 Exported Access Programs

Name	In	Out	Exceptions
get_output	-	$<$ $X_{0,0}, X_{0,1}, \ldots, X_{1,0}, X_{1,1}, \ldots, X_{I,J} >$ where $x_{i,j} : \mathbb{R}$	-

14.4 Semantics

14.4.1 State Variables

None.

14.4.2 Environment Variables

None.

14.4.3 Assumptions

1. The user requires the memory location of the output matrix, as in it does not need to be written to any external file.

14.4.4 Access Routine Semantics

If there are no inputs, how are these found?

get_output():

- output: out $:= < X_{0,0}, X_{0,1}, \ldots, X_{1,0}, X_{1,1}, \ldots, X_{I,J} >$ where $x_{i,j} : \mathbb{R}$
  where X is the time frequency representation of the data as calculated by Time_Freq_Analysis.

14.4.5 Local Functions

None.

15 MIS of Compute Transform

15.1 Module

comp_transform

15.2 Uses

Read Data Module 9, Wavelet Module 12, STFT Module 11, Zero Pad Module 16, Matrix Data Structure Module 17

15.3 Syntax

15.3.1 Exported Constants

None.

15.3.2 Exported Access Programs

Name	In	Out	Exceptions
comp_transform	$< x_1, \ldots, x_N >$ where $x_n : \mathbb{R}, \ N : \mathbb{N}, f_1 : \mathbb{R}, f_2 : \mathbb{R}, \ T : \{`W'`, `S'`\}$	$< X_{0,0}, X_{0,1}, \ldots, X_{1,0}, X_{1,1}, \ldots, X_{I,J} >$ where $x_{i,j} : \mathbb{R}$	-

15.4 Semantics

15.4.1 State Variables

None.

15.4.2 Environment Variables

None.

15.4.3 Assumptions

None.

15.4.4 Access Routine Semantics

comp_transform():

- output: $< X_{0,0}, X_{0,1}, \ldots, X_{1,0}, X_{1,1}, \ldots, X_{I,J} >$ where $x_{i,j} : \mathbb{R}$

Such that X is calculated in the following way:

1. The input signal is read using `read_data` 9 using the parameters specified by the Input Parameter Module 8.

2. The signal is zero-padded using Zero Pad Module.

3. Some computations are done regarding the boundary configuration using `calc_freq_res` and `calc_time_res` from 10 which are needed for the following step.

4. The signal is transformed using ether `comp_waveletT` if $T = `W'$ or `comp_STFT` if $T = `T'$

5. The matrix output from the transforms are complex, to convert them to a real power values the matrix is X is computed from as followed:
$X_{i,j} = \sqrt{X_{\mathbb{C}}.real^2 +_{\mathbb{C}} .im^2}$
Where $X_{\mathbb{C}}.real$ is the real part of the transform and $X_{\mathbb{C}}.im$ is the imaginary part.

15.4.5 Local Functions

None.

15.5 Considerations

The Zero-Pad Module extends the size of the signal x by 2 times the window size WIN_SIZE, however, this doesn't affect the size of the output transform matrix.

16 MIS of Zero Pad Module

16.1 Module

zero_pad

16.2 Uses

None.

16.3 Syntax

16.3.1 Exported Constants

None.

16.3.2 Exported Access Programs

Name	In	Out	Exceptions
zero_pad_sig	$< x_1, \ldots, x_N >$ where $x_n : \mathbb{R}, N : \mathbb{N}, WIN\_SIZE$	$< x_1, \ldots, x_{N+2WIN\_SIZE} >$	-

Is this a constant? Usually all caps means constant.

16.4 Semantics

16.4.1 State Variables

None.

16.4.2 Environment Variables

None.

16.4.3 Assumptions

None.

16.4.4 Access Routine Semantics

zero_pad_sig():

- output: $< x_1, \ldots, x_{N+2WIN\_SIZE} >$ such that $x_n = 0$ from $n[0, WIN\_SIZE]$, $x_{n+WIN\_SIZE} = \hat{x}_n$ from $n[0, N]$ where $\hat{x}$ is the original signal and N is the length of the original signal.

16.4.5 Local Functions

None.

17 MIS of Matrix Data Structure Module

17.1 Module

mat

17.2 Uses

None.

17.3 Syntax

17.3.1 Exported Constants

None.

17.3.2 Exported Access Programs

Name	In	Out	Exceptions
init	$X : \mathbb{N}, Y : \mathbb{N}$	$< X_{0,0}, X_{0,1}, \ldots, X_{1,0}, X_{1,1}, \ldots, X_{X,Y} >$ where $x_{x,y} : NULL$	
m	$x : \mathbb{N}, y : \mathbb{N}$	$m : \mathbb{R}$	-

17.4 Semantics

(handwritten: What does this mean?)

17.4.1 State Variables

None.

17.4.2 Environment Variables

None.

17.4.3 Assumptions

None.

17.4.4 Access Routine Semantics

mat.init():

- output: $< X_{0,0}, X_{0,1}, \ldots, X_{1,0}, X_{1,1}, \ldots, X_{X,Y} >$
  Where $X_{x,y}$ is null but it is large able to hold type $\mathbb{R}$.

(handwritten: ?)

mat.m():

- output: $m : \mathbb{R}$
  m is the data in the matrix at the specified index.

17.4.5 Local Functions

None.

18 MIS of Plotting Module

18.1 Module

plot

18.2 Uses

None.

18.3 Syntax

18.3.1 Exported Constants

None.

18.3.2 Exported Access Programs

Name	In	Out	Exceptions
plot_matrix	$< X_{0,0}, X_{0,1}, \ldots, X_{1,0}, X_{1,1}, \ldots, X_{X,Y} >$ where $x_{x,y} : \mathbb{R}$	$b : \mathbb{B}$	bad_path

18.4 Semantics

18.4.1 State Variables

None.

18.4.2 Environment Variables

None.

18.4.3 Assumptions

None.

A plotting module would usually have an environment variable for the screen

18.4.4 Access Routine Semantics

plot_matrix():

- output: out:=
$$\begin{cases} F & \text{if output file was not created sucessfully} \\ T & \text{if output file was created sucessfully} \end{cases}$$

- exception: exc:= bad_path if out file was not written successfully. *[handwritten: aren't R, G, B usually represented by natural numbers?]*

18.4.5   Local Functions

Name	In	Out	Description
calc_colour	$x : \mathbb{R}$	$R, B, G : \mathbb{R}$	converts the matrix value into corresponding R,G,B values for heat map

[handwritten: How?]

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.