Software Requirements Specification for Live Neuro: Live Neuro

Bo Liang

April 10, 2025

Contents

Revision History

Date	Version	Notes
Feb 3, 2025	1.0	Initial Draft
Apr 9, 2025	1.1	update based on feedback

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.

Table 1: Table of Units

symbol	**unit**	**SI**
s	time	second
m	length	meter
db	sound	decibel
cm	Electric dipole moment	Coulomb metre

1.2 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.

Table 2: Table of Symbols

symbol	**description**	**units**
t	time	s
m	length	m
db	sound	db
cm	Electric dipole moment	cm

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
Live Neuro	interactive data visualization tool linking multiple data plots together
TM	Theoretical Model

1.4 ~~Mathematical Notation~~

- ~~Goal Statement~~
- ~~Instance Models~~
- ~~Requirements~~
- ~~Introduction~~
- ~~Specific System Description~~

2 Introduction

Neuron data based on brain activity is often complex and multi-sourced. To clearly describe the activity of different neurons, multidimensional data is typically required. ~~An~~ Live Neuro - an interactive data visualization tool is particularly useful for effectively presenting these data, allowing users to explore and understand the relationships and transformations between different data points.

2.1 Purpose of Document

The following section provides an overview of the Software Requirements Specification (SRS) for the interactive neural data visualization tool.The developed program will be referred to as ~~"Live Neuro," "~~ "Live Neuro" based on the original, manually created version ~~.~~ and the purpose of this program is to serve as a basic data visualization foundation module in Eelbrain, making all neuro-related plots interactive within jupyter notebook, which is not currently available in Eelbrain

This section explains the purpose of this document, the scope of the requirements, the characteristics of the intended reader, and the organization of the document.

2.2 Scope of Requirements

The scope of requirements include the whole stimuli-response process neural data and the interactive data visualization

2.3 Characteristics of Intended Reader

Reviewers of this documentation should have an undergraduate-level understanding of ~~mathmatics and high~~ math and undergraduate school level understanding of neuro science The users of Live Neuro Neuro can have a lower level of expertise, as explained in (Section 3.2)

2.4 Organization of Document

The organization of this document follows the template for an SRS for scientific computing software proposed by ~~koothoor2013, smithLai2005, smithEtAl2007, and smithKoothoor2016~~koothoor2013, smithEtAl2007 , and smithKoothoor2016 . 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 and trace back to find any additional information they require.

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

Fig1 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 (Live Neuro). Arrows are used to show the data flow

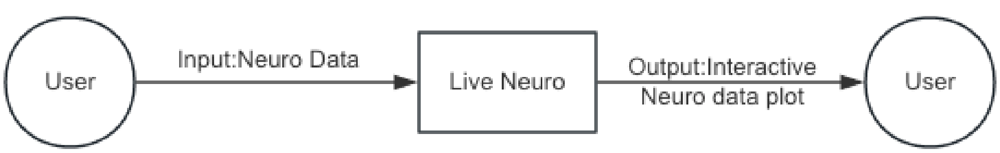

Figure 1: System Context

- User Responsibilities:
  - Provide the input data to the system, ensuring no errors in the data entry
  - Take care that consistent units are used for input variables
- Live Neuro Responsibilities:
  - Detect data type mismatch, such as a string of characters instead of a floating point number
  - Determine if the inputs satisfy the required software constraints, excluding invalid or corrupt data from analysis
  - Calculate the required outputs

3.2 User Characteristics

The end user of Live Neuro should have an understanding of ~~undergraduate mathmatics and computer science~~ Neuro Science including the basic neuro data structure and neuro science analysis algorithm

3.3 System Constraints

~~There are no system constraints~~The project should be developed under the plot module of Eelbrain, and the basic visualization fundamental Library should be Plotly or any other Library with interactive function in jupyter notebook.

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, and definitions that are used.

4.1 Problem Description

Live Neuro is intended to solve the problem of interactive neuro data visualization

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:

- ~~//todo~~ dipole: In neuroscience, a dipole refers to a pair of opposite electrical charges (positive and negative) that are separated by a small distance, typically generated by neuron activity.

4.1.2 Physical System Description

The physical system of Live Neuro, as shown in ~~Figure2~~Figure 2, includes the following elements:

PS: ~~Current Dipoles can be used to measure the~~ Arrows in the Figure 2 are neuronal current dipole, representing the intensity of neuronal activity

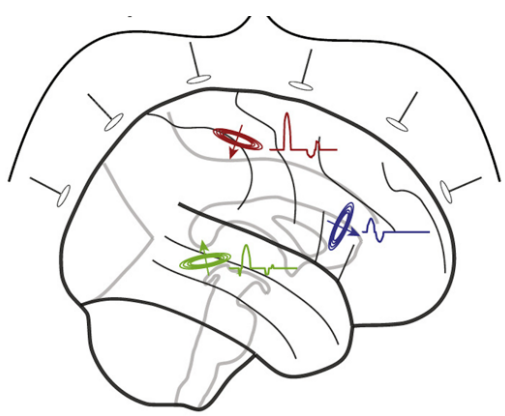

Figure 2: Current Dipoles placed on the scalp

4.1.3 Goal Statements

Given the ~~Acoustic Stimuli and Semantics Stimuli~~Neuro Data, the goal statements are:

GS1: ~~Predicted MEG/EEG data~~ Implement multidimensional neural data visualization

GS2: Link Interactive neural data ~~visualization plots~~ plots together

4.2 Solution Characteristics Specification

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 [TM], general definition [GD], data definition [DD], instance model [IM], or likely change [LC], in which the respective assumption is used.

A1: The Stimulus data is continuous

A2: The neuron data is complete

4.2.2 Theoretical Models

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

RefName: **TM:1**

Label: Neural stimulation-response model

Equation: $j_{m,t,i} = f_i\left(e_t, e_{t-1}, \cdots, e_1\right) + v_{m,t,i}$

Description: The above equation gives Neural stimulation-response model, where $j_{m,t,i}$ is the dipole current j of source m, at time t, in the i-th direction. $v_{m,t,i}$ is the background activities of source m, at time t, in the i-th direction. $f_i\left(e_t, e_{t-1}, \cdots, e_1\right)$ is the stimulus-driven component. e_t is the speech envelop driven by acoustic and semantics stimuli.

Notes: None.

Source: https://doi.org/10.1016/j.neuroimage.2020.116528

Ref. By: GD??, IM??

Preconditions for TM:1: None

Derivation for TM:1: Not Applicable

4.2.3 General Definitions

This section collects the laws and equations that will be used in building the instance models.

Number	GD1
Label	Cortical Dipole Moment
SI Units	nAm
Equation	$f_i(e_t, e_{t-1}, \cdots, e_1) = \sum_{l=0}^{L-1} \tau_{m,i,l} e_{t-l} = (\boldsymbol{\tau}_{m,i})^\top \mathbf{e}_t, i \in \{R, A, S\},$
Description	$\tau_{m,i}$ can be thought of as a matrix corresponding to the activity of dipole source m along the coordinate axis determined by i. The length of the filter L is typically determined by a priori assumptions on the effective integration window of the underlying neural process.
Source	https://doi.org/10.1016/j.neuroimage.2020.116528
Ref. By	DD??

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.

Number	DD1
Label	coefficient of finite impulse response
Symbol	$\tau_{m,i}$
SI Units	~~Float~~N/A
Equation	$\tau_{m,i} := [\tau_{m,i,0}, \tau_{m,i,1} \cdots, \tau_{m,i,L-1}]^\top$
Description	$\tau_{m,i}$ can be thought of as a ~~TRF~~ matrix corresponding to the activity of dipole source m along the coordinate axis determined by i.
Sources	https://doi.org/10.1016/j.neuroimage.2020.116528
Ref. By	~~IM??~~IM??

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 **??** to replace the abstract symbols in the models identified in Sections 4.2.2 and 4.2.3.

Number	IM1
Label	**get neural dipole current**
Input	$e_3, e_2, e_1, v_{m,3,R}$
Output	$j_{m,3,R}$
Description	$\boldsymbol{j}_{m,3,R} = f_R(e_3, e_2, e_1) + v_{m,3,R}$ $j_{m,3,R}$ donates the m^{th} neural current dipole of time 3 in the Right direction.$f_R(e_3, e_2, e_1)$ donates the predicted neural current dipole of time 3 in the Right direction.$v_{m,3,R}$ donates the background activities of m^{th} neural current dipole of time 3 in the Right direction
Sources	~~Citation here~~ https://doi.org/10.1016/j.neuroimage.2020.116528
~~Ref. By IM??~~	

4.2.6 Input Data Constraints

Table **??** shows the data constraints on the input output 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.

The specification parameters in ~~Table ?? are listed in Table ??.~~ below

Table 1 *Input variable*

~~Input Variables~~

Var	Physical Constraints	Software Constraints	Typic
~~e_t $e_t > 0$ $e_t \leq e_t$max 20 dB80%~~ $v_{m,t}$	$v_{m,t} > 0$	$v_{m,t} \leq v_{m,t}$max	11nAm

~~(*)~~

Table 2 *Specification Parameter Values*

~~Specification Parameter Values~~

Var	Value
~~$e_t$max 60 dB~~ $v_{m,t}$max	20 nAm

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

~~R: Acoustic stimuli must be continuous~~

~~R: Acoustic stimuli can be converted to speech envelope~~

~~R: Calculation result of TRF model has no error~~

R1: the interactive data plots generated by Live Neuro should be exactly identical to original plots

R2: ~~the output of LiveNeuro should be interactive between different plots~~ The output of the software should consist of multiple data visualizations that are interconnected, with linked data interactions, and can be controlled interactively via mouse input.

5.2 Nonfunctional Requirements

NFR1: The generated data ~~charts should accurately reflect the specifics of the data and meet~~ visualizations should not only accurately represent the underlying data but also adhere to the standards of scientific ~~research.~~ rigor, including clarity, reproducibility, and interpretability. They must effectively convey key patterns, relationships, and trends in a manner that facilitates meaningful analysis and supports evidence-based conclusions.

NFR2: Users with knowledge of neuro science and computer science, as described in Section 3.2, should be able to successfully use the software with minimal training. The interface and functionality are designed to align with the interdisciplinary skill sets of such users, enabling them to efficiently perform data analysis and visualization tasks without the need for extensive onboarding or technical assistance.

NFR3: The effort required to make any of the likely changes listed for Live Neuro should be less than 20% of the original development time.

NFR4: LiveNeuro shall run on Linus ,Windows 10+ and MacOS operating system

6 Use Cases

6.1 UC01: Load Neuro Data for Visualization

Actors: Researcher
Description: The user loads a dataset containing neural recordings into the tool for visualization.
Preconditions: The user has a valid data file in the supported format.
Postconditions: Data is loaded and visible in the visualization plots.
Basic Flow:

1. User clicks the "Load Data" button.
2. System opens a file selection dialog.
3. User selects a valid neuro data file.
4. System loads and displays the data in multiple synchronized plots.

6.2 UC02: Interactive Selection on Plot A Highlights Related Data in Plot B

Actors: Researcher
Description: The user selects a region in one plot to highlight corresponding data in another plot.
Preconditions: Data is already loaded and visualized.
Postconditions: The selected data segment is highlighted across related plots.
Basic Flow:

1. User selects a region in Plot A using mouse drag or click.
2. System identifies related data points in Plot B.

6.3 UC03: Filter Data Based on Time Range

Actors: Researcher
Description: The user filters the visualized data to focus on a specific time interval or brain region.
Preconditions: Data is loaded and plots are visible.
Postconditions: Only data matching the filter criteria is shown in plots.
Basic Flow:

1. User opens filter panel.
2. User inputs desired time range.
3. System filters and updates plots to reflect criteria.

6.4 UC04: Export Customized Visualizations as Image or Report

Actors: Researcher
Description: The user exports the current view or a report of visualized data for documentation or sharing.
Preconditions: A data visualization is active.
Postconditions: The visualization is saved as an image or included in a report file.
Basic Flow:

1. User clicks "Export" button.
2. System provides export options (image, PDF report).
3. User selects format and destination.
4. System saves the file.

7 Likely Changes

LC1: The interactive method(mouse clicking, dragging, zooming etc.) may be modified or added according to the real needs

LC2: The supported plotting function may increase

8 Unlikely Changes

LC3: The underlying stimuli-response model(TRF) will not change.

9 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 **??** shows the dependencies of theoretical models, general definitions, data definitions, and instance models with each other. Table **??** shows the dependencies of instance models, requirements, and data constraints on each other. Table **??** shows the dependencies of theoretical models, general definitions, data definitions, instance models, and likely changes on the assumptions.

height	A1	A2	~~A3 A4~~ TM4.2.2 ~~A1~~	DD1	IM1
~~A2~~ A1					
~~A3~~ A2					
~~A4~~ TM4.2.2 ~~DD1~~	X	X			
DD1	X	X			
IM1	X	X	X	X	~~X X~~

~~Traceability Matrix Showing the Connections Between Items of Different Sections~~

	IM1	R1	R2 ~~R3 R4 R5~~
IM1		X	~~X X X~~
R1	X		X
R2	X	X	~~X~~
~~R3 X X X R4 X X R5~~			

~~Traceability~~

~~Matrix Showing the Connections Between Items of Different Sections~~

10 Reference

Proloy Das, Christian Brodbeck, Jonathan Z. Simon, Behtash Babadi, Neuro-current response functions: A unified approach to MEG source analysis under the continuous stimuli paradigm, NeuroImage, Volume 211, 2020, 116528, ISSN 1053-8119,

Gramfort, A., Luessi, M., Larson, E., Engemann, D. A., Strohmeier, D., Brodbeck, C., ... Hämäläinen, M. (2013). MEG and EEG data analysis with MNE-Python.Frontiers in Neuroinformatics 7, 267.

Gramfort, A., Luessi, M., Larson, E., Engemann, D.A., Strohmeier, D., Brodbeck, C., Parkkonen, L. and Hämäläinen, M.S., 2014. MNE software for processing MEG and EEG data. *neuroimage*, *86*, pp.446-460.