

# Module Interface Specification for ImgBeamer

Joachim de Fourestier

March 23, 2023

# 1 Revision History

| Date       | Version | Notes   |
|------------|---------|---|
| 2023/03/18 | 0.1.0   | Creation  |
|            | 0.1.1   | Update module hierarchy                               |
| 2023/03/19 | 0.1.2   | Add in module specifications                          |
| 2023/03/20 | 0.1.3   | Add in minor missing type information.                |
| 2023/03/22 | 0.1.4   | Fix some typos, formatting, and various minor issues. |

## 2 Symbols, Abbreviations and Acronyms

---

| symbol | description              |
|--------|--------------------------|
| HID    | Human Interface Device   |
| URL    | Uniform Resource Locator |

---

See the SRS [\[2\]](#) and MG [\[1\]](#) Documentation for additional items.

# Contents

|          |   |           |
|----------|---|-----------|
| <b>1</b> | <b>Revision History</b>                       | <b>i</b>  |
| <b>2</b> | <b>Symbols, Abbreviations and Acronyms</b>    | <b>ii</b> |
| <b>3</b> | <b>Introduction</b>                           | <b>1</b>  |
| <b>4</b> | <b>Notation</b>                               | <b>1</b>  |
| <b>5</b> | <b>Module Decomposition</b>                   | <b>3</b>  |
| <b>6</b> | <b>MIS of Application Control</b>             | <b>4</b>  |
| 6.1      | Module . . . . .                              | 4         |
| 6.2      | Uses . . . . .                                | 4         |
| 6.3      | Syntax . . . . .                              | 4         |
| 6.3.1    | Exported Constants . . . . .                  | 4         |
| 6.3.2    | Exported Access Programs . . . . .            | 4         |
| 6.4      | Semantics . . . . .                           | 4         |
| 6.4.1    | State Variables . . . . .                     | 4         |
| 6.4.2    | Environment Variables . . . . .               | 4         |
| 6.4.3    | Assumptions . . . . .                         | 4         |
| 6.4.4    | Access Routine Semantics . . . . .            | 4         |
| 6.4.5    | Local Functions . . . . .                     | 5         |
| <b>7</b> | <b>MIS of Graphical User Interface (GUI)</b>  | <b>6</b>  |
| 7.1      | Module . . . . .                              | 6         |
| 7.2      | Uses . . . . .                                | 6         |
| 7.3      | Syntax . . . . .                              | 6         |
| 7.3.1    | Exported Constants . . . . .                  | 6         |
| 7.3.2    | Exported Access Programs . . . . .            | 6         |
| 7.4      | Semantics . . . . .                           | 6         |
| 7.4.1    | State Variables . . . . .                     | 7         |
| 7.4.2    | Environment Variables . . . . .               | 7         |
| 7.4.3    | Assumptions . . . . .                         | 7         |
| 7.4.4    | Access Routine Semantics . . . . .            | 7         |
| 7.4.5    | Local Functions . . . . .                     | 8         |
| <b>8</b> | <b>MIS of Information and Metrics Display</b> | <b>9</b>  |
| 8.1      | Module . . . . .                              | 9         |
| 8.2      | Uses . . . . .                                | 9         |
| 8.3      | Syntax . . . . .                              | 9         |
| 8.3.1    | Exported Constants . . . . .                  | 9         |
| 8.3.2    | Exported Access Programs . . . . .            | 9         |

|           |                                      |           |
|-----------|--------------------------------------|-----------|
| 8.4       | Semantics . . . . .                  | 9         |
| 8.4.1     | State Variables . . . . .            | 9         |
| 8.4.2     | Environment Variables . . . . .      | 9         |
| 8.4.3     | Assumptions . . . . .                | 9         |
| 8.4.4     | Access Routine Semantics . . . . .   | 9         |
| 8.4.5     | Local Functions . . . . .            | 10        |
| <b>9</b>  | <b>MIS of Image Export</b>           | <b>11</b> |
| 9.1       | Module . . . . .                     | 11        |
| 9.2       | Uses . . . . .                       | 11        |
| 9.3       | Syntax . . . . .                     | 11        |
| 9.3.1     | Exported Constants . . . . .         | 11        |
| 9.3.2     | Exported Access Programs . . . . .   | 11        |
| 9.4       | Semantics . . . . .                  | 11        |
| 9.4.1     | State Variables . . . . .            | 11        |
| 9.4.2     | Environment Variables . . . . .      | 11        |
| 9.4.3     | Assumptions . . . . .                | 11        |
| 9.4.4     | Access Routine Semantics . . . . .   | 11        |
| 9.4.5     | Local Functions . . . . .            | 12        |
| <b>10</b> | <b>MIS of Display Control</b>        | <b>13</b> |
| 10.1      | Module . . . . .                     | 13        |
| 10.2      | Uses . . . . .                       | 13        |
| 10.3      | Syntax . . . . .                     | 13        |
| 10.3.1    | Exported Constants . . . . .         | 13        |
| 10.3.2    | Exported Access Programs . . . . .   | 13        |
| 10.4      | Semantics . . . . .                  | 14        |
| 10.4.1    | State Variables . . . . .            | 14        |
| 10.4.2    | Environment Variables . . . . .      | 14        |
| 10.4.3    | Assumptions . . . . .                | 14        |
| 10.4.4    | Access Routine Semantics . . . . .   | 14        |
| 10.4.5    | Local Functions . . . . .            | 14        |
| <b>11</b> | <b>MIS of Drawing Stage / Canvas</b> | <b>15</b> |
| 11.1      | Module . . . . .                     | 15        |
| 11.2      | Uses . . . . .                       | 15        |
| 11.3      | Syntax . . . . .                     | 15        |
| 11.3.1    | Exported Constants . . . . .         | 15        |
| 11.3.2    | Exported Access Programs . . . . .   | 15        |
| 11.4      | Semantics . . . . .                  | 15        |
| 11.4.1    | State Variables . . . . .            | 15        |
| 11.4.2    | Environment Variables . . . . .      | 16        |
| 11.4.3    | Assumptions . . . . .                | 16        |

|           |   |           |
|-----------|---|-----------|
| 11.4.4    | Access Routine Semantics . . . . .                                | 16        |
| <b>12</b> | <b>MIS of Image Rendering</b>                                     | <b>17</b> |
| 12.1      | Module . . . . .  | 17        |
| 12.2      | Uses . . . . .  | 17        |
| 12.3      | Syntax . . . . .  | 17        |
| 12.3.1    | Exported Constants . . . . .                                      | 17        |
| 12.3.2    | Exported Access Programs . . . . .                                | 17        |
| 12.4      | Semantics . . . . .   | 17        |
| 12.4.1    | State Variables . . . . .   | 17        |
| 12.4.2    | Environment Variables . . . . .                                   | 17        |
| 12.4.3    | Assumptions . . . . .   | 18        |
| 12.4.4    | Access Routine Semantics . . . . .                                | 18        |
| 12.4.5    | Local Functions . . . . .   | 18        |
| <b>13</b> | <b>MIS of Image Metrics Calculation</b>                           | <b>19</b> |
| 13.1      | Module . . . . .  | 19        |
| 13.2      | Uses . . . . .  | 19        |
| 13.3      | Syntax . . . . .  | 19        |
| 13.3.1    | Exported Constants . . . . .                                      | 19        |
| 13.3.2    | Exported Access Programs . . . . .                                | 19        |
| 13.4      | Semantics . . . . .   | 19        |
| 13.4.1    | State Variables, Environment Variables, and Assumptions . . . . . | 19        |
| 13.4.2    | Access Routine Semantics . . . . .                                | 19        |
| 13.4.3    | Local Functions . . . . .   | 19        |
| <b>14</b> | <b>MIS of Ground Truth Visualization</b>                          | <b>20</b> |
| 14.1      | Module . . . . .  | 20        |
| 14.2      | Uses . . . . .  | 20        |
| 14.3      | Syntax . . . . .  | 20        |
| 14.3.1    | Exported Constants . . . . .                                      | 20        |
| 14.3.2    | Exported Access Programs . . . . .                                | 20        |
| 14.4      | Semantics . . . . .   | 20        |
| 14.4.1    | State Variables . . . . .   | 20        |
| 14.4.2    | Environment Variables and Assumptions . . . . .                   | 20        |
| 14.4.3    | Access Routine Semantics . . . . .                                | 21        |
| 14.4.4    | Local Functions . . . . .   | 21        |
| <b>15</b> | <b>MIS of Subregion Visualization</b>                             | <b>22</b> |
| 15.1      | Module . . . . .  | 22        |
| 15.2      | Uses . . . . .  | 22        |
| 15.3      | Syntax . . . . .  | 22        |
| 15.3.1    | Exported Constants . . . . .                                      | 22        |

|           |   |           |
|-----------|---|-----------|
| 15.3.2    | Exported Access Programs . . . . .              | 22        |
| 15.4      | Semantics . . . . .                             | 22        |
| 15.4.1    | State Variables . . . . .                       | 22        |
| 15.4.2    | Environment Variables . . . . .                 | 22        |
| 15.4.3    | Assumptions . . . . .                           | 23        |
| 15.4.4    | Access Routine Semantics . . . . .              | 23        |
| 15.4.5    | Local Functions . . . . .                       | 23        |
| <b>16</b> | <b>MIS of Spot Profile Visualization</b>        | <b>24</b> |
| 16.1      | Module . . . . .                                | 24        |
| 16.2      | Uses . . . . .                                  | 24        |
| 16.3      | Syntax . . . . .                                | 24        |
| 16.3.1    | Exported Constants . . . . .                    | 24        |
| 16.3.2    | Exported Access Programs . . . . .              | 24        |
| 16.4      | Semantics . . . . .                             | 24        |
| 16.4.1    | State Variables . . . . .                       | 24        |
| 16.4.2    | Environment Variables . . . . .                 | 24        |
| 16.4.3    | Assumptions . . . . .                           | 24        |
| 16.4.4    | Access Routine Semantics . . . . .              | 25        |
| 16.4.5    | Local Functions . . . . .                       | 25        |
| <b>17</b> | <b>MIS of Spot Content Visualization</b>        | <b>26</b> |
| 17.1      | Module . . . . .                                | 26        |
| 17.2      | Uses . . . . .                                  | 26        |
| 17.3      | Syntax . . . . .                                | 26        |
| 17.3.1    | Exported Constants . . . . .                    | 26        |
| 17.3.2    | Exported Access Programs . . . . .              | 26        |
| 17.4      | Semantics . . . . .                             | 26        |
| 17.4.1    | State Variables . . . . .                       | 26        |
| 17.4.2    | Environment Variables . . . . .                 | 26        |
| 17.4.3    | Assumptions . . . . .                           | 27        |
| 17.4.4    | Access Routine Semantics . . . . .              | 27        |
| 17.4.5    | Local Functions . . . . .                       | 27        |
| <b>18</b> | <b>MIS of Spot Signal Visualization</b>         | <b>28</b> |
| 18.1      | Module . . . . .                                | 28        |
| 18.2      | Uses . . . . .                                  | 28        |
| 18.3      | Syntax . . . . .                                | 28        |
| 18.3.1    | Exported Constants . . . . .                    | 28        |
| 18.3.2    | Exported Access Programs . . . . .              | 28        |
| 18.4      | Semantics . . . . .                             | 28        |
| 18.4.1    | State Variables . . . . .                       | 28        |
| 18.4.2    | Environment Variables and Assumptions . . . . . | 28        |

|           |   |           |
|-----------|---|-----------|
| 18.4.3    | Access Routine Semantics . . . . .              | 29        |
| 18.4.4    | Local Functions . . . . .                       | 29        |
| <b>19</b> | <b>MIS of Spot Layout Visualization</b>         | <b>30</b> |
| 19.1      | Module . . . . .                                | 30        |
| 19.2      | Uses . . . . .                                  | 30        |
| 19.3      | Syntax . . . . .                                | 30        |
| 19.3.1    | Exported Constants . . . . .                    | 30        |
| 19.3.2    | Exported Access Programs . . . . .              | 30        |
| 19.4      | Semantics . . . . .                             | 30        |
| 19.4.1    | State Variables . . . . .                       | 30        |
| 19.4.2    | Environment Variables and Assumptions . . . . . | 30        |
| 19.4.3    | Access Routine Semantics . . . . .              | 31        |
| 19.4.4    | Local Functions . . . . .                       | 31        |
| <b>20</b> | <b>MIS of Sample Subregion Visualization</b>    | <b>32</b> |
| 20.1      | Module . . . . .                                | 32        |
| 20.2      | Uses . . . . .                                  | 32        |
| 20.3      | Syntax . . . . .                                | 32        |
| 20.3.1    | Exported Constants . . . . .                    | 32        |
| 20.3.2    | Exported Access Programs . . . . .              | 32        |
| 20.4      | Semantics . . . . .                             | 32        |
| 20.4.1    | State Variables . . . . .                       | 32        |
| 20.4.2    | Environment Variables and Assumptions . . . . . | 33        |
| 20.4.3    | Access Routine Semantics . . . . .              | 33        |
| 20.4.4    | Local Functions . . . . .                       | 33        |
| <b>21</b> | <b>MIS of Resulting Subregion Visualization</b> | <b>34</b> |
| 21.1      | Module . . . . .                                | 34        |
| 21.2      | Uses . . . . .                                  | 34        |
| 21.3      | Syntax . . . . .                                | 34        |
| 21.3.1    | Exported Constants . . . . .                    | 34        |
| 21.3.2    | Exported Access Programs . . . . .              | 34        |
| 21.4      | Semantics . . . . .                             | 34        |
| 21.4.1    | State Variables . . . . .                       | 34        |
| 21.4.2    | Environment Variables and Assumptions . . . . . | 35        |
| 21.4.3    | Access Routine Semantics . . . . .              | 35        |
| 21.4.4    | Local Functions . . . . .                       | 35        |
| <b>22</b> | <b>MIS of Result Image Visualization</b>        | <b>36</b> |
| 22.1      | Module . . . . .                                | 36        |
| 22.2      | Uses . . . . .                                  | 36        |
| 22.3      | Syntax . . . . .                                | 36        |



|        |                                    |    |
|--------|------------------------------------|----|
| 22.3.1 | Exported Constants . . . . .       | 36 |
| 22.3.2 | Exported Access Programs . . . . . | 36 |
| 22.4   | Semantics . . . . .                | 36 |
| 22.4.1 | State Variables . . . . .          | 36 |
| 22.4.2 | Environment Variables . . . . .    | 37 |
| 22.4.3 | Assumptions . . . . .              | 37 |
| 22.4.4 | Access Routine Semantics . . . . . | 37 |
| 22.4.5 | Local Functions . . . . .          | 37 |

### 3 Introduction

The following document details the Module Interface Specifications for ImgBeamer (SEM image formation demo tool). Complementary documents include the System Requirement Specifications and Module Guide. The full documentation and implementation can be found at [https://github.com/joedf/CAS741\\_w23](https://github.com/joedf/CAS741_w23).

### 4 Notation

The structure of the MIS for modules comes from Hoffman and Strooper [4], with the addition that template modules have been adapted from [3]. The mathematical notation comes from Chapter 3 of Hoffman and Strooper [4]. 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 ImgBeamer.

| Data Type              | Notation           | Description   |
|------------------------|--------------------|---|
| integer                | $\mathbb{Z}$       | a number without a fractional component in $(-\infty, \infty)$  |
| positive integer       | $\mathbb{Z}_+$     | a positive integer ( $\mathbb{Z}$ ) in $(0, \infty)$  |
| unsigned 8-bit integer | $\mathbb{U}$       | a number without a fractional component in $(0, 255)$   |
| natural number         | $\mathbb{N}$       | a number without a fractional component in $[1, \infty)$  |
| real                   | $\mathbb{R}$       | any number in $(-\infty, \infty)$   |
| positive real          | $\mathbb{R}_+$     | any real number in $(0, \infty)$  |
| unit interval          | $\mathbb{A}$       | any real number in $(0, 1)$   |
| imageData [6]          | $\mathbb{I}_{w,h}$ | <b>data:</b> a one dimensional array of positive integers from 0 to 255 in RGBA order (pixel components) start from the top left pixel to the bottom right pixel with a <b>width:</b> $\mathbb{Z}_+$ width of $w$ and <b>height:</b> $\mathbb{Z}_+$ height of $h$ . |

The specification of ImgBeamer uses some derived data types: sequences, strings, tuples, and `drawingObject`. 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. `drawingObject` is a geometry object (provided by Konva): the fill can be an image, a colour, or even another shape. They can have a width, height, rotation, position (x,y), and many other properties. `imageDrawingObject` is essentially `drawingObject` with an image as the fill. `drawingLayer` is a layer on a drawing stage (provided by Konva). A drawing stage

may have many layers. In addition, ImgBeamer 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 [1] document for this project.

| Level 1                 | Level 2                  | Level 3                         |
|-------------------------|--------------------------|---------------------------------|
| Hardware-Hiding Module  |                          |                                 |
|                         | Application Control      |                                 |
|                         | Input                    | Ground Truth Image Input        |
|                         |                          | Imaging Parameters Input        |
|                         |                          | Spot Profile Input              |
|                         | Output                   | Information and Metrics Display |
|                         |                          | Image Export                    |
| Behaviour-Hiding Module | Visualization Display    | Ground Truth                    |
|                         |                          | Subregion                       |
|                         |                          | Spot Profile                    |
|                         |                          | Spot Content                    |
|                         |                          | Spot Signal                     |
|                         |                          | Spot Layout                     |
|                         |                          | Sampled Subregion               |
|                         |                          | Resulting Subregion             |
|                         | Display Control          |                                 |
|                         | Graphical User Interface |                                 |
|                         | Image Manipulation       | Drawing Stage / Canvas Module   |
|                         |                          | Rendering                       |
|                         |                          | Metrics Calculation             |

Table 1: Module Hierarchy

## 6 MIS of Application Control

### 6.1 Module

main (M2)

### 6.2 Uses

GUI Module Specification (7)

### 6.3 Syntax

#### 6.3.1 Exported Constants

None

#### 6.3.2 Exported Access Programs

| Name | In | Out | Exceptions |
|------|----|-----|------------|
| main | -  | -   | -          |

### 6.4 Semantics

#### 6.4.1 State Variables

None

#### 6.4.2 Environment Variables

None

#### 6.4.3 Assumptions

- The application is run in an HTML5 compliant web browser.
- The GUI is running and displayed without issue.

#### 6.4.4 Access Routine Semantics

main():

- transition: Initializes the GUI, modifies the state and environment variables of the GUI Module Specification (7).

#### 6.4.5 Local Functions

`UpdateBaseImage()`: Updates the GUI and propagates a change in the input ground truth image throughout the application.

## 7 MIS of Graphical User Interface (GUI)

### 7.1 Module

gui (M18)

### 7.2 Uses

- Hardware Hiding Module (M1)
- Display Control Module (M17)
- Ground Truth Image Input Module (M3)
- Imaging Parameters Input Module (M4)
- Spot Profile Input Module (M5)
- Image Export Module (M6)
- Information and Metrics Display Module (M7)

### 7.3 Syntax

#### 7.3.1 Exported Constants

- **G\_BoxSize**: A value ( $\mathbb{N}$ ) describing both the pixel width and height used for each visualization display “box”.
- **G\_MATH\_TOFIXED**: Used for display for fixed decimal number length rounding (ex. “4.1234” at fixed length “2” results in “4.12”).

#### 7.3.2 Exported Access Programs

| Name | In                               | Out                                 | Exceptions |
|------|----------------------------------|-------------------------------------|------------|
| gui  | baseImage ( $\mathbb{I}_{w,h}$ ) | displayReference,<br>event handlers | -          |

### 7.4 Semantics

[Didn't do MIS descriptions of the Input modules because they are essentially just buttons or text boxes with event handlers. Can be implemented however a developer wishes as long the SRS value constraints are followed... Or are full descriptions also needed for these? Not sure if they would add much value than already provided here or just informational noise. Maybe I can write this as a note here (instead of a comment)? —Author]

#### 7.4.1 State Variables

- **baseImage**: The ground truth image as processed and given by M3 as  $\mathbb{I}_{w,h}$ .
- **resultImage**: A reference to resulting image as processed and given by the Display Control M17 as  $\mathbb{I}_{w,h}$ .
- **imageRows**: Rasterization grid rows given by M4 as  $\mathbb{Z}_+$ .
- **imageCols**: Rasterization grid columns given by M4 as  $\mathbb{Z}_+$ .
- **imageMag**: Magnification of the subregion as given by M4 as  $\mathbb{R}_+$ .
- **spotWidth**: The spot's width given by M5 as  $\mathbb{Z}_+$ .
- **spotHeight**: The spot's height given by M5 as  $\mathbb{Z}_+$ .
- **spotAngle**: The spot's angle given by M5 as  $\mathbb{R}$ .
- **dispControl**: a reference to the Display Control (M17).

#### 7.4.2 Environment Variables

- Keyboard
- Mouse
- Screen
- File System

#### 7.4.3 Assumptions

- The file system is able to read and provide the image file as specified by the user through an OS file-open dialog. Otherwise, if the file is not found, denied access, or cancelled, no changes should occur.
- The OS and WebBrowser are able to provide basic text or number input user controls with some basic built-in validation, and is able to handle events from Human Interface Devices (HIDs such as a mouse, keyboard, or touchscreen).

#### 7.4.4 Access Routine Semantics

OnImageLoaded():



- transition: Sets up user control event handlers (e.g., mouse clicks or drag, button presses, text input change, ...) as needed for the user input modules (M3, M4 and M5), initializes the Display Control Module (M17) with the individual GUI draw controls/locations for each visualization and obtains an update function reference for redraws or state changes. If another image is loaded (i.e. the image is changed), the Display Control is reinitialized with the new image.

[I am not sure what transition means, couldn't find it as a defined term in the slides. Defined what the function/method does. I hope this is right, continuing as so... — Author]

- output:
  - doUpdate(): notifies the Display Control Module (M17) to update / redraw the visualization displays.
  - updateInfoDisplay(): notifies the Information Display Module (M7) to update when needed (such as an input value change from the mentioned input modules).
  - doExport(): Event handler for the "Export" button press, it calls the Image Export Module (M6).

#### 7.4.5 Local Functions

doUpdate(), updateInfoDisplay(), and doExport() as described above.

## 8 MIS of Information and Metrics Display

### 8.1 Module

infoDisp (M7)

### 8.2 Uses

Metrics Calculation Module (M21)

### 8.3 Syntax

#### 8.3.1 Exported Constants

None

#### 8.3.2 Exported Access Programs

| Name       | In   | Out | Exceptions |
|------------|--|-----|------------|
| updateInfo | textDisplayControl,<br>baseImage ( $\mathbb{I}_{w,h}$ ),<br>resultImage ( $\mathbb{I}_{w,h}$ ),<br>imageMag ( $\mathbb{R}_+$ ) | -   | -          |

### 8.4 Semantics

#### 8.4.1 State Variables

None

#### 8.4.2 Environment Variables

The decimal length for rounding the number for display as defined by Module Specification (7).

#### 8.4.3 Assumptions

- A suitable display control (capable of displaying text and numbers) is constructed and displayed in the GUI for use by this module.

#### 8.4.4 Access Routine Semantics

updateInfo(textDisplayControl, baseImage, resultImage, imageMag):

- `transition`: Calls the Metrics Calculation Module (M21) to compare the given images (`baseImage` and `resultImage`) to get metric value ( $\mathbb{R}$ ). The magnification (`imageMag`) and metric values are then rounded and pushed as formatted descriptive text to `textDisplayControl`.

#### 8.4.5 Local Functions

None

## 9 MIS of Image Export

### 9.1 Module

imgExport (M6)

### 9.2 Uses

None

### 9.3 Syntax

#### 9.3.1 Exported Constants

None

#### 9.3.2 Exported Access Programs

| Name   | In   | Out       | Exceptions  |
|--------|--|-----------|-------------|
| export | resultImage ( $\mathbb{I}_{w,h}$ ),<br>outputPath (string) | ImageFile | InvalidPath |

### 9.4 Semantics

#### 9.4.1 State Variables

None

#### 9.4.2 Environment Variables

The File System.

#### 9.4.3 Assumptions

The output location is valid, writable, and accessible.

#### 9.4.4 Access Routine Semantics

export(resultImage, outputPath):

- output: an image file representing **resultImage** at location **outputPath**.
- exception: **InvalidPath** meaning the location cannot be written to, either because the directory is nonexistent, the path contains invalid characters, or inadequate write permissions.

#### 9.4.5 Local Functions

`GetSuggestedFileName()`: generates a suggested filename with a timestamp that is displayed in the save-file dialog where possible.

## 10 MIS of Display Control

### 10.1 Module

dispControl (M17)

### 10.2 Uses

1. Rendering Module (M20)
2. Ground Truth Visualization Module (M8)
3. Subregion Visualization Module (M9)
4. Spot Profile Visualization Module (M10)
5. Spot Content Visualization Module (M11)
6. Spot Signal Visualization Module (M12)
7. Spot Layout Visualization Module (M13)
8. Sampled Subregion Visualization Module (M14)
9. Resulting Subregion Visualization Module (M15)
10. Resulting Image Visualization Module (M16)

### 10.3 Syntax

#### 10.3.1 Exported Constants

None

#### 10.3.2 Exported Access Programs

| Name        | In  | Out   | Exceptions |
|-------------|---|---|------------|
| Init        | gtImage ( $\mathbb{I}_{w,h}$ ),<br>drawControls: GUI<br>controls for 2 to 10 in<br>section 10.2 | a reference to the<br>doUpdate function for<br>each | -          |
| doUpdateAll | -   | -   | -          |

## 10.4 Semantics

### 10.4.1 State Variables

- References to drawing stages/canvases for all the visualization/display modules mentioned in section [10.2](#)
- ... and each corresponding update function references
- `gtImage`: a reference to the ground truth image data (as provided by [M3](#)).
- `subregionImage`: a reference to `imageDrawingObject` (as provided by [M9](#)).

### 10.4.2 Environment Variables

- Mouse
- Keyboard
- Screen

### 10.4.3 Assumptions

None

### 10.4.4 Access Routine Semantics

`Init(gtImage, drawControls...):`

- `transition`: Initializes the drawing stages/canvases in each of the draw-control locations (`drawControls`) as provided by the GUI Module ([M18](#)) and passes them to each corresponding visualization module.
- `output`: a `doUpdate` function reference for each of the visualization modules.

`doUpdateAll():`

- `transition`: updates all the visualization displays by calling all the corresponding `doUpdate` function references.

### 10.4.5 Local Functions

None

## 11 MIS of Drawing Stage / Canvas

### 11.1 Module

stage (M19)

### 11.2 Uses

None

### 11.3 Syntax

#### 11.3.1 Exported Constants

None

#### 11.3.2 Exported Access Programs

| Name         | In   | Out                            | Exceptions        |
|--------------|--|--------------------------------|-------------------|
| init         | container, width ( $\mathbb{Z}_+$ ), height ( $\mathbb{Z}_+$ ) | drawing stage                  | ContainerNotFound |
| getLayers    | -  | array of the layers            | -                 |
| getContext   | -  | drawing context [7]            | -                 |
| getContainer | -  | display control / container    | -                 |
| toCanvas     | -  | canvasAPI object [7]           | -                 |
| toDataURL    | -  | a URL to an exported image [7] | -                 |

### 11.4 Semantics

Currently, using the implementing by the Konva [5] javascript library. Largely wraps around the HTML Canvas API object with added functionality such as layering and “transformers” for node-editable shapes.

#### 11.4.1 State Variables

- width/height: the width and height of the drawing stage in pixels.
- Layers: drawing layers
- Container: the display control / container where to “paint” the images as provided by the GUI Module (M18).



- Event handlers: all the Konva objects (layers, geometries, stage) may have event handlers for HID events.

#### 11.4.2 Environment Variables

- The HIDs (e.g., mouse, keyboard) for user input events
- The Screen for display output

#### 11.4.3 Assumptions

Any drawing exceptions will result in throwing errors that may be caught as needed, but will simply result in blank (or black) images with no interruption in any drawings in progress or drawing loops.

#### 11.4.4 Access Routine Semantics

`init()`:

- transition: Initializes a drawing stage object with the given options where `container` is the control or location given by the GUI Module (M18).
- output: the drawing stage object.
- exception: `ContainerNotFound` meaning the given control is nonexistent or could not be found.

`getLayers()`:

- output: an array of all the individual drawing layers within the stage.

`getContext()`:

- output: the drawing context as defined by the CanvasAPI [7].

`getContainer()`:

- output: the display container as defined/given by the GUI Module (M18) when the stage is initialized.

`toCanvas()`:

- output: the canvasAPI element / object [7].

`toDataURL()`:

- output: a URL pointing to an image exported in-memory within the WebBrowser that can “downloaded” and saved a location specified by the user.

## 12 MIS of Image Rendering

### 12.1 Module

renderUtils (M20)

### 12.2 Uses

Drawing Stage / Canvas Module (M19)

### 12.3 Syntax

#### 12.3.1 Exported Constants

defaultLineColor: the default line color (RGBA) to use for drawing grids (255,255,255,204)  
- types:  $(\mathbb{Z}_+, \mathbb{Z}_+, \mathbb{Z}_+, \mathbb{Z}_+)$ .

#### 12.3.2 Exported Access Programs

| Name                 | In   | Out   | Exceptions    |
|----------------------|--|---|---------------|
| drawGrid             | gridLayer<br>(drawingLayer), rect<br>(drawingObject),<br>rows $(\mathbb{Z}_+)$ , cols $(\mathbb{Z}_+)$ ,<br>lineColor            | cell size<br>(width/height in<br>pixels, $\mathbb{Z}_+$ ) | badGridParams |
| repeatDrawOnGrid     | layer<br>(drawingLayer), rect<br>(drawingObject),<br>rows $(\mathbb{Z}_+)$ , cols $(\mathbb{Z}_+)$ ,<br>shape<br>(drawingObject) | -   | badGridParams |
| ComputeProbeValue_gs | image $(\mathbb{I}_{w,h})$ , probe   | grayscale value ( $\mathbb{U}$ )                          | -             |
| get_avg_pixel_gs     | rawImageData $(\mathbb{I}_{w,h})$  | grayscale value ( $\mathbb{U}$ )                          | -             |

### 12.4 Semantics

#### 12.4.1 State Variables

None.

#### 12.4.2 Environment Variables

None

### 12.4.3 Assumptions

None

### 12.4.4 Access Routine Semantics

`drawGrid(gridLayer, rect, rows, cols, lineColor = defaultLineColor):`

- transition: Draws a line (optional colour `lineColor`) grid with the specified number of `rows` and `cols` (columns) on the given drawing layer (`gridLayer`) within the given grid rectangular bounds (`rect`).
- output: the computed size in pixel of a cell within the grid drawn.
- exception: `badGridParams` meaning non-integer or non-positive values were given for `rows` and `cols`.

`repeatDrawOnGrid(layer, rect, rows, cols, shape):`

- transition: Draw a given geometry (`shape`) or `imageDrawingObject` repeated over a grid pattern with the specified number of `rows` and `cols` (columns) on the given drawing layer (`layer`) within the given grid rectangular bounds (`rect`).
- exception: `badGridParams` meaning non-integer or non-positive values were given for `rows` and `cols`.

`ComputeProbeValue_gs(image, probe):`

- transition: internally uses `get_avg_pixel_gs()` to calculate the pixel value of a locally composited or “stenciled” or “clipped” image (for sampling the region defined by the `shape` or `probe`, like a cookie cutter). Pixels that have been “stenciled” out are set to blank pixels (where all RGBA components are equal to 0) and the image is cropped to small rectangular bounding box of the “stencil” shape (`probe`).
- output: Gives the average pixel value (grayscale intensity:  $\mathbb{U}$ ) by sampling the given image (`image`) object with the given shape / geometry (`probe`).

`get_avg_pixel_gs(rawImageData):`

- output: Gives the average pixel value (grayscale intensity:  $\mathbb{U}$ ) from a given `imageData` array (`rawImageData`) of the RGBA pixel values ignoring any blank pixels (where all RGBA components are equal to 0).

### 12.4.5 Local Functions

None

## 13 MIS of Image Metrics Calculation

### 13.1 Module

metrics (M21)

### 13.2 Uses

None

### 13.3 Syntax

#### 13.3.1 Exported Constants

None

#### 13.3.2 Exported Access Programs

| Name    | In   | Out                               | Exceptions          |
|---------|--|-----------------------------------|---------------------|
| compare | image1 ( $\mathbb{I}_{w,h}$ ), image2 ( $\mathbb{I}_{w,h}$ ) | similarity ratio ( $\mathbb{A}$ ) | DifferentImageSizes |

### 13.4 Semantics

See the SRS [2] and MG [1] for more information.

#### 13.4.1 State Variables, Environment Variables, and Assumptions

None

#### 13.4.2 Access Routine Semantics

compare(image1, image2):

- transition: Compares the two images and computes a value representing the similarity.
- output: Gives a value ( $\mathbb{A}$ ) where 1.0 means a perfect match and 0 means zero similarity.
- exception: DifferentImageSizes meaning the size of image1 and image2 do not match.

#### 13.4.3 Local Functions

None

## 14 MIS of Ground Truth Visualization

### 14.1 Module

drawGroundtruthImage (M8)

### 14.2 Uses

- Rendering Module (M20)
- DrawingStage Module (M19)

### 14.3 Syntax

#### 14.3.1 Exported Constants

None

#### 14.3.2 Exported Access Programs

| Name                 | In                                | Out                             | Exceptions |
|----------------------|-----------------------------------|---------------------------------|------------|
| drawGroundtruthImage | stage, gtImage,<br>subregionImage | imageDrawingObject,<br>doUpdate | -          |

### 14.4 Semantics

#### 14.4.1 State Variables

These are kept for mutation, update calls, and performance reasons.

- **stage**: a reference to drawing stage.
- **rect**: a reference to a rectangle geometry.
- **gtImage**: a reference to imageDrawingObject for the ground truth image.
- **subregionImage**: a reference to imageDrawingObject for the subregion image.

#### 14.4.2 Environment Variables and Assumptions

None

### 14.4.3 Access Routine Semantics

`drawGroundtruthImage(stage, gtImage, subregionImage):`

- **transition**: Defines a drawing arrangement to fill the stage with the ground truth image (`gtImage` as provided by the Display Control M17) with a semi-transparent rectangle (`rect`) representing the bounds of the `subregionImage` (as provided by the Display Control M17).
- **output**: an object with a reference to the update function (`doUpdate`) and a reference to `rect`.

### 14.4.4 Local Functions

`doUpdate()`: Update the drawing based on the state variables.

## 15 MIS of Subregion Visualization

### 15.1 Module

drawSubregionImage (M9)

### 15.2 Uses

- Rendering Module (M20)
- DrawingStage Module (M19)

### 15.3 Syntax

#### 15.3.1 Exported Constants

None

#### 15.3.2 Exported Access Programs

| Name               | In                                | Out            | Exceptions |
|--------------------|-----------------------------------|----------------|------------|
| drawSubregionImage | stage, gtImage,<br>updateCallback | subregionImage | -          |

### 15.4 Semantics

#### 15.4.1 State Variables

These are kept for mutation, update calls, and performance reasons.

- **stage**: a reference to drawing stage.
- **gtImage**: a reference to imageDrawingObject for the ground truth image.
- **subregionImage**: a reference to imageDrawingObject for the subregion image.
- **updateCallback**: an optional reference to a function call when an update occurs (i.e. when view bounds change).
- mouse events (scroll and drag)

#### 15.4.2 Environment Variables

The HIDs.

### 15.4.3 Assumptions

None

### 15.4.4 Access Routine Semantics

`drawSubregionImage(stage, gtImage, updateCallback = null):`

- **transition:** Draw a view displaying a copy of the ground truth image (`gtImage` as provided by the Display Control M17) representing the current subregion / ROI. This view can be panned and zoomed with mouse events. The `updateCallback` function reference is called when mouse events (drag or scroll) causes the of the view bounds to change.
- **output:** a reference to `subregionImage` `imageDrawingObject` (which can be used like `rect`) representing the bounds of the current view.

### 15.4.5 Local Functions

`doUpdate()`: Update the drawing based on the state variables that change on mouse event such as dragging or scrolling events (pan and zoom) and calls the `updateCallback`.



## 16 MIS of Spot Profile Visualization

### 16.1 Module

drawSpotProfile (M10)

### 16.2 Uses

- Rendering Module (M20)
- DrawingStage Module (M19)

### 16.3 Syntax

#### 16.3.1 Exported Constants

None

#### 16.3.2 Exported Access Programs

| Name            | In    | Out                     | Exceptions |
|-----------------|-------|-------------------------|------------|
| drawSpotProfile | stage | beam<br>(drawingObject) | -          |

### 16.4 Semantics

#### 16.4.1 State Variables

These are kept for mutation, update calls, and performance reasons.

- **stage**: a reference to the drawing stage.
- **beam**: a reference to the ellipse geometry.
- Mouse events handled by Konva for shape node-editing / “transformers”.

#### 16.4.2 Environment Variables

The HIDs.

#### 16.4.3 Assumptions

None

#### 16.4.4 Access Routine Semantics

`drawSpotProfile(stage)`:

- transition: On the given drawing **stage**, draws an editable ellipse shape representing the beam/spot shape.
- output: a reference to the ellipse geometry (**beam**).

#### 16.4.5 Local Functions

None

## 17 MIS of Spot Content Visualization

### 17.1 Module

`drawSpotContent` (M11)

### 17.2 Uses

- Rendering Module (M20)
- DrawingStage Module (M19)

### 17.3 Syntax

#### 17.3.1 Exported Constants

None

#### 17.3.2 Exported Access Programs

| Name                         | In  | Out                 | Exceptions |
|------------------------------|---|---------------------|------------|
| <code>drawSpotContent</code> | <code>stage</code> , <code>subregionImage</code> ,<br><code>sBeam</code> ( <code>drawingObject</code> ),<br><code>updateCallback</code> | <code>sImage</code> | -          |

### 17.4 Semantics

#### 17.4.1 State Variables

These are kept for mutation, update calls, and performance reasons.

- `stage`: a reference to the drawing stage.
- `sImage`: a reference to the subregion image clone (`imageDrawingObject`).
- `sBeam`: a local reference to the beam “stencil” geometry clone (not changed).
- `updateCallback`: an optional reference to a function call when an update occurs (i.e. when the `sImage` position and scaling to changes).
- mouse events (scroll and drag)

#### 17.4.2 Environment Variables

The HIDs.

### 17.4.3 Assumptions

None

### 17.4.4 Access Routine Semantics

`drawSpotContent(stage, subregionImage, sBeam, updateCallback = null):`

- transition: On a given drawing stage (`stage`), draws an image clone (based on `subregionImage`) of the subregion (`sImage`) that is “stenciled” or clipped by the `sBeam` geometry/shape. This image can be panned and zoomed by mouse events. The `updateCallback` function reference is called when mouse events (drag or scroll) causes the image (`sImage`) position and scaling to changes.
- output: a reference to the image (`sImage`) being moved and scaled.

### 17.4.5 Local Functions

`doUpdate()`: Update the drawing based on the state variables that change on mouse event such as dragging or scrolling events (pan and zoom) and calls the `updateCallback`.

## 18 MIS of Spot Signal Visualization

### 18.1 Module

drawSpotSignal (M12)

### 18.2 Uses

- Rendering Module (M20)
- DrawingStage Module (M19)

### 18.3 Syntax

#### 18.3.1 Exported Constants

None

#### 18.3.2 Exported Access Programs

| Name           | In  | Out      | Exceptions |
|----------------|---|----------|------------|
| drawSpotSignal | sourceStage,<br>destStage, sBeam<br>(drawingObject) | doUpdate | -          |

### 18.4 Semantics

#### 18.4.1 State Variables

These are kept for mutation, update calls, and performance reasons.

- **sourceStage**: a reference to the drawing stage from M11 given by the Display Control M17.
- **destStage**: a reference to the drawing stage to the spot signal representation draw on.
- **sBeam**: a local reference to the beam “stencil” geometry clone (not changed).
- **doUpdate**: an optional reference to a function call when an update occurs.

#### 18.4.2 Environment Variables and Assumptions

None

### 18.4.3 Access Routine Semantics

`drawSpotSignal(sourceStage, destStage, sBeam):`

- **transition:** On a given drawing stage (`destStage`), draws the `sBeam` geometry/shape filled in by the computed average pixel value from the clipped / “stenciled” image content as displayed in Spot Content (M11).
- **output:** a reference to an update function (`doUpdate`) to call (by the Display Control M17) when a redraw is needed (such as a change in Spot Content (M11)).

#### 18.4.4 Local Functions

`doUpdate()`: Update the drawing based on the state variables.

## 19 MIS of Spot Layout Visualization

### 19.1 Module

drawSpotLayout (M13)

### 19.2 Uses

- Rendering Module (M20)
- DrawingStage Module (M19)

### 19.3 Syntax

#### 19.3.1 Exported Constants

None

#### 19.3.2 Exported Access Programs

| Name           | In  | Out      | Exceptions |
|----------------|---|----------|------------|
| drawSpotLayout | drawStage,<br>subregionImage,<br>imgParams, beam<br>(drawingObject) | doUpdate | -          |

### 19.4 Semantics

#### 19.4.1 State Variables

These are kept for mutation, update calls, and performance reasons.

- **drawStage**: a reference to the drawing stage.
- **subregionImage**: a reference to the subregion image (imageDrawingObject).
- **beam**: a reference to the beam geometry.
- **imgParams**: a reference to function to call to get the rasterization grid parameters (number of rows **imageRows** and columns **imageCols**, and magnification (**imageMag**) provided by M4 through the Display Control M17).
- **doUpdate**: an optional reference to a function call when an update occurs.

#### 19.4.2 Environment Variables and Assumptions

None

### 19.4.3 Access Routine Semantics

`drawSpotLayout(drawStage, subregionImage, imgParams, beam):`

- **transition:** On the given stage, draws a grid over the `subregionImage` with the `beam` geometry clone in the center of each cell in the drawn grid representing the individual location beam/spot sampling location and spot area coverage.
- **output:** a reference to the update function (`doUpdate`).

### 19.4.4 Local Functions

`doUpdate()`: Update the drawing based on the state variables.



## 20 MIS of Sample Subregion Visualization

### 20.1 Module

`drawSampledSubregion` (M14)

### 20.2 Uses

- Rendering Module (M20)
- DrawingStage Module (M19)

### 20.3 Syntax

#### 20.3.1 Exported Constants

None

#### 20.3.2 Exported Access Programs

| Name                              | In  | Out                   | Exceptions |
|-----------------------------------|---|-----------------------|------------|
| <code>drawSampledSubregion</code> | <code>drawStage</code> ,<br><code>subregionImage</code> ,<br><code>imgParams</code> , <code>beam</code><br>( <code>drawingObject</code> ) | <code>doUpdate</code> | -          |

### 20.4 Semantics

#### 20.4.1 State Variables

These are kept for mutation, update calls, and performance reasons.

- `drawStage`: a reference to the drawing stage.
- `subregionImage`: a reference to the subregion image (`imageDrawingObject`).
- `beam`: a reference to the beam geometry.
- `imgParams`: a reference to function to call to get the rasterization grid parameters (number of rows `imageRows` and columns `imageCols`, and magnification (`imageMag`) provided by M4 through the Display Control M17).
- `doUpdate`: an optional reference to a function call when an update occurs.

## 20.4.2 Environment Variables and Assumptions

None

## 20.4.3 Access Routine Semantics

`drawSampledSubregion(drawStage, subregionImage, imgParams, beam):`

- `transition`: On the given stage, draws the `subregionImage` with “stenciled” or “clipped” the `beam` geometry clone at the center of each cell of the rasterization grid. This display represents the image content to be sampled by the beam/spot at discrete location and the area covered by the beam.
- `output`: a reference to the update function (`doUpdate`).

## 20.4.4 Local Functions

`doUpdate()`: Update the drawing based on the state variables.

## 21 MIS of Resulting Subregion Visualization

### 21.1 Module

drawResultingSubregion (M15)

### 21.2 Uses

- Rendering Module (M20)
- DrawingStage Module (M19)

### 21.3 Syntax

#### 21.3.1 Exported Constants

None

#### 21.3.2 Exported Access Programs

| Name                   | In   | Out      | Exceptions |
|------------------------|--|----------|------------|
| drawResultingSubregion | stage,<br>subregionRect,<br>gtImage, imgParams,<br>beam<br>(drawingObject) | doUpdate | -          |

### 21.4 Semantics

#### 21.4.1 State Variables

These are kept for mutation, update calls, and performance reasons.

- **stage**: a reference to the drawing stage.
- **subregionRect**: a reference to the subregion bounds.
- **gtImage**: a reference to the ground truth image (imageDrawingObject).
- **imgParams**: a reference to function to call to get the rasterization grid parameters (number of rows **imageRows** and columns **imageCols**, and magnification (**imageMag**) provided by M4 through the Display Control M17).
- **beam**: a reference to the beam geometry (drawingObject).
- **doUpdate**: an optional reference to a function call when an update occurs.

## 21.4.2 Environment Variables and Assumptions

None

## 21.4.3 Access Routine Semantics

`drawResultingSubregion(stage, subregionRect, gtImage, imgParams, beam):`

- **transition:** On the given stage (`stage`), draws the resampled subregion (using `gtImage` cropped to the bounds of `subregionRect`) meaning each cell in the rasterization grid (as defined by (`imgParams`)) is filled with the corresponding computed average pixel value using the “stenciled” or “clipped” image content with the `beam` geometry at the center of each cell as represented by the Sampled Subregion display (M14).
- **output:** a reference to the update function (`doUpdate`).

## 21.4.4 Local Functions

`doUpdate()`: Update the drawing based on the state variables.

## 22 MIS of Result Image Visualization

### 22.1 Module

drawResultingImage (M16)

### 22.2 Uses

- Rendering Module (M20)
- DrawingStage Module (M19)

### 22.3 Syntax

#### 22.3.1 Exported Constants

None

#### 22.3.2 Exported Access Programs

| Name               | In  | Out                | Exceptions |
|--------------------|---|--------------------|------------|
| drawResultingImage | stage, beam,<br>gtImage,<br>subregionRect,<br>imgParams | updateConfigValues | -          |

### 22.4 Semantics

#### 22.4.1 State Variables

These are kept for mutation, update calls, and performance reasons.

- **stage**: a reference to the drawing stage.
- **beam**: a reference to the beam geometry (**drawingObject**).
- **gtImage**: a reference to the ground truth image (**imageDrawingObject**).
- **subregionRect**: a reference to the subregion bounds.
- **imgParams**: a reference to function to call to get the rasterization grid parameters (number of rows **imageRows** and columns **imageCols**, and magnification (**imageMag**) provided by M4 through the Display Control M17).

## 22.4.2 Environment Variables

None

## 22.4.3 Assumptions

The `subregionRect` is smaller than the full extent of the ground truth image (`gtImage`).

## 22.4.4 Access Routine Semantics

`drawResultingImage(stage, beam, gtImage, subregionRect, imgParams):`

- transition: On the given stage (`stage`), continuously draws (row by row for responsiveness and performance) the resampled full image (`gtImage`) based on the beam shape (`beam`: Spot Profile M5), the rasterization grid as defined by `imgParams` for `subregionRect` (similar to Resulting Subregion M15) but extended to the full extent of the ground truth image, keeping the same relative cell size (meaning more cells - or rows and columns - that are “smaller” in the full image).
- output: returns a reference to `updateConfigValues` to call (by the Display Control M17) when there is a change in the magnification (`imageMag`), the rasterization grid (`imageRows` and `imageCols`) or the spot profile (beam shape, M5).

## 22.4.5 Local Functions

`updateConfigValues():` Update the drawing based on the state variables.

## References

- [1] J. de Fourestier. Module guide for imgbeamer, 2023. URL [https://github.com/joedf/CAS741\\_w23/blob/main/docs/Design/SoftArchitecture/MG.pdf](https://github.com/joedf/CAS741_w23/blob/main/docs/Design/SoftArchitecture/MG.pdf).
- [2] J. de Fourestier. Software requirements specification for imgbeamer: Scanning electron microscope image formation, 2023. URL [https://github.com/joedf/CAS741\\_w23/blob/main/docs/SRS/SRS.pdf](https://github.com/joedf/CAS741_w23/blob/main/docs/SRS/SRS.pdf).
- [3] Carlo Ghezzi, Mehdi Jazayeri, and Dino Mandrioli. *Fundamentals of Software Engineering*. Prentice Hall, Upper Saddle River, NJ, USA, 2nd edition, 2003.
- [4] 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>.
- [5] Anton Lavrenov. Konva.js - JavaScript 2d canvas library, December 2021. URL <https://konvajs.org/index.html>.
- [6] MDN. ImageData - Web APIs | MDN, February 2023. URL <https://developer.mozilla.org/en-US/docs/Web/API/ImageData>.
- [7] W3C. HTML living standard, the canvas element, Mar 2023. URL <https://html.spec.whatwg.org/multipage/canvas.html>.