UNIVERSITÄT DUISBURG-ESSEN

BACHELOR THESIS

Development and Comparison of Overview Techniques for Extreme Resolution Datasets

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"To see a world in a grain of sand, hold infinity in the palm of your hand. "

William Blake

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Abstract

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Development and Comparison of Overview Techniques for Extreme Resolution Datasets

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In this thesis, three main overview techniques and two secondary preview techniques of the overviews are developed and implemented using the Mandelbrot set as the source of extreme resolution datasets. For these datasets, a hierarchical structure is used to present the index information of the current region of interest. Using the developed software in this thesis, it is possible to intuitively understand the hierarchical state of the current observing area with the whole. This thesis also compares the different overview techniques which in combination consists of six different ways.

It is worth mentioning that the Mandelbrot set that are implemented in this thesis is a very good example for extreme high resolution datasets because it is a dataset that can theoretically provide infinitely high resolution.

The technology stack used in this thesis is pure web technology, a classic combination of `HTML` / `JavaScript` / `CSS`, and the program offers the possibility to adapt and replace the pure front-end technology with front and back end separation solution easily.

Acknowledgements

The acknowledgments and the people to thank go here

Contents

List of Figures

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List of Abbreviations

Acronyms

CSS Cascading Style Sheets.

DOM Document Object Model.

HTML Hypertext Markup Language.

HTTP Hypertext Transfer Protocol.

JS JavaScript.

JSON Java Script Object Notation.

UI User Interface.

URL Uniform Resource Locator.

Glossary

Full HD `1920 x 1080` px; also known as **Full HD** or **FHD** and **BT.709**.

Map MiniMap / Overview.

Chapter 1

Introduction and Motivation

1.1 Introduction

1.2 Related Work

- **A Review of Overview+Detail, Zooming, and Focus+Context Interfaces** http://www.cosc.canterbury.ac.nz/andrew.cockburn/papers/fc.pdf
- **A Review of Focus and Context Interfaces** http://www.cs.umd.edu/hcil/trs/2006-09/2006-09.pdf
- **Keeping Things in Context: A Comparative Evaluation of Focus Plus Context Screens, Overviews, and Zooming** http://ww.w.patrickbaudisch.com/publications/2002-Baudisch-CHI02-KeepingThingsInContext.pdf
- **Sigma Lenses: Focus-Context Transitions Combining Space, Time and Translucence** https://hal.inria.fr/inria-00271301/document
- **Focus Plus Context Screens: Combining Display Technology with Visualization Techniques** http://byu.danrolsenjr.org/cs656/Papers/FocusPlusContext.pdf
- **Minimap – A Web Page Visualization Method for Mobile Phones** https://www.researchgate.net/profile/Elina_Vartiainen2/publication/221517401_Minimap_-_a_web_page_visualization_method_for_mobile_phones/links/54ec42e00cf2ff89649f
Minimap-a-web-page-visualization-method-for-mobile-phones.pdf

Chapter 2

Background

2.1 Web Technology Stack

2.2 HTML5 And Canvas API

2.3 Mandelbrot Set

The Mandelbrot set is a famous example of a fractal in mathematics. It is named after Benoît Mandelbrot, a Polish-French-American mathematician.[1]. The reason this thesis is using Mandelbrot set as the source of extreme resolution dataset is because Mandelbrot set can provide theoretically infitely high resolution datasets. In this section, we'll introduce briefly Mandelbrot set, its algorithms ideas for visualization.

2.3.1 What Is Mandelbrot Set

First we define a sequence

$$z_n, n = 0, 1, 2..$$

The initial value of z is $z_0 = 0$. And then

$$z_1 = z_0^2 + c = c$$

Where c is a constant in the complex plane.

The rest of z_n is as follows:

$$z_{n+1} = z_n^2 + c$$

For different constant c, the absolute value of z_n could remain bounded however large n gets or be divergent.

The Mandelbrot set is the set of values of c in the complex plane for which this sequence remains bounded.

[1] // https://simple.wikipedia.org/wiki/Mandelbrot_set

2.3.2 Important Properties of the Mandelbrot Set

A property of Mandelbrot set is as follows:

A complex number c belongs to the Mandelbrot set M, if and only if the absolute value of z_n is not larger than 2, for all $n = 0, 1, 2, ..$

2.3.3 Simple Graphical Presentation

The following figure Figure 2.1 Mandelbrot Set Graphical Presentation is a simple graphical representation of Mandelbrot set. A point c in the complex plane is conventionally colored *black* if it belongs to the Mandelbrot set M, and *white* if not.

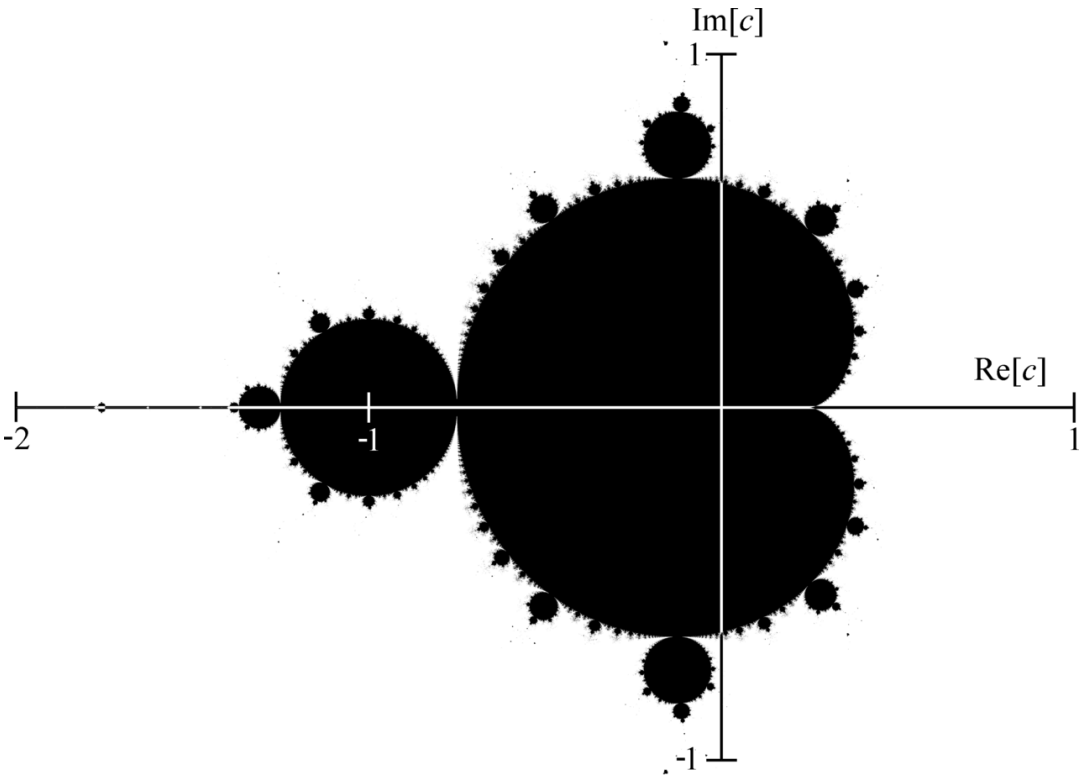

FIGURE 2.1: A simple graphical representation of Mandelbrot set.

2.3.4 Algorithms For Visualization

For all c in complex plane:

For each c, we calculate sequence $z_n, n = 0, 1, .., max$:

$z_0 = 0$, (initial value),

$z_{n+1} = z_n^2 + c$

If the value of z_{n+1} is larger than 2, then:

c does not belong to M. In this case, we set the color of c to *white* and the calculation of sequence is stopped.

If $n = max$, then:

c belongs to M and we set the color of c to *black*.

2.3.5 Algorithms Idea For Graphical Representation with Grayscale

In the above algorithm in 2.3.4 Algorithms For Visualization, c is set to either *black* or *white*. If the iteration number n is equal to the maximum iteration number max and the value of z_n still less than 2, then c has the color *black*. If the iteration number n is smaller than max then at this moment the absolute value of z_n becomes larger than 2. In this case, we cannot set the color of c to *black*, because c dose not belong to Mandelbrot set. However, we set a color with a portion of *black*, to indicate how close c is to be in *black* area.

For all c in complex plane:

For each c, we calculate sequence $z_n, n = 0, 1, .., max$:

$z_0 = 0$, (initial value),

$z_{n+1} = z_n^2 + c$

If the value of z_{n+1} is larger than 2, then:

c does not belong to M. In this case, we set the color of c to ~~*white*~~ *grayscale*[2] *depending on the number of iteration* n and the calculation of sequence is stopped.

If $n = max$, then:

c belongs to M and we set the color of c to *black*.

[2] In the current implementation, this color is set to be grayscaled red, rgb($grayscale\% \times 255$, 0, 0).

Chapter 3

Requirements and Concepts

3.1 Main Section 1

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Aliquam ultricies lacinia euismod. Nam tempus risus in dolor rhoncus in interdum enim tincidunt. Donec vel nunc neque. In condimentum ullamcorper quam non consequat. Fusce sagittis tempor feugiat. Fusce magna erat, molestie eu convallis ut, tempus sed arcu. Quisque molestie, ante a tincidunt ullamcorper, sapien enim dignissim lacus, in semper nibh erat lobortis purus. Integer dapibus ligula ac risus convallis pellentesque.

3.1.1 Subsection 1

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3.1.2 Subsection 2

Morbi rutrum odio eget arcu adipiscing sodales. Aenean et purus a est pulvinar pellentesque. Cras in elit neque, quis varius elit. Phasellus fringilla, nibh eu tempus venenatis, dolor elit posuere quam, quis adipiscing urna leo nec orci. Sed nec nulla auctor odio aliquet consequat. Ut nec nulla in ante ullamcorper aliquam at sed dolor. Phasellus fermentum magna in augue gravida cursus. Cras sed pretium lorem. Pellentesque eget ornare odio. Proin accumsan, massa viverra cursus pharetra, ipsum nisi lobortis velit, a malesuada dolor lorem eu neque.

3.2 Main Section 2

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Curabitur luctus tempus justo. Vestibulum risus lectus, adipiscing nec condimentum quis, condimentum nec nisl. Aliquam dictum sagittis velit sed iaculis. Morbi tristique augue sit amet nulla pulvinar id facilisis ligula mollis. Nam elit libero, tincidunt ut aliquam at, molestie in quam. Aenean rhoncus vehicula hendrerit.

Chapter 4

Implementation

In this chapter, the overall structure of the project, how the files are arranged and the functionalities of each components, will be described in details.

4.1 Files And Folders

The folder names and file names are mostly self-explanatory or conventional in this project. They'll be described briefly in this section.

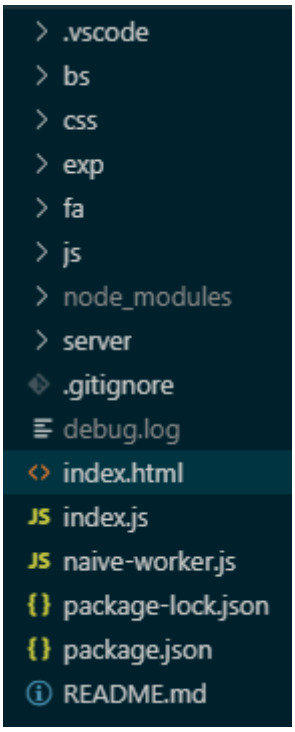

FIGURE 4.1: A glimpse of files and folders.

4.1.1 Folders

Folder `./.vscode` The configured Visual Studio Code workspace settings file. This file is included and stored inside the workspace and only apply when the workspace

is opened which overrides Visual Studio Code's default user settings. The author tweaked this file to make some parts of VS Code's editor, user interface, and functional behavior more fitting to review or to base future work upon this project[1].

VS Code provides two different scopes for settings:

- User Settings - Settings that apply globally to any instance of VS Code you open.
- Workspace Settings - Settings stored inside your workspace and only apply when the workspace is opened.

Workspace settings override user settings[1].

Folder `./js` All the third-party open source JavaScript (JS) dependencies are stored in this folder. Sometimes third-party open source projects include a bundle of JavaScript (JS) and Cascading Style Sheets (CSS) files, here only the pure JS projects' files are included.

Folder `./css` The CSS files of the projects are included. Firstly there is a `./css/common.css` file, which sets the overall styles of the project, basically whatever the users can see at the very first glance when they open this project. Then there are several other CSS files, each sets a specific portion of the styles in this project. These files include:

- CSS File `./css/dock.css` sets the iOS-Dock look-like styles, making the focused item larger with larger margins and adjacent items smaller and smaller margins with their corresponding nearby items.
- CSS File `./css/minibar.css` sets the customed scrollbar styles that's being added upon the default styles of the dependency *MiniBar* which is used to create custom scrollbars.
- CSS File `./css/stacked.css` sets the styles of the stacked cards effect.
- CSS File `./css/tabs.css` sets the related styles of the tabs effect.

Note that most of the effects require not only the CSS stylings but also JS actions in order to work.

Folder `./fa` Assets of the dependency *Font Awesome*, including all resources of the open source part. This dependency is used for the fonts of the icons in this project.

Folder `./bs` Assets of the open source project *Bootstrap* by *Twitter*. This dependency is used for the stylings of the web elements inside the control panel, such as input boxes, dropdown menus and font styles in control panel. It also comes with some nice utilities for general web elements style setting.

[1] To learn more about this file, see `https://code.visualstudio.com/docs/getstarted/settings`.

Folder `./node_modules` Packages pulled from the JS dependency management tool *npm*[2] are stored in this folder. The required dependency here is the package `minibarjs` under this folder – in folder `./node_modules/minibarjs`. Conventionally this folder shouldn't be included or committed to the version control system[3], because all the packages info are recorded in the file `package.json` and `package-lock.json` and if any dependencies are missing, running the *npm* command `npm install` should be able to pull all necessary dependencies into this folder, however, considering this project sometimes can be run in an environment without internet connection, this folder is included in the final static zipped package.

Folder `./exp` Some trivial *Python*, JS and Hypertext Markup Language (HTML) codes left from the prototypes of implementation at the beginning of this project. Some of them are using different algorithms and different scripts trying to achieve similar results to this project. They are not in use anymore and only kept for future references.

4.1.2 Top Level Files

File `index.html` This entry HTML file of this project. When a server is being run on the local machine, this is the first file getting executed. When a different implementation of the back end using techniques other than a web worker, for example a `WebSocket`, is developed and being adapted to this project, double-clicking on this file should also start this project.

File `index.js` The main JS script file of the project. This file gets included at the very end of the HTML file `index.html`.

File `naive-worker.js` The back end calculation JS script. The only job of this script is to receive information of the image the front end is asking for, and post the result message back to the front end. This piece of scripts not only post the complete results back, but also slices of results when the calculation takes longer than a certain amount of time and let the front end decide what to do with the partial results[4].

File `package.json` A description file of the JS package management tool *npm*. This file can have many descriptions about what *npm* should do for this workspace[5] but here it most importantly specifies which packages to pull from the global repository, in the Java Script Object Notation (JSON) field `'dependencies'`. Dependencies are specified in a simple object that maps a package name to a version range. The version range is a string which has one or more space-separated descriptors. Dependencies can also be identified with a tarball or git URL[5].

[2] Build amazing things — Essential JavaScript development tools that help you go to market faster and build powerful applications using modern open source code[4]. Too know more about *npm*, see `https://www.npmjs.com/`.

[3] This is actually also what this project is following.

[4] In this project, what the front end will do after receiving partial results is that it will still render the slices of images onto the canvas and high light the painted partial image with green borders.

[5] For for detailed information, see `https://docs.npmjs.com/files/package.json`.

File `package-lock.json` A generated file from *npm* package manager which locks the version of the dependencies of this specific workspace. Take the current project as an example, in file `package.json` there is this part in the JSON body:

```
{
  ..
  "dependencies": {
    ..
    "minibarjs": "^0.4.0",
    ..
  },
  ..
}
```

This piece of code only specified that the version of the package `minibarjs` that we require will match all `0.x.x` releases including `0.5.x`, but will hold off on `1.x.x`. This file `package-lock.json` will "lock" the version inside current workspace to a specific version with a hashed fingerprint of the files, in the current project with a version number of `0.4.0` and a hash fingerprint `sha512-iCUE/YVWn+Oht+NV2fLBS8bAVxED/9l6A5i1qJ2OcsCrc0tXHamgpWCo7uL+23HQOUyFPvpw1izw2l3vzVKkXg==`.

File `README.md` A brief introduction file for the global version control system *GitHub*. Trivial.

File `.gitignore` Version control settings file, telling which files should not be committed to *Git* system. Not relavant to the project but the version control during the development phase of this project. Trivial.

4.2 Start the Project

Although this project is a pure web project, it cannot be started by simply double-clicking on the entry file `index.html`, because modern browsers usually don't not allow local scripts to directly start *Web Workers*[6] for security concerns. However, *Web Worker* is being used in this project as simple means for doing heavy calculations in background threads without interfering with the User Interface (UI), therefore, in order to start the project, a simple Hypertext Transfer Protocol (HTTP) server must be up and running on the local machine.

It is also worth mentioning that this project should be running with Google Chrome browser as it supports most of the advanced visual effects and modern web technology syntax, known as *HTML5*[7]. The recommended version of Google Chrome is `76.0.x`.

To start and keep a HTTP server running, the simplest and recommended way would be to use *Python*'s `http.server`. To do that[2]:

[6] Web Workers are a simple means for web content to run scripts in background threads.[3]

[7] See `https://developer.mozilla.org/en-US/docs/Web/Guide/HTML/HTML5` for more detailed information.

Install Python If you are using *Linux* or *macOS*, it should be available on the system already. If you are a *Windows* user, *Python* installer can be downloaded from the *Python* homepage and the instructions can be followed to install it:

- Go to `python.org`
- Under the *Download* section, click the link for `Python 3.xxx`.
- At the bottom of the page, choose the *Windows x86 executable installer* and download it.
- When it has downloaded, run it.
- On the first installer page, make sure you check the *"Add Python 3.xxx to PATH"* checkbox.
- Click *Install*, then click *Close* when the installation has finished.

Verification Open a *Command Prompt* (Windows) / *Terminal* (macOS / Linux). To check *Python* is installed, enter the following command:

```
python -V
```

Navigation The above command should return a version number. If this is OK, navigate to the directory that the files of this project is inside, using the `cd` command.

```
# include the directory name to enter it, for example
cd Desktop/fractals
```

Start the Server Enter the command to start up the server in that directory:

```
# If Python version returned above is 3.X:
python -m http.server

# Or simply:
py -m http.server

# If Python version returned above is 3.X
# and on non-Windows machines:
python3 -m http.server

# If Python version returned above is 2.X,
# or if on macOS using the default Python
# installed:
python -m SimpleHTTPServer
```

By default, the above actions will run the contents of the directory where the files of this project are located on a local web server, on port 8000. In order to view this project now, simply go to this server by going to the Uniform Resource Locator (URL) `localhost:8000` in your web browser, to be specific and recommended in Google Chrome. Here the project entry `index.html` will be run by default and users can see directly the result.

4.3 Front End

Since this project is a pure web project, the front end occupies a large portion of the codes.

4.3.1 HTML Entry `index.html`

The entry of the project is where this program gets started, in similar concept of the `main()` function in `C` or the `public static void main(String[] args)` function in `Java`. The entry point is a HTML file and as expected named `index.html`. It introduces the front end structure of the project in raw.

First part of the HTML file is the `<head>` part. In this part, the character set of this web page is defined as *UTF-8*, the size of the entire HTML document as fullscreen size, scaling not allowed and not shrinking to display its content.

```
<meta charset="utf-8">
<meta name="viewport" content="width=device-width,
    initial-scale=1, shrink-to-fit=no">
```

And then all the needed CSS files are included to end the `<head>` part. Besides the CSS files which will be described in subsection 4.3.3 CSSs For Overview Effects, the necessary CSS files from third-party open source vendors are also included, including *Bootstrap*'s CSS part, *FontAwesome* and *MiniBar* CSS assets.

The `<body>` part is the essential part of the HTML entry, which describes the structure of what users can "actually see". It begins first with three `<div>` tags for the most important three parts of this project, the container for main background canvases, the container for mini-maps, and the container for the control panel floating on the top right corner of the UI screen. The positioning, sizes and container behaviours of these `<div>`s are defined in the CSS files which are already included. Before users set any effects up, these properties mostly come from the file `./css/common.css`.

After the visual `<div>` part, several `<script>` tags come after it to include what's necessary for the essential coding part. Here firstly are the dependencies of the project, including *jQuery*, *Bootstrap*'s JS part, and *MiniBar*'s JS part. And then at the very end the main JS file `index.js` is included and all the core programs of this project goes in there.

Worth noting that conventionally all JS files should be included at the very end of the page as what we are doing now, unless the JS file is needed before the render phase of the web page. This way if the JS file is a little bit bigger than usual, the loading of the JS files won't affect the rendering process of the DOM documents.

4.3.2 Main JavaScript `index.js`

The main JS file `index.js` is where the core codes are. In this file there is firstly the definition of required classes from bottom level to the top, then the instantiation of them and putting the front end HTML elements into action to display the overall results.

There in total four classes defined.

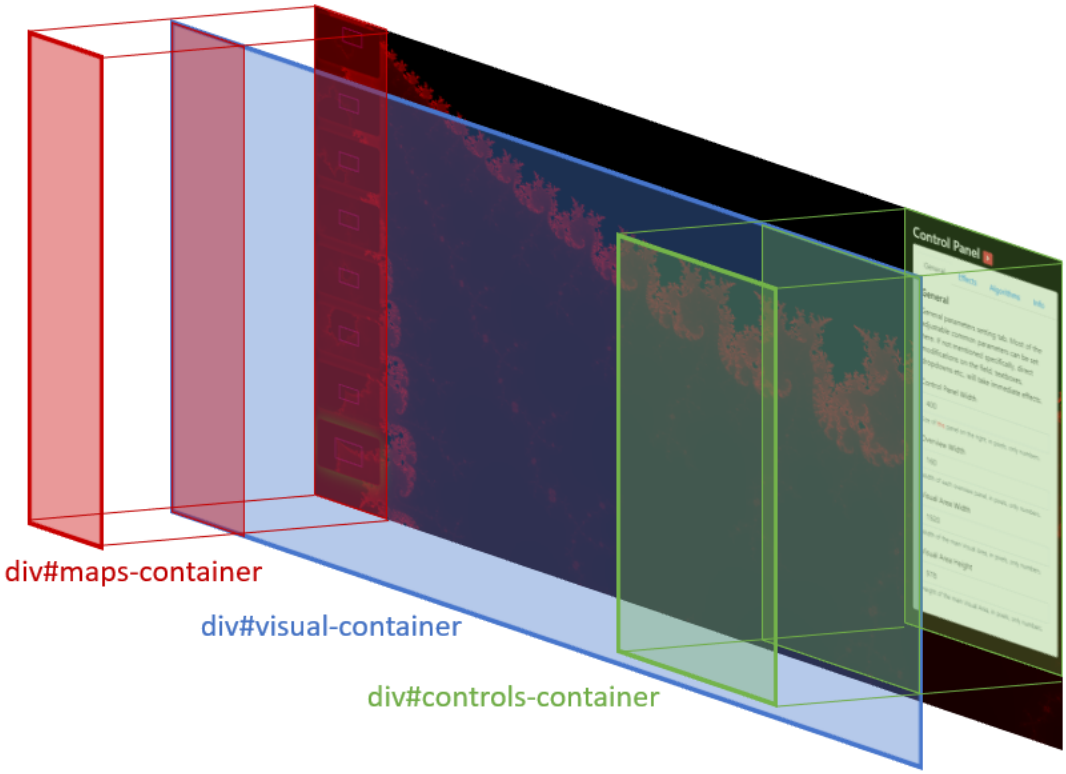

FIGURE 4.2: Document Object Model (DOM) structure in `<body>` tag.

4.3.2.1 Class `MandelWorker`

The class `MandelWorker` is in charge of sending a message to the back end and when a result is sent back, doing some other actions.

When instantiated, an instance of a native *Web Worker* will also be created as a private property of this class. `MandelWorker` instantiates the *Web Worker* by the script `naiveworker.js`, which means that the script `naiveworker.js` will be the core of the worker and this worker will be doing whatever in that script when it is asked to[8].

Function `work(params...)`

The function `work(params...)` is the interface between `MandelWorker` and the outside invoker. To get an image from the source, one must invoke this function with the needed parameters as follows:

- `magnif` The magnification level of the result image to be expected from the *Web Worker*.
- `centerX` The `x` component of the center coordinates on the mathmatical plane of the result image to be expected from the worker.
- `centerY` The `y` component of this coordinates.
- `width` The width in pixels of the result image.

[8] See `https://developer.mozilla.org/en-US/docs/Web/API/Web_Workers_API/Using_web_workers#Spawning_a_dedicated_worker` for more detailed information of the process of instantiating a *Web Worker*.

- `height` The height in pixels of the result image.
- `callback` The function to execute when a result message is received.
- `callbackThis` The "this" context where the `callback` function should be executed under.

Here what's worth mentioning is the parameter `magnif`. The magnification level is a number representing the number of pixels that together has a length of 1 on the mathmatical axis. As shown in Figure 4.3 Magnification Level is an image with the magnification level of 2, since 2 pixels have the length of 1 on the mathmatical axis.

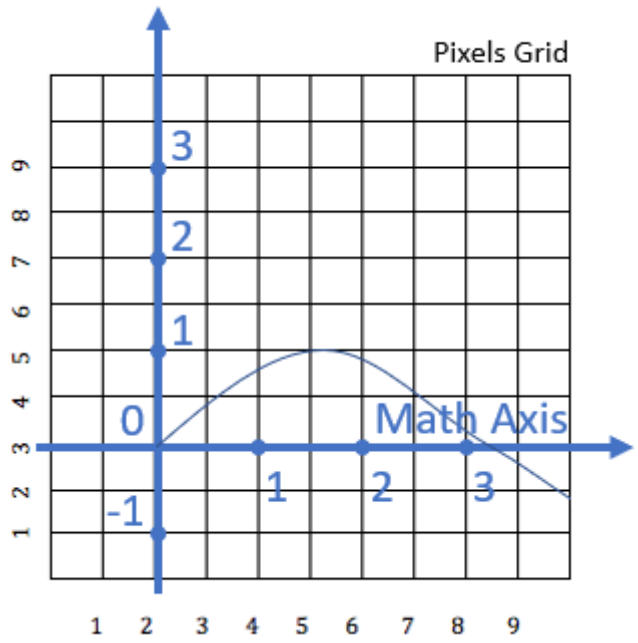

FIGURE 4.3: Magnification level in aspect of mathmatical axis.

Once this function is invoked, `MandelWorker` will tell its own *Web Worker* to start working on datasets fetching[9], and if any sorts of results come through that worker, hit the `workerResponse(e)` function of the current `MandelWorker`.

Function `workerResponse(e)`

The function `workerResponse(e)` will be called when a response from the *Web Worker* is sent back. It basically does one thing: checking if the parameters of `callback` and `callbackThis` were set when function `work(params...)` got invoked in the first place. If they were set to any function, call it under the conext of the parameter `callbackThis`.

Function `destroy()`

The function `destroy()` as the name implies is the method to destroy and release the resources for current `MandelWorker`. It terminates the *Web Worker*, sets the response

[9] In the context of the current project, is actually image generation.

method to `null` so no responses will be dealt furthermore and sets all other references to `null` as well so the internal JS engine can garbage collect[10] all these instance to avoid memory leakage when the calculation gets heavy.

4.3.2.2 Class `MapVisualPair`

An abstract concept of pairing a minimap[11] with an active focus region with higher resolution, as Figure 4.4 Map Visual Pair is an example of what they actually are respectively.

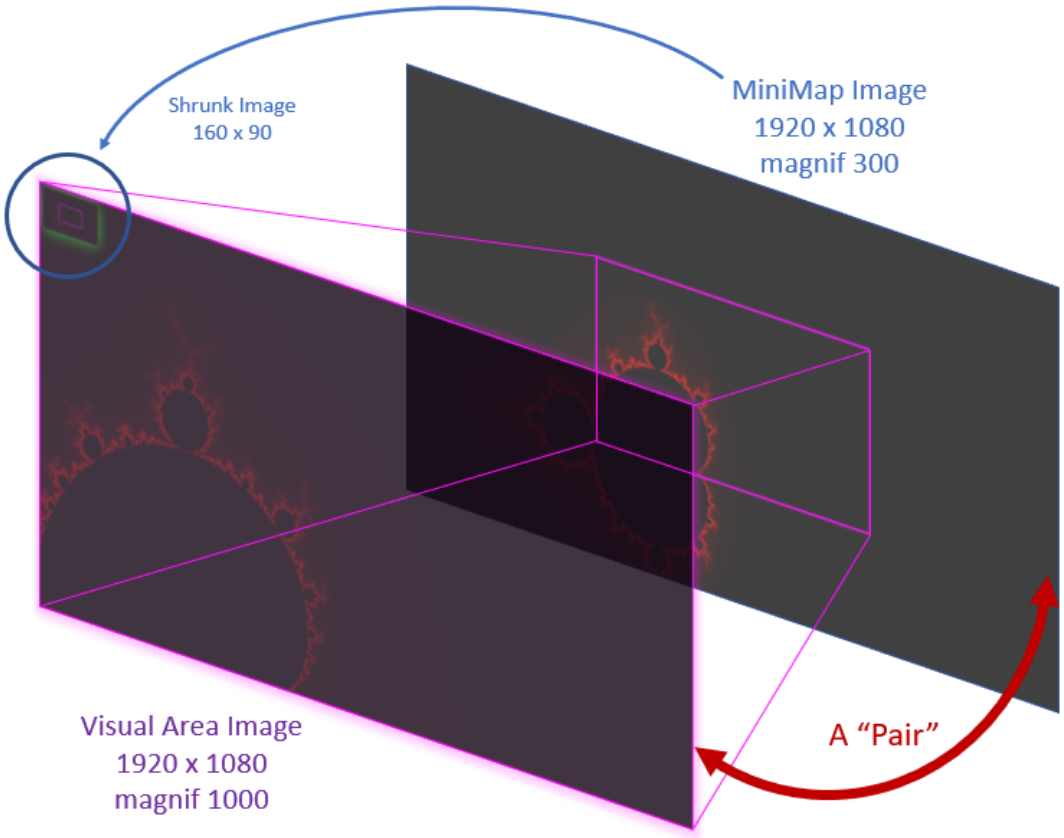

FIGURE 4.4: Map area image and visual area(current focus region) image.

The minimap representing a relatively "larger" area in the dataset and the visual area, which represents the active observing region, actually have both same resolution so they can both be displayed on a Full HD screen. Although the visual area seems "smaller" in comparison with the Map area, since it's an active region that is being observed by the user, the size of this visual area only represents its dimensions on the mathmatical plane and not smaller pixels-wise.

[10] In computer science, garbage collection (GC) is a form of automatic memory management. The garbage collector, or just collector, attempts to reclaim garbage, or memory occupied by objects that are no longer in use by the program[6].

[11] Same concept in current project as an *overview*.

The Map image, however, will normally be shrunk and put on the left side of the screen, till the user hovers over a specific Map that will trigger the preview process of this program so he can have a glance of this image in a Full HD way.

The reason to pair up a visual area with a Map area is that whenever the user wants to browse around the dataset, the focusing coordinates on the visual area should also reflect back to the Map area, and the rectangle representing the current observing area should also get updated automatically. When there are more hierarchies of Maps present, this pairing mechanism becomes extremely helpful because the changes on the active region will flow all the way up to all levels of Maps necessary. Here Figure 4.5 Pairing Multiple Levels of Maps is a simple illustration of it.

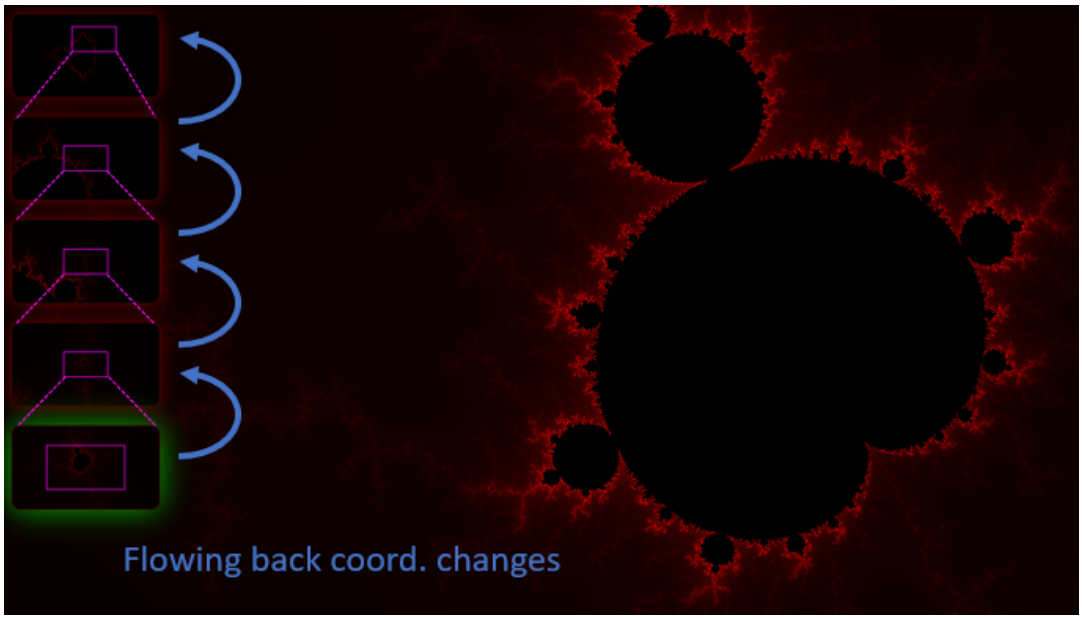

FIGURE 4.5: When multiple hierarchies of Maps present, visual area changes, all Maps changes.

Function `init(mapCanvas, previewCanvas, visCanvas = null)`

This function will initialize the current `MapVisualPair`, bounding a `mapCanvas`, a `previewCanvas` and a `visCanvas` all of type `<canvas>` element to this class. When internally a drawing action should be performed, related images will be drawn on corresponding canvas.

The canvas `mapCanvas` will be used to draw the shrunk version of the Map image. `previewCanvas` will be used to draw the normal(Full HD) version of the Map image. And `visCanvas` will be used to draw the visual area image in Full HD if set.

After bounding the canvases, this function will also check if any event handlers are bound to the events `mouseover` and `mouseout` to the `mapCanvas` element, and record corresponding info to the element to avoid attemps to rebound event handlers to the same `<canvas>` element. In this way, only one event handler for `mouseover` and `mouseout` will be triggered when the user hovers their mouse on the `<canvas>` and when the user put their cursor out of the element.

The handlers this function is going to bound to the `mapCanvas` element are going to first add CSS class `.nearby` to adjacent siblings of this canvas, and check if any additional callbacks this class should call. The callbacks, if any, which are set in the private properties `mouseOverCallback` and `mouseOutCallback`, will be called under set context `mouseOverCallbackThis` and `mouseOutCallbackThis` when user performs corresponding actions. As mentioned before, they will also be called only once because the bounding information is recorded. In the project, these callbacks and the contexts of them are set by a manager class 4.3.2.4 Class `EffectManager`.

Function `destroy()`

This function as the name implies releases all in-use resources, including `Workers`, unbinding bound event handlers, clearing references to the canvases and their 2d contexts.

Function `drawMapHoverArea(offsetRealX = 0, offsetRealY = 0)`

When the class is told to draw images on corresponding canvas elements, it will not automatically draw the purple rectangle indicating the current observing visual area, since the cached image data does not include this rectangle — it doesn't belong to the extreme resolution dataset itself, therefore, this function exists to draw this current focus area using a purple rectangle to indicate it, drawing this rectangle on the `mapCanvas` whenever invoked. Note that whenever the image from the calculation side is fetched, without invoking this function, no current obeserving area rectangle will be shown, since the newly fetched image data will cover the old one also the old drawn rectangle.

The parameters `offsetRealX` and `offsetRealY` can also be set, as the purple rectangle to be drawn will then have an offset of (`offsetRealX`, `offsetRealY`) with respect to the center of the current observing area on the mathmatical complex plane.

Function `drawPreviewHoverArea(offsetRealX = 0, offsetRealY = 0)`

Like the function `drawMapHoverArea`, this function will also draw a rectangle representing the current observing visual area, but on another canvas `previewCanvas`. The reason to separate these two functions is that the canvas `previewCanvas` isn't always visible and if these two functions are combined, it'll draw unintended purple rectangles on wrong canvases.

Function `moveTo(x = null, y = null)`

This function is used to move the current `MapVisualPair` around. The parameters of coordinates are on the mathmatical complex plane, i.e. with respect to the entire datasets.

Note that these two parameters can be omitted and when omitted, the current `MapVisualPair` will simply send a ping to the calculation side and grab new image data for current observing coordinates, like a "refresh" action.

Properties `visMagnif` and `mapMagnif`

The magnification for the pair of these two canvases. See Figure 4.3 Magnification Level for the explanation of magnification level.

Properties `visCenterX` and `visCenterY`

The coordinates of the center point of the current observing visual area, with respect to the mathmatical complex plane.

Properties `visCanvasWidth` and `visCanvasHeight`

The width and height in **pixels** of the image data of the whole visual area. In Figure 4.4 Map Visual Pair, they're the dimensions of the whole visual area image. These properties have to exist because the dimensions of this area cannot always be fetched from the `visCanvas` property, as it is an optional parameter during the `init(params..)` phase and sometimes is absent.

Properties `visImgOffsetX` and `visImgOffsetY`

These two properties are set for the dragging actions that are realized in 4.3.2.3 Class `MinimapManager`. They represents the current dragging offset with respect to the top left corner of the `visCanvas`. The reference point being top left corner not the center point is because in web canvas drawing system, the (0, 0) point is the top left corner, unlike in mathmatical complex plane it being the center.

Properties `mapCenterX` and `mapCenterY`

Like the properties `visCenterX` and `visCenterY`, these two properties represents the coordinates of the center point of the current Map area, with respect to the mathmatical complex plane. In Figure 4.4 Map Visual Pair, they're the center coordinates of the Map image.

4.3.2.3 Class `MinimapManager`

The manager class of all the minimaps, controlling all their behaviours on the top level.

Inits

```
initMaps(visCanvas,previewCanvas,mapsContainer,visualContainer,hoverX=0,
hoverY=0)
```

```
initPairMainDrag()
```

Mouse Down(drag to browse around)

```
pairMainMouseDown(e)
```

```
pairMainMouseMove(e)
```

```
pairMainMouseUp(e)
```

```
pairMainStepDrag(timestamp)
```

Mouse Wheel(zoom in and out)

```
initPairMainWheel()
```

```
pairMainWheel(e)
```

```
pairMainTimeoutWheel()
```

```
pairMainStepWheel()
```

4.3.2.4 Class `EffectManager`

This class manages the behaviours, activation and deactivation of the overview effects and the preview effects of the overviews.

General functions: `init()`, `getInfo(el)`

Fade in / out related functions: `fadeMouseOver(e, currentPair)`, `fadeMouseOut(e, currentPair)`

Zoom in / out through related functions: `zoomMouseOver(e, currentPair)`, `zoomStep(timestamp)`, `zoomMouseOut(e, currentPair)`

General preview effects functions: `updatePreview()`, `updateFadePreview()`, `updateZoomPreview()`, `destroyPreview()`

General overview effects functions: `destroy()`, `update()`

Scrollbar + Dock effects specific functions: `initScrollbar()`, `destroyScrollbar()`, `updateScrollbar()`

Stacked Cards effects specific functions: `initStacked()`, `destroyStacked()`, `updateStacked()`

Tabs effects specific functions: `initTabs()`, `destroyTabs()`, `updateTabs()`

4.3.2.5 Instantiation, Variables And the Rest

- `screenWidth`
- `screenHeight`
- `mapWidth`
- `mapHeight`
- `controlPanelWidth`
- `visMagnif`
- `mapMagnif`
- `hoverX`
- `hoverY`
- `mainCanvas`
- `previewCanvas`
- `$('#visual-container')`
- `$('#maps-container')`

4.3.3 CSSs For Overview Effects

Folder `./css` includes five CSS files, each setting up some visual effects of the project.

File `./css/common.css` first sets up all general appearance of the elements on the web page when no parameters or effects are set. File `./css/dock.css` sets up the appearance when *Scrollbar + Dock* is activated, only the iOS Dock part and file

`./css/minibar.css` sets up the scroll bar part. File `./css/stacked.css` sets up the effects of stacked cards. File `./css/tabs.css` sets up the effects of the tab selection on the top.

4.3.4 Scrollbar + Dock Effect

4.3.5 Stacked Cards Effect

4.3.6 Tabs Effect

4.4 Back End Calculation

The back end calculation is done in the JS file `naive-worker.js`. This file is being used for initializing the *WebWorker*s inside `index.js` dynamically. Whenever a calculation or extraction for a specific region of a dataset is needed, the main JS file `index.js` is going to send a message to `naive-worker.js` with desired parameters and this back end will respond with corresponding image data.

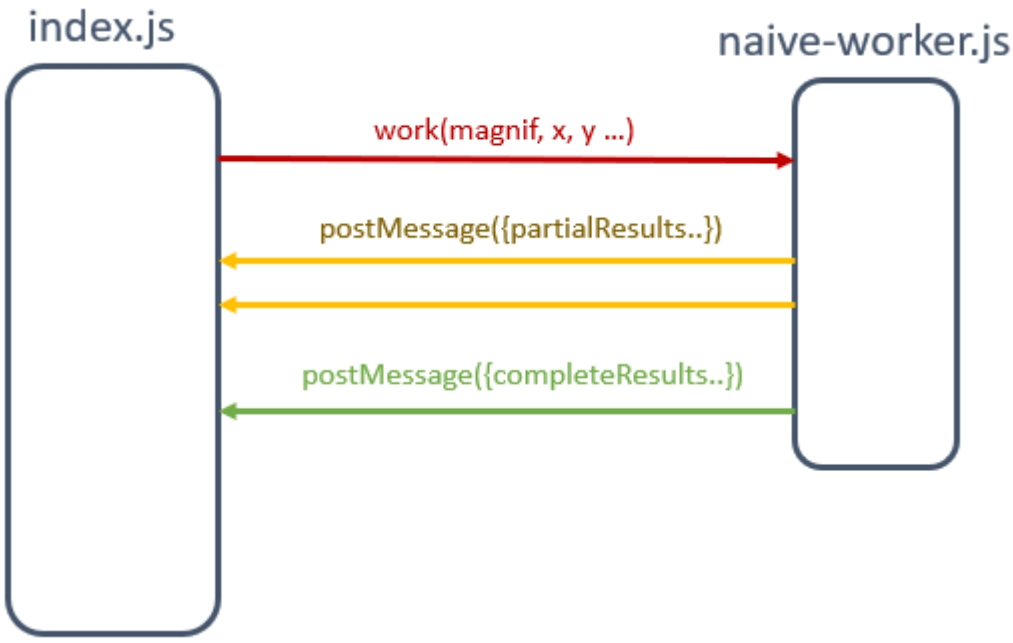

FIGURE 4.6: Message exchange between `index.js` and `naive-worker.js`.

4.4.1 Global Scope

In the global scope of this file, the following things were done.

Includes The `decimal.js` dependency is included for high-precision floating points calculation. Default parameters for the dependency is set.

Constants Constants of default screen width and default screen height are defined in case the front end doesn't give these parameters.

Canvas An `OffscreenCanvas` instance is created and instantiated with the dimensions of by default the values of the defined constants. The `OffscreenCanvas` will be used as the canvas to generate the desired image on, and since it's not being shown on the screen, will occupy less system resources and boost the calculation speed. Corresponding variables is declared after the instantiation, respectively `canvas` for the `OffscreenCanvas` itself and `ctx` as the 2d context of the canvas.

4.4.2 Message Reception

See Figure 4.6 Message Exchange.

4.4.3 Iteration Limit

4.4.4 Iteration Count for One Point

4.4.5 Image Generation

4.4.6 High Precision Version

4.5 Utility Assets

Other open source third-party utilities lie in different folders with corresponding names.

4.5.1 Folder `./js`

In `./js` folder, all JS third-party files are here, including:

- File `decimal.min.js` is for high-precision floating points calculation for JavaScript (JS).
- File `jquery-3.4.1.min.js` is for DOM traversal and manipulation, event handling and animation.
- File `bootstrap.bundle.min.js` is for some basic styling of the control panel sitting on top right corner of the screen.

4.5.2 Folder `./fa`

4.5.3 Folder `./bs`

4.5.4 Folder `./css`

Chapter 5

Discussion

5.1 Main Section 1

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Aliquam ultricies lacinia euismod. Nam tempus risus in dolor rhoncus in interdum enim tincidunt. Donec vel nunc neque. In condimentum ullamcorper quam non consequat. Fusce sagittis tempor feugiat. Fusce magna erat, molestie eu convallis ut, tempus sed arcu. Quisque molestie, ante a tincidunt ullamcorper, sapien enim dignissim lacus, in semper nibh erat lobortis purus. Integer dapibus ligula ac risus convallis pellentesque.

5.1.1 Subsection 1

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5.1.2 Subsection 2

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5.2 Main Section 2

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Appendix A

Frequently Asked Questions

A.1 Where can I find the source code of this project?

This source code of the project is hosted on *GitHub* as a private repository on `https://github.com/divyinfo/fractals.git`. You could ask the author at danyun.lei@stud.uni-due.de for further assitance such as asking for a view or collaboration access.

A.2 Is there LaTeX source code for this thesis?

Yes, it is hosted on *GitHub* as a private repository on `https://github.com/divyinfo/fractals-report.git`. You could contact the author at danyun.lei@stud.uni-due.de if further assitance is needed.

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