CONTENTS

Chapter 1

todo

```
TODO
functionality
    numeric calculus
        range/interval/window size
        precision abcisses, ordenate axis/resolution of image
        maximum module
            coordinates c where maximum module
        number of elements

model
    mandelbrot set sequence
    beloging to mandelbrot set


    fractal boundary
    module of a complex number

    data structure
        big numbers
            many significant digits

        cartesian coordenates
            real and imaginary parts of mandelbrot set's elements

view
    cartesian representation


REVISION HISTORY
```

16/01/2024	15:15-17:00	fractal theory complex number library printing module-library mandelbrot algorithm code
18/01/2024	16:00-19:00	mandelbrot theory mandelbrot algorithm traverse algorithm
20/01/2024	10:00-11:00	data print precision isMandelbrotElement()

Chapter 2

hologram

Chapter 3

fractal

3.1. theory

https://en.wikipedia.org/wiki/Fractal

a fractal is a geometrical shape
a curve

a plane
Sierpiński carpet
the technique of subdividing a shpe into smaller copies of itself and removing one or more copies
https://en.wikipedia.org/wiki/Sierpi%C5%84ski_carpet
a three dimensions, cubes
Menger sponge
https://en.wikipedia.org/wiki/Menger_sponge

a function/equation
increase presision in
domain
different, and not necessarily more precise only,
image

infinitely increase in precision

because sequence defined recursively

Chapter 4

mandelbrot set

https://en.wikipedia.org/wiki/Mandelbrot_set https://ics.uci.edu/~eppstein/junkyard/mand-area.html https://math.stackexchange.com/questions/1134054/proof-of-x-intersection-of-the-mandelbrot-set https://complex-analysis.com/content/mandelbrot_set.html
buddhabrot representation
https://www.kaggle.com/code/wgunderwood/the-mandelbrot-set

```
definition
----------
    Mandelbrot set 'M'
        two-dimensional set defined in the complex-number plane

        compact set
            since it is closed (no punctures)
            and bound subset (no missing points)
                contained in the closed disk of radius 2 around an origin (z0=0

        element/point 'c' is in 'M'
            if
                module '|z|' complex number 'z' in sequence f(z) = z^2 + c, def
                absolute value of z_{n}, |z_{n}| <= 2, for all n >= 0

            otherwise
                absolute value exceeds 2, the sequence will escape to inifinity

        sequence
        ----------
            origin      o = or + oi·j
                        z0 = zr0 + zi0·j
```

```
                    z0 = o
                    zr0 = or
                    zi0 = oi

            distance    d0 = dr0 + di0·j
                           = z0 - o
                           = zr0 + zi0·j - or - oi·j
                           = zr0-or + (zi0-oi)·j
                           = or-or + (oi-oi)·j
                           = 0 + 0·j

            candidate   c = a + b·i

            |z0|+2
            f(z) = z^2 + c is <= |z0|+2

            complex number z0 =             0 + 0i                          ;
            complex number z1 = f(z0)       = z0^2 + c  = (a+bi)^2 + c      ;
            complex number z2 = f(z1)       = z1^2 + c  = c^2 + c           ;
            complex number z3 = f(z2)       = z2^2 + c  = (c^2 + c)^2 + c

            complex number |z0|   =     (0^2 + 0^2i)^1/2
            complex number |z1|   =
            complex number |z2|   =
            complex number |z3|   =

            no diverge to infinity

axis intersection
----------
    the intersection of 'M' with the real axis is the interval [-2, 1/4]
    abscissa    x-axis  real part
    ordinate    y-axis  imaginary part

fractal boundary
    definition
        boundary of the Mandelbrot set 'M' is a fractal curve.
        boundary complex numbers which magnitude is 2, threshold must be at lea

        complex number z = -2 + 0i, z = -2
        has the largest magnitue with in the mandelbrot set
```

```
JULIA SET
        if c is held constant and the inital value of 'z' is varied instead, the co
```

```
COMPLEX NUMBERS
        Function module/magnitude |z| of a complex number 'z', z=a+bj
        https://en.wikipedia.org/wiki/Complex_number
            z = x + y·j
            |z| = sqrt(x^2 + y^2)
```

```
COMPUTING
    element 'c' in 'M'
        maximum number of iterations n=500?
        all '|z|' <= 2

    element 'c' not in 'M'
        one '|z|' > 2

        infinity inf=10^8?

    ordenate bounds

    fractal dimensions
        cartisian vertix coordinates
            (-2.0,2.0), (0.25, 2.0)
            (-2.0,-2.0), (0.25,-2.0)
```

```
COLORING
    only boundary, in black color
        2 >= |z| >= 1.995

    coordinate
        treating the real and imaginary parts of 'c' as image coordinates

    pixel
        pixels may be colored according to how soon the sequence
            |f_{c}(z)|, |f_{c}(f_{c}(z))|, |f_{c}(f_{c}(f_{c}(z)))|
            crosses an arbitrarily chosen threshold
                the threshold must at least 2, as -2 is the complex number
                    with the largest magnitude within the set,
                but otherwise the threshold is arbitrary.

                mandelbrot subset by threshold lower than 2???

    soon
        number of iteration

    distance
        difference |2-|z_{i}||, |z_{i}| <= 2, |z_{i+1}| > 2




    color gradient
    https://en.wikipedia.org/wiki/Color_gradient
        axial gradient
            axial gradient or, also called, linear color gradient
            segment defined by two points
            on color for each point of the segment

        color space
            2d
                plane (r in [0,255], g in [0,255])
```

```
            3d
                rgba (0-255, 0-255, 0-255, 0-255)
                2d rgb profiles
                https://en.wikipedia.org/wiki/Color_gradient#/media/File:Gnuplot_HS
                https://en.wikipedia.org/wiki/Color_gradient#/media/File:Matlab_gra

                3d rgb profiles
                https://en.wikipedia.org/wiki/Color_gradient#/media/File:0_3d_60_75

HISTORY
 first
    Benoit Mandelbrot
    mathematician
    coined word 'fractal'
    wrote influencial book 'The Fractal Geometry of Nature', in 1982.
    first mandelbrot set image in the cover of 'Scientific American', 1985.
since then
```

Chapter 5

image

5.1. file format

```
TYPE OF IMAGE FORMAT
----------------------------------------

raw images
    camara lenses capture raw information

png images
    a png is a raster: pixel-based image format
    stores pixels in a raster format
    one color channel
        monochrome or palette index
    three color channel
        rgb
    four color channel
        rgba, rgb with an alpha channel for transparency

jpg images
    no alpha channel support
    color information retained in rgb
    compression by discarding data

svg
    not a vector image like svg

raw pixel images dataset
    http://yann.lecun.com/exdb/mnist/
```

```
" .:-=+*#\%@"
" .°*oO#@"
" _.,-=+:;cba!?0123456789\$W#@"
```

5.2. greyscale

```
MATRIX OF GREYSCALE MODEL
https://en.wikipedia.org/wiki/Grayscale
----------------------------------------

    values in each pixel is a single sample representing only
the amount of light, intensity of light, luminance, brightness.

    numerical representation of a greyscale
commonly stored in 8 bits/pixel per sampled pixel

converting color to greyscale
    no alpha component

    luminance Y_{lineal}
    Y_{lineal} = 0.2126·R_{linear} + 0.7152·G_{linear} + 0.0722·B_{linear}
    Y_{lineal} belongs to [0,1]
```

5.3. rgb

```
RGB COLOR MODEL
https://en.wikipedia.org/wiki/RGB_color_model
----------------------------------------

truecolor image
    linear colorspace
    human perception

additive model
```

```
    addition or combination of primary colors red, green, blue in different intensi
    zero intensity of each component gives black
    maximum intensity of each component gives white

three color channels 8 bits per channel, values 0-255
     24 bits/pixel
     (2^8)^3 = 16777216 colors
```

Chapter 6

integer

gnu libc
integers
https://www.gnu.org/software/libc/manual/html_node/Integers.html