Almog Draw Library

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Chapter 1

Class Index

1.1 Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

Chapter 2

File Index

2.1 File List

Here is a list of all files with brief descriptions:

Chapter 3

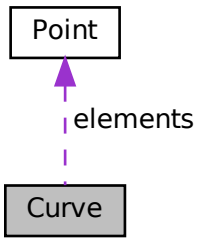
Class Documentation

3.1 Curve Struct Reference

Polyline of points with a uniform color.

`#include <Almog_Draw_Library.h>`

Collaboration diagram for Curve:



Public Attributes

- uint32_t color
- size_t length
- size_t capacity
- Point * elements

3.1.1 Detailed Description

Polyline of points with a uniform color.

Definition at line 94 of file Almog_Draw_Library.h.

3.1.2 Member Data Documentation

3.1.2.1 capacity

```
size_t Curve::capacity
```

Allocated capacity.

Definition at line 97 of file Almog_Draw_Library.h.

3.1.2.2 color

```
uint32_t Curve::color
```

ARGB color (0xAARRGGBB) for the entire curve.

Definition at line 95 of file Almog_Draw_Library.h.

Referenced by adl_curve_add_to_figure(), and adl_curves_plot_on_figure().

3.1.2.3 elements

```
Point* Curve::elements
```

Point array.

Definition at line 98 of file Almog_Draw_Library.h.

Referenced by adl_curves_plot_on_figure(), adl_grid_draw(), and setup().

3.1.2.4 length

```
size_t Curve::length
```

Number of points used.

Definition at line 96 of file Almog_Draw_Library.h.

Referenced by adl_curves_plot_on_figure(), adl_grid_draw(), and setup().

The documentation for this struct was generated from the following file:

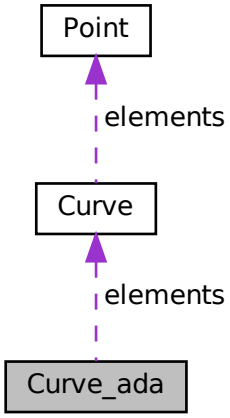
- Almog_Draw_Library.h

3.2 Curve_ada Struct Reference

Dynamic array of curves (polyline container).

`#include <Almog_Draw_Library.h>`

Collaboration diagram for Curve_ada:



Public Attributes

- size_t length
- size_t capacity
- Curve * elements

3.2.1 Detailed Description

Dynamic array of curves (polyline container).

Definition at line 107 of file Almog_Draw_Library.h.

3.2.2 Member Data Documentation

3.2.2.1 capacity

`size_t Curve_ada::capacity`

Allocated capacity.

Definition at line 109 of file Almog_Draw_Library.h.

3.2.2.2 elements

```
Curve* Curve_ada::elements
```

Curves array.

Definition at line 110 of file Almog_Draw_Library.h.

Referenced by adl_curves_plot_on_figure(), and adl_grid_draw().

3.2.2.3 length

```
size_t Curve_ada::length
```

Number of curves used.

Definition at line 108 of file Almog_Draw_Library.h.

Referenced by adl_curves_plot_on_figure(), and adl_grid_draw().

The documentation for this struct was generated from the following file:

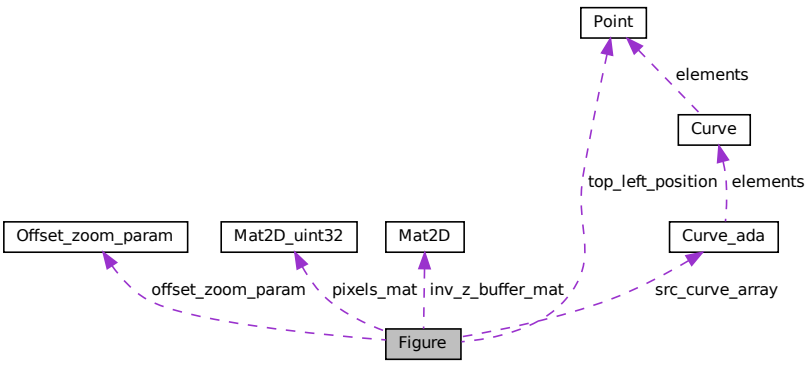
- Almog_Draw_Library.h

3.3 Figure Struct Reference

Plotting figure holding a pixel buffer, z-buffer and plot state.

```
#include <Almog_Draw_Library.h>
```

Collaboration diagram for Figure:



Public Attributes

- int min_x_pixel
- int max_x_pixel
- int min_y_pixel
- int max_y_pixel
- float min_x
- float max_x
- float min_y
- float max_y
- int x_axis_head_size
- int y_axis_head_size
- Offset_zoom_param offset_zoom_param
- Curve_ada src_curve_array
- Point top_left_position
- Mat2D_uint32 pixels_mat
- Mat2D inv_z_buffer_mat
- uint32_t background_color
- bool to_draw_axis
- bool to_draw_max_min_values

3.3.1 Detailed Description

Plotting figure holding a pixel buffer, z-buffer and plot state.

A Figure owns an internal pixel buffer and an inverse-Z buffer used by the plotting utilities. It also stores axis extents, paddings and appearance flags.

Definition at line 174 of file Almog_Draw_Library.h.

3.3.2 Member Data Documentation

3.3.2.1 background_color

```
uint32_t Figure::background_color
```

Clear color for figure.

Definition at line 195 of file Almog_Draw_Library.h.

Referenced by adl_2Dscalar_interp_on_figure(), adl_curves_plot_on_figure(), and setup().

3.3.2.2 inv_z_buffer_mat

```
Mat2D Figure::inv_z_buffer_mat
```

Owned inverse-Z buffer (double).

Definition at line 193 of file Almog_Draw_Library.h.

Referenced by adl_2Dscalar_interp_on_figure(), adl_curves_plot_on_figure(), and adl_figure_alloc().

3.3.2.3 max_x

```
float Figure::max_x
```

Max X value in source data.

Definition at line 181 of file Almog_Draw_Library.h.

Referenced by adl_2Dscalar_interp_on_figure(), adl_curve_add_to_figure(), adl_curves_plot_on_figure(), adl_figure_alloc(), and adl_max_min_values_draw_on_figure().

3.3.2.4 max_x_pixel

```
int Figure::max_x_pixel
```

Right bound (pixel space).

Definition at line 176 of file Almog_Draw_Library.h.

Referenced by adl_2Dscalar_interp_on_figure(), adl_axis_draw_on_figure(), adl_curves_plot_on_figure(), adl_figure_alloc(), and adl_max_min_values_draw_on_figure().

3.3.2.5 max_y

```
float Figure::max_y
```

Max Y value in source data.

Definition at line 183 of file Almog_Draw_Library.h.

Referenced by adl_2Dscalar_interp_on_figure(), adl_curve_add_to_figure(), adl_curves_plot_on_figure(), adl_figure_alloc(), and adl_max_min_values_draw_on_figure().

3.3.2.6 max_y_pixel

```
int Figure::max_y_pixel
```

Bottom bound (pixel space).

Definition at line 178 of file Almog_Draw_Library.h.

Referenced by adl_2Dscalar_interp_on_figure(), adl_axis_draw_on_figure(), adl_curves_plot_on_figure(), adl_figure_alloc(), and adl_max_min_values_draw_on_figure().

3.3.2.7 min_x

```
float Figure::min_x
```

Min X value in source data.

Definition at line 180 of file Almog_Draw_Library.h.

Referenced by adl_2Dscalar_interp_on_figure(), adl_curve_add_to_figure(), adl_curves_plot_on_figure(), adl_figure_alloc(), and adl_max_min_values_draw_on_figure().

3.3.2.8 min_x_pixel

```
int Figure::min_x_pixel
```

Left padding (pixel space).

Definition at line 175 of file Almog_Draw_Library.h.

Referenced by adl_2Dscalar_interp_on_figure(), adl_axis_draw_on_figure(), adl_curves_plot_on_figure(), adl_figure_alloc(), and adl_max_min_values_draw_on_figure().

3.3.2.9 min_y

```
float Figure::min_y
```

Min Y value in source data.

Definition at line 182 of file Almog_Draw_Library.h.

Referenced by adl_2Dscalar_interp_on_figure(), adl_curve_add_to_figure(), adl_curves_plot_on_figure(), adl_figure_alloc(), and adl_max_min_values_draw_on_figure().

3.3.2.10 min_y_pixel

```
int Figure::min_y_pixel
```

Top padding (pixel space).

Definition at line 177 of file Almog_Draw_Library.h.

Referenced by adl_2Dscalar_interp_on_figure(), adl_axis_draw_on_figure(), adl_curves_plot_on_figure(), adl_figure_alloc(), and adl_max_min_values_draw_on_figure().

3.3.2.11 offset_zoom_param

```
Offset_zoom_param Figure::offset_zoom_param
```

Pan/zoom parameters.

Definition at line 188 of file Almog_Draw_Library.h.

Referenced by adl_2Dscalar_interp_on_figure(), adl_axis_draw_on_figure(), adl_curves_plot_on_figure(), adl_figure_alloc(), and adl_max_min_values_draw_on_figure().

3.3.2.12 pixels_mat

```
Mat2D_uint32 Figure::pixels_mat
```

Owned ARGB pixel buffer.

Definition at line 192 of file Almog_Draw_Library.h.

Referenced by adl_2Dscalar_interp_on_figure(), adl_axis_draw_on_figure(), adl_curves_plot_on_figure(), adl_figure_alloc(), adl_figure_copy_to_screen(), and adl_max_min_values_draw_on_figure().

3.3.2.13 src_curve_array

```
Curve_ada Figure::src_curve_array
```

Curves to plot.

Definition at line 189 of file Almog_Draw_Library.h.

Referenced by adl_curve_add_to_figure(), adl_curves_plot_on_figure(), and adl_figure_alloc().

3.3.2.14 to_draw_axis

```
bool Figure::to_draw_axis
```

Draw axes when plotting.

Definition at line 196 of file Almog_Draw_Library.h.

Referenced by adl_2Dscalar_interp_on_figure(), adl_curves_plot_on_figure(), and setup().

3.3.2.15 to_draw_max_min_values

```
bool Figure::to_draw_max_min_values
```

Draw min/max labels.

Definition at line 197 of file Almog_Draw_Library.h.

Referenced by adl_2Dscalar_interp_on_figure(), adl_curves_plot_on_figure(), and setup().

3.3.2.16 top_left_position

```
Point Figure::top_left_position
```

On-screen copy position.

Definition at line 190 of file Almog_Draw_Library.h.

Referenced by adl_figure_alloc(), and adl_figure_copy_to_screen().

3.3.2.17 x_axis_head_size

```
int Figure::x_axis_head_size
```

Computed X-axis arrow head size (px).

Definition at line 185 of file Almog_Draw_Library.h.

Referenced by adl_axis_draw_on_figure(), and adl_max_min_values_draw_on_figure().

3.3.2.18 y_axis_head_size

```
int Figure::y_axis_head_size
```

Computed Y-axis arrow head size (px).

Definition at line 186 of file Almog_Draw_Library.h.

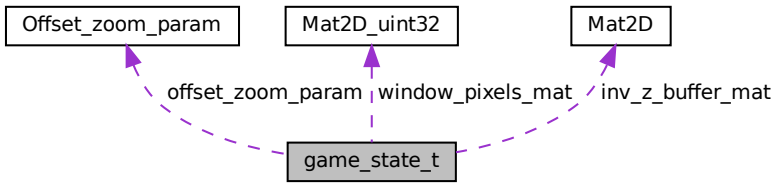
Referenced by adl_axis_draw_on_figure(), and adl_max_min_values_draw_on_figure().

The documentation for this struct was generated from the following file:

- Almog_Draw_Library.h

3.4 game_state_t Struct Reference

Collaboration diagram for game_state_t:



Public Attributes

- int game_is_running
- float delta_time
- float elapsed_time
- float const_fps
- float fps
- float frame_target_time
- int to_render
- int to_update
- size_t previous_frame_time
- int left_button_pressed
- int to_limit_fps
- int to_clear_renderer
- int space_bar_was_pressed
- int w_was_pressed
- int s_was_pressed
- int a_was_pressed
- int d_was_pressed
- int e_was_pressed
- int q_was_pressed

- SDL_Window * window
- int window_w
- int window_h
- SDL_Renderer * renderer
- TTF_Font * font
- SDL_Surface * window_surface
- SDL_Texture * window_texture
- Mat2D_uint32 window_pixels_mat
- Mat2D inv_z_buffer_mat
- Offset_zoom_param offset_zoom_param

3.4.1 Detailed Description

Definition at line 38 of file display.c.

3.4.2 Member Data Documentation

3.4.2.1 a_was_pressed

```
int game_state_t::a_was_pressed
```

Definition at line 55 of file display.c.

Referenced by main().

3.4.2.2 const_fps

```
float game_state_t::const_fps
```

Definition at line 42 of file display.c.

Referenced by main(), setup(), and update_window().

3.4.2.3 d_was_pressed

```
int game_state_t::d_was_pressed
```

Definition at line 56 of file display.c.

Referenced by main().

3.4.2.4 delta_time

```
float game_state_t::delta_time
```

Definition at line 40 of file display.c.

Referenced by fix_framerate(), main(), and update_window().

3.4.2.5 e_was_pressed

```
int game_state_t::e_was_pressed
```

Definition at line 57 of file display.c.

Referenced by main().

3.4.2.6 elapsed_time

```
float game_state_t::elapsed_time
```

Definition at line 41 of file display.c.

Referenced by main(), and update_window().

3.4.2.7 font

```
TTF_Font* game_state_t::font
```

Definition at line 64 of file display.c.

Referenced by main().

3.4.2.8 fps

```
float game_state_t::fps
```

Definition at line 43 of file display.c.

Referenced by main(), and update_window().

3.4.2.9 frame_target_time

```
float game_state_t::frame_target_time
```

Definition at line 44 of file display.c.

Referenced by fix_framerate(), main(), and update_window().

3.4.2.10 game_is_running

```
int game_state_t::game_is_running
```

Definition at line 39 of file display.c.

Referenced by main(), and process_input_window().

3.4.2.11 inv_z_buffer_mat

```
Mat2D game_state_t::inv_z_buffer_mat
```

Definition at line 70 of file display.c.

Referenced by check_window_mat_size(), render(), render_window(), and setup_window().

3.4.2.12 left_button_pressed

```
int game_state_t::left_button_pressed
```

Definition at line 48 of file display.c.

Referenced by main(), and process_input_window().

3.4.2.13 offset_zoom_param

```
Offset_zoom_param game_state_t::offset_zoom_param
```

Definition at line 72 of file display.c.

Referenced by main(), process_input_window(), and render().

3.4.2.14 previous_frame_time

```
size_t game_state_t::previous_frame_time
```

Definition at line 47 of file display.c.

Referenced by fix_framerate(), main(), and process_input_window().

3.4.2.15 q_was_pressed

```
int game_state_t::q_was_pressed
```

Definition at line 58 of file display.c.

Referenced by main().

3.4.2.16 renderer

```
SDL_Renderer* game_state_t::renderer
```

Definition at line 63 of file display.c.

Referenced by destroy_window(), initialize_window(), and main().

3.4.2.17 s_was_pressed

```
int game_state_t::s_was_pressed
```

Definition at line 54 of file display.c.

Referenced by main().

3.4.2.18 space_bar_was_pressed

```
int game_state_t::space_bar_was_pressed
```

Definition at line 52 of file display.c.

Referenced by main(), and process_input_window().

3.4.2.19 to_clear_renderer

```
int game_state_t::to_clear_renderer
```

Definition at line 50 of file display.c.

Referenced by main(), and render_window().

3.4.2.20 to_limit_fps

```
int game_state_t::to_limit_fps
```

Definition at line 49 of file display.c.

Referenced by fix_framerate(), main(), setup(), and update_window().

3.4.2.21 to_render

```
int game_state_t::to_render
```

Definition at line 45 of file display.c.

Referenced by main(), and process_input_window().

3.4.2.22 to_update

```
int game_state_t::to_update
```

Definition at line 46 of file display.c.

Referenced by main(), and process_input_window().

3.4.2.23 w_was_pressed

```
int game_state_t::w_was_pressed
```

Definition at line 53 of file display.c.

Referenced by main().

3.4.2.24 window

```
SDL_Window* game_state_t::window
```

Definition at line 60 of file display.c.

Referenced by check_window_mat_size(), destroy_window(), initialize_window(), main(), render_window(), setup_window(), and update_window().

3.4.2.25 window_h

```
int game_state_t::window_h
```

Definition at line 62 of file display.c.

Referenced by check_window_mat_size(), initialize_window(), main(), setup_window(), and update_window().

3.4.2.26 window_pixels_mat

```
Mat2D_uint32 game_state_t::window_pixels_mat
```

Definition at line 69 of file display.c.

Referenced by check_window_mat_size(), copy_mat_to_surface_RGB(), destroy_window(), render(), render_window(), and setup_window().

3.4.2.27 window_surface

```
SDL_Surface* game_state_t::window_surface
```

Definition at line 66 of file display.c.

Referenced by check_window_mat_size(), copy_mat_to_surface_RGB(), destroy_window(), and setup_window().

3.4.2.28 window_texture

```
SDL_Texture* game_state_t::window_texture
```

Definition at line 67 of file display.c.

Referenced by destroy_window().

3.4.2.29 window_w

```
int game_state_t::window_w
```

Definition at line 61 of file display.c.

Referenced by check_window_mat_size(), initialize_window(), main(), setup_window(), and update_window().

The documentation for this struct was generated from the following file:

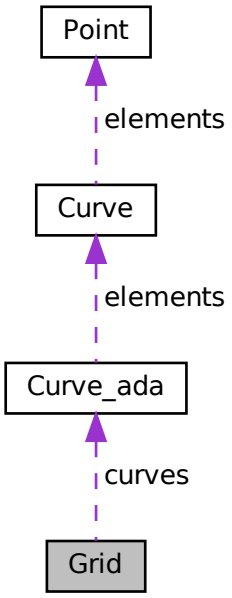
- display.c

3.5 Grid Struct Reference

Grid definition (as lines) in a chosen plane.

```
#include <Almog_Draw_Library.h>
```

Collaboration diagram for Grid:



Public Attributes

- Curve_ada curves
- float min_e1
- float max_e1
- float min_e2
- float max_e2
- int num_samples_e1
- int num_samples_e2
- float de1
- float de2
- char plane [3]

3.5.1 Detailed Description

Grid definition (as lines) in a chosen plane.

Definition at line 203 of file Almog_Draw_Library.h.

3.5.2 Member Data Documentation

3.5.2.1 curves

```
Curve_ada Grid::curves
```

Line segments implementing the grid.

Definition at line 204 of file Almog_Draw_Library.h.

Referenced by adl_cartesian_grid_create(), and adl_grid_draw().

3.5.2.2 de1

```
float Grid::de1
```

Step size along axis 1.

Definition at line 213 of file Almog_Draw_Library.h.

Referenced by adl_cartesian_grid_create().

3.5.2.3 de2

```
float Grid::de2
```

Step size along axis 2.

Definition at line 214 of file Almog_Draw_Library.h.

Referenced by adl_cartesian_grid_create().

3.5.2.4 max_e1

```
float Grid::max_e1
```

Axis 1 max.

Definition at line 207 of file Almog_Draw_Library.h.

Referenced by adl_cartesian_grid_create().

3.5.2.5 max_e2

```
float Grid::max_e2
```

Axis 2 max.

Definition at line 209 of file Almog_Draw_Library.h.

Referenced by adl_cartesian_grid_create().

3.5.2.6 min_e1

```
float Grid::min_e1
```

Axis 1 min.

Definition at line 206 of file Almog_Draw_Library.h.

Referenced by adl_cartesian_grid_create().

3.5.2.7 min_e2

```
float Grid::min_e2
```

Axis 2 min.

Definition at line 208 of file Almog_Draw_Library.h.

Referenced by adl_cartesian_grid_create().

3.5.2.8 num_samples_e1

```
int Grid::num_samples_e1
```

Number of divisions along axis 1.

Definition at line 211 of file Almog_Draw_Library.h.

Referenced by adl_cartesian_grid_create().

3.5.2.9 num_samples_e2

```
int Grid::num_samples_e2
```

Number of divisions along axis 2.

Definition at line 212 of file Almog_Draw_Library.h.

Referenced by adl_cartesian_grid_create().

3.5.2.10 plane

```
char Grid::plane[3]
```

Plane tag: "XY","XZ","YZ","YX","ZX","ZY".

Definition at line 216 of file Almog_Draw_Library.h.

Referenced by adl_cartesian_grid_create().

The documentation for this struct was generated from the following file:

- Almog_Draw_Library.h

3.6 Mat2D Struct Reference

Dense row-major matrix of doubles.

```
#include <Matrix2D.h>
```

Public Attributes

- size_t rows
- size_t cols
- size_t stride_r
- double * elements

3.6.1 Detailed Description

Dense row-major matrix of doubles.

- rows: number of rows (height)
- cols: number of columns (width)
- stride_r: number of elements between successive rows in memory (for contiguous storage, stride_r == cols)
- elements: pointer to contiguous storage of size rows ∗ cols

Definition at line 81 of file Matrix2D.h.

3.6.2 Member Data Documentation

3.6.2.1 cols

```
size_t Mat2D::cols
```

Definition at line 83 of file Matrix2D.h.

Referenced by adl_2Dscalar_interp_on_figure(), adl_curves_plot_on_figure(), adl_figure_alloc(), mat2D_add(), mat2D_add_col_to_col(), mat2D_add_row_time_factor_to_row(), mat2D_add_row_to_row(), mat2D_alloc(), mat2D_calc_norma(), mat2D_col_is_all_digit(), mat2D_copy(), mat2D_copy_mat_to_mat_at_window(), mat2D_cross(), mat2D_det(), mat2D_det_2x2_mat(), mat2D_dot(), mat2D_dot_product(), mat2D_fill(), mat2D_fill_sequence(), mat2D_get_col(), mat2D_get_row(), mat2D_invert(), mat2D_LUP_decomposition_with_swap(), mat2D_make_identity(), mat2D_mat_is_all_digit(), mat2D_minor_alloc_fill_from_mat(), mat2D_mult(), mat2D_mult_row(), mat2D_offset2d(), mat2D_print(), mat2D_print_as_col(), mat2D_rand(), mat2D_row_is_all_digit(), mat2D_set_identity(), mat2D_set_rot_mat_x(), mat2D_set_rot_mat_y(), mat2D_set_rot_mat_z(), mat2D_solve_linear_sys_LUP_decomposition(), mat2D_sub(), mat2D_sub_col_to_col(), mat2D_sub_row_time_factor_to_row(), mat2D_sub_row_to_row(), mat2D_swap_rows(), mat2D_transpose(), mat2D_triangulate(), render(), and render_window().

3.6.2.2 elements

```
double* Mat2D::elements
```

Definition at line 85 of file Matrix2D.h.

Referenced by adl_2Dscalar_interp_on_figure(), adl_curves_plot_on_figure(), adl_figure_alloc(), mat2D_alloc(), mat2D_free(), mat2D_print_as_col(), and render_window().

3.6.2.3 rows

```
size_t Mat2D::rows
```

Definition at line 82 of file Matrix2D.h.

Referenced by adl_2Dscalar_interp_on_figure(), adl_curves_plot_on_figure(), adl_figure_alloc(), mat2D_add(), mat2D_add_col_to_col(), mat2D_add_row_to_row(), mat2D_alloc(), mat2D_calc_norma(), mat2D_copy(), mat2D_copy_mat_to_mat_at_window(), mat2D_cross(), mat2D_det(), mat2D_det_2x2_mat(), mat2D_dot(), mat2D_dot_product(), mat2D_fill(), mat2D_fill_sequence(), mat2D_get_col(), mat2D_get_row(), mat2D_invert(), mat2D_LUP_decomposition_with_swap(), mat2D_make_identity(), mat2D_mat_is_all_digit(), mat2D_minor_alloc_fill_from_mat(), mat2D_mult(), mat2D_offset2d(), mat2D_print(), mat2D_print_as_col(), mat2D_rand(), mat2D_set_identity(), mat2D_set_rot_mat_x(), mat2D_set_rot_mat_y(), mat2D_set_rot_mat_z(), mat2D_solve_linear_sys_LUP_decomposition(), mat2D_sub(), mat2D_sub_col_to_col(), mat2D_sub_row_to_row(), mat2D_transpose(), mat2D_triangulate(), render(), and render_window().

3.6.2.4 stride_r

```
size_t Mat2D::stride_r
```

Definition at line 84 of file Matrix2D.h.

Referenced by mat2D_alloc(), and mat2D_offset2d().

The documentation for this struct was generated from the following file:

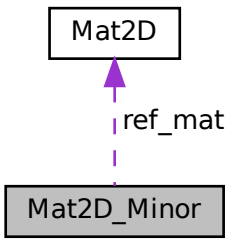
- Matrix2D.h

3.7 Mat2D_Minor Struct Reference

A minor "view" into a reference matrix.

```
#include <Matrix2D.h>
```

Collaboration diagram for Mat2D_Minor:



Public Attributes

- size_t rows
- size_t cols
- size_t stride_r
- size_t * rows_list
- size_t * cols_list
- Mat2D ref_mat

3.7.1 Detailed Description

A minor "view" into a reference matrix.

Represents a minor by excluding one row and one column of a reference matrix. It holds index lists mapping into the reference matrix, without owning the data of the reference matrix itself.

Memory ownership:

- rows_list and cols_list are heap-allocated by minor allocators and must be freed with mat2D_minor_free.
- The underlying matrix data (ref_mat.elements) is not owned by the minor and must not be freed by the minor functions.

Definition at line 119 of file Matrix2D.h.

3.7.2 Member Data Documentation

3.7.2.1 cols

```
size_t Mat2D_Minor::cols
```

Definition at line 121 of file Matrix2D.h.

Referenced by mat2D_det_2x2_mat_minor(), mat2D_minor_alloc_fill_from_mat(), mat2D_minor_alloc_fill_from_mat_minor(), mat2D_minor_det(), and mat2D_minor_print().

3.7.2.2 cols_list

```
size_t* Mat2D_Minor::cols_list
```

Definition at line 124 of file Matrix2D.h.

Referenced by mat2D_minor_alloc_fill_from_mat(), mat2D_minor_alloc_fill_from_mat_minor(), and mat2D_minor_free().

3.7.2.3 ref_mat

```
Mat2D Mat2D_Minor::ref_mat
```

Definition at line 125 of file Matrix2D.h.

Referenced by mat2D_minor_alloc_fill_from_mat(), and mat2D_minor_alloc_fill_from_mat_minor().

3.7.2.4 rows

```
size_t Mat2D_Minor::rows
```

Definition at line 120 of file Matrix2D.h.

Referenced by mat2D_det_2x2_mat_minor(), mat2D_minor_alloc_fill_from_mat(), mat2D_minor_alloc_fill_from_mat_minor(), mat2D_minor_det(), and mat2D_minor_print().

3.7.2.5 rows_list

```
size_t* Mat2D_Minor::rows_list
```

Definition at line 123 of file Matrix2D.h.

Referenced by mat2D_minor_alloc_fill_from_mat(), mat2D_minor_alloc_fill_from_mat_minor(), and mat2D_minor_free().

3.7.2.6 stride_r

```
size_t Mat2D_Minor::stride_r
```

Definition at line 122 of file Matrix2D.h.

Referenced by mat2D_minor_alloc_fill_from_mat(), and mat2D_minor_alloc_fill_from_mat_minor().

The documentation for this struct was generated from the following file:

- Matrix2D.h

3.8 Mat2D_uint32 Struct Reference

Dense row-major matrix of uint32_t.

```
#include <Matrix2D.h>
```

Public Attributes

- size_t rows
- size_t cols
- size_t stride_r
- uint32_t * elements

3.8.1 Detailed Description

Dense row-major matrix of uint32_t.

- rows: number of rows (height)
- cols: number of columns (width)
- stride_r: number of elements between successive rows in memory (for contiguous storage, stride_r == cols)
- elements: pointer to contiguous storage of size rows * cols

Definition at line 98 of file Matrix2D.h.

3.8.2 Member Data Documentation

3.8.2.1 cols

```
size_t Mat2D_uint32::cols
```

Definition at line 100 of file Matrix2D.h.

Referenced by adl_2Dscalar_interp_on_figure(), adl_axis_draw_on_figure(), adl_figure_alloc(), adl_figure_copy_to_screen(), adl_line_draw(), adl_point_draw(), adl_quad_fill(), adl_quad_fill_interpolate_color_mean_value(), adl_quad_fill_interpolate_normal_m adl_tri_fill_Pinedas_rasterizer(), adl_tri_fill_Pinedas_rasterizer_interpolate_color(), adl_tri_fill_Pinedas_rasterizer_interpolate_normal check_window_mat_size(), copy_mat_to_surface_RGB(), mat2D_alloc_uint32(), mat2D_fill_uint32(), mat2D_offset2d_uint32(), and render_window().

3.8.2.2 elements

```
uint32_t* Mat2D_uint32::elements
```

Definition at line 102 of file Matrix2D.h.

Referenced by copy_mat_to_surface_RGB(), mat2D_alloc_uint32(), mat2D_free_uint32(), and render_window().

3.8.2.3 rows

```
size_t Mat2D_uint32::rows
```

Definition at line 99 of file Matrix2D.h.

Referenced by adl_2Dscalar_interp_on_figure(), adl_axis_draw_on_figure(), adl_figure_alloc(), adl_figure_copy_to_screen(), adl_line_draw(), adl_max_min_values_draw_on_figure(), adl_point_draw(), adl_quad_fill(), adl_quad_fill_interpolate_color_mean_val adl_quad_fill_interpolate_normal_mean_value(), adl_tri_fill_Pinedas_rasterizer(), adl_tri_fill_Pinedas_rasterizer_interpolate_color(), adl_tri_fill_Pinedas_rasterizer_interpolate_normal(), check_window_mat_size(), copy_mat_to_surface_RGB(), mat2D_alloc_uint32(), mat2D_fill_uint32(), mat2D_offset2d_uint32(), and render_window().

3.8.2.4 stride_r

```
size_t Mat2D_uint32::stride_r
```

Definition at line 101 of file Matrix2D.h.

Referenced by mat2D_alloc_uint32(), and mat2D_offset2d_uint32().

The documentation for this struct was generated from the following file:

- Matrix2D.h

3.9 Offset_zoom_param Struct Reference

Pan/zoom parameters relative to screen center.

```
#include <Almog_Draw_Library.h>
```

Public Attributes

- float zoom_multiplier
- float offset_x
- float offset_y
- int mouse_x
- int mouse_y

3.9.1 Detailed Description

Pan/zoom parameters relative to screen center.

The coordinates are shifted by (offset_x, offset_y) and scaled by zoom_multiplier about the screen center. The mouse fields are optional and can be used by UI code that updates the pan/zoom.

Definition at line 65 of file Almog_Draw_Library.h.

3.9.2 Member Data Documentation

3.9.2.1 mouse_x

```
int Offset_zoom_param::mouse_x
```

Optional: last mouse x (pixels).

Definition at line 69 of file Almog_Draw_Library.h.

3.9.2.2 mouse_y

```
int Offset_zoom_param::mouse_y
```

Optional: last mouse y (pixels).

Definition at line 70 of file Almog_Draw_Library.h.

3.9.2.3 offset_x

```
float Offset_zoom_param::offset_x
```

Horizontal pan offset (pixels).

Definition at line 67 of file Almog_Draw_Library.h.

Referenced by adl_line_draw(), adl_point_draw(), and process_input_window().

3.9.2.4 offset_y

```
float Offset_zoom_param::offset_y
```

Vertical pan offset (pixels).

Definition at line 68 of file Almog_Draw_Library.h.

Referenced by adl_line_draw(), adl_point_draw(), and process_input_window().

3.9.2.5 zoom_multiplier

```
float Offset_zoom_param::zoom_multiplier
```

Zoom scale factor (>0).

Definition at line 66 of file Almog_Draw_Library.h.

Referenced by adl_line_draw(), adl_point_draw(), main(), and process_input_window().

The documentation for this struct was generated from the following file:

- Almog_Draw_Library.h

3.10 Point Struct Reference

Homogeneous 2D/3D point with per-vertex depth (z) and w.

```
#include <Almog_Draw_Library.h>
```

Public Attributes

- float x
- float y
- float z
- float w

3.10.1 Detailed Description

Homogeneous 2D/3D point with per-vertex depth (z) and w.

x,y are screen-space coordinates for rasterization. z,w are used for perspective-correct interpolation via inverse-Z buffering.

Definition at line 81 of file Almog_Draw_Library.h.

3.10.2 Member Data Documentation

3.10.2.1 w

```
float Point::w
```

Homogeneous w.

Definition at line 85 of file Almog_Draw_Library.h.

Referenced by adl_2Dscalar_interp_on_figure(), adl_cartesian_grid_create(), adl_quad_fill(), adl_quad_fill_interpolate_color_mean_v adl_quad_fill_interpolate_normal_mean_value(), adl_tri_fill_Pinedas_rasterizer(), adl_tri_fill_Pinedas_rasterizer_interpolate_color(), and adl_tri_fill_Pinedas_rasterizer_interpolate_normal().

3.10.2.2 x

```
float Point::x
```

X coordinate (pixels).

Definition at line 82 of file Almog_Draw_Library.h.

Referenced by adl_2Dscalar_interp_on_figure(), adl_cartesian_grid_create(), adl_curve_add_to_figure(), adl_curves_plot_on_figure(), adl_figure_copy_to_screen(), adl_quad_fill(), adl_quad_fill_interpolate_color_mean_value(), adl_quad_fill_interpolate_normal_mean_value(), adl_tan_half_angle(), adl_tri_draw(), adl_tri_fill_Pinedas_rasterizer(), adl_tri_fill_Pinedas_rasterizer_interpolate_color(), and adl_tri_fill_Pinedas_rasterizer_interpolate_normal().

3.10.2.3 y

```
float Point::y
```

Y coordinate (pixels).

Definition at line 83 of file Almog_Draw_Library.h.

Referenced by adl_2Dscalar_interp_on_figure(), adl_cartesian_grid_create(), adl_curve_add_to_figure(), adl_curves_plot_on_figure(), adl_figure_copy_to_screen(), adl_quad_fill(), adl_quad_fill_interpolate_color_mean_value(), adl_quad_fill_interpolate_normal_mean_value(), adl_tan_half_angle(), adl_tri_draw(), adl_tri_fill_Pinedas_rasterizer(), adl_tri_fill_Pinedas_rasterizer_interpolate_color(), and adl_tri_fill_Pinedas_rasterizer_interpolate_normal().

3.10.2.4 z

```
float Point::z
```

Depth value.

Definition at line 84 of file Almog_Draw_Library.h.

Referenced by adl_2Dscalar_interp_on_figure(), adl_cartesian_grid_create(), adl_quad_fill(), adl_quad_fill_interpolate_color_mean_v adl_quad_fill_interpolate_normal_mean_value(), adl_tri_fill_Pinedas_rasterizer(), adl_tri_fill_Pinedas_rasterizer_interpolate_color(), and adl_tri_fill_Pinedas_rasterizer_interpolate_normal().

The documentation for this struct was generated from the following file:

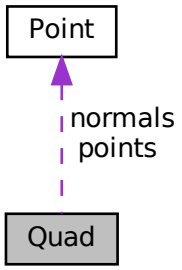
- Almog_Draw_Library.h

3.11 Quad Struct Reference

Quad primitive with optional per-vertex attributes.

`#include <Almog_Draw_Library.h>`

Collaboration diagram for Quad:



Public Attributes

- Point points [4]
- Point normals [4]
- uint32_t colors [4]
- bool to_draw
- float light_intensity [4]

3.11.1 Detailed Description

Quad primitive with optional per-vertex attributes.

Definition at line 134 of file Almog_Draw_Library.h.

3.11.2 Member Data Documentation

3.11.2.1 colors

`uint32_t Quad::colors[4]`

Optional per-vertex ARGB colors.

Definition at line 137 of file Almog_Draw_Library.h.

Referenced by adl_2Dscalar_interp_on_figure(), adl_quad2tris(), adl_quad_fill_interpolate_color_mean_value(), and setup().

3.11.2.2 light_intensity

```
float Quad::light_intensity[4]
```

Per-vertex light intensity multiplier.

Definition at line 139 of file Almog_Draw_Library.h.

Referenced by adl_2Dscalar_interp_on_figure(), adl_quad2tris(), adl_quad_fill(), adl_quad_fill_interpolate_color_mean_value(), adl_quad_fill_interpolate_normal_mean_value(), and setup().

3.11.2.3 normals

```
Point Quad::normals[4]
```

Optional normals (unused here).

Definition at line 136 of file Almog_Draw_Library.h.

3.11.2.4 points

```
Point Quad::points[4]
```

Quad vertices (0..3 order).

Definition at line 135 of file Almog_Draw_Library.h.

Referenced by adl_2Dscalar_interp_on_figure(), adl_quad2tris(), adl_quad_draw(), adl_quad_fill(), adl_quad_fill_interpolate_color_m
adl_quad_fill_interpolate_normal_mean_value(), and setup().

3.11.2.5 to_draw

```
bool Quad::to_draw
```

Whether to include in rendering.

Definition at line 138 of file Almog_Draw_Library.h.

Referenced by adl_2Dscalar_interp_on_figure(), adl_quad2tris(), adl_quad_mesh_draw(), adl_quad_mesh_fill(), adl_quad_mesh_fill_interpolate_color(), adl_quad_mesh_fill_interpolate_normal(), and setup().

The documentation for this struct was generated from the following file:

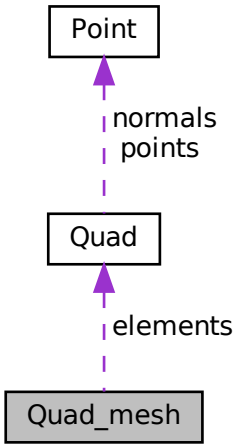
- Almog_Draw_Library.h

3.12 Quad_mesh Struct Reference

Dynamic array of quads (quad mesh).

`#include <Almog_Draw_Library.h>`

Collaboration diagram for Quad_mesh:



Public Attributes

- size_t length
- size_t capacity
- Quad * elements

3.12.1 Detailed Description

Dynamic array of quads (quad mesh).

Definition at line 160 of file Almog_Draw_Library.h.

3.12.2 Member Data Documentation

3.12.2.1 capacity

`size_t Quad_mesh::capacity`

Allocated capacity.

Definition at line 162 of file Almog_Draw_Library.h.

3.12.2.2 elements

```
Quad* Quad_mesh::elements
```

Quad array.

Definition at line 163 of file Almog_Draw_Library.h.

Referenced by adl_quad_mesh_draw(), adl_quad_mesh_fill(), adl_quad_mesh_fill_interpolate_color(), and adl_quad_mesh_fill_interpolate_normal().

3.12.2.3 length

```
size_t Quad_mesh::length
```

Number of quads used.

Definition at line 161 of file Almog_Draw_Library.h.

Referenced by adl_quad_mesh_draw(), adl_quad_mesh_fill(), adl_quad_mesh_fill_interpolate_color(), and adl_quad_mesh_fill_interpolate_normal().

The documentation for this struct was generated from the following file:

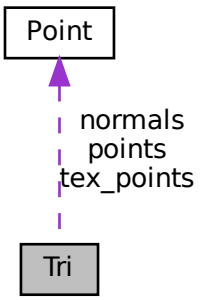
- Almog_Draw_Library.h

3.13 Tri Struct Reference

Triangle primitive with optional per-vertex attributes.

```
#include <Almog_Draw_Library.h>
```

Collaboration diagram for Tri:



Public Attributes

- Point points [3]
- Point tex_points [3]
- Point normals [3]
- uint32_t colors [3]
- bool to_draw
- float light_intensity [3]

3.13.1 Detailed Description

Triangle primitive with optional per-vertex attributes.

Definition at line 119 of file Almog_Draw_Library.h.

3.13.2 Member Data Documentation

3.13.2.1 colors

```
uint32_t Tri::colors[3]
```

Optional per-vertex ARGB colors.

Definition at line 123 of file Almog_Draw_Library.h.

Referenced by adl_quad2tris(), adl_tri_fill_Pinedas_rasterizer_interpolate_color(), and setup().

3.13.2.2 light_intensity

```
float Tri::light_intensity[3]
```

Per-vertex light intensity multiplier.

Definition at line 125 of file Almog_Draw_Library.h.

Referenced by adl_quad2tris(), adl_tri_fill_Pinedas_rasterizer(), adl_tri_fill_Pinedas_rasterizer_interpolate_color(), adl_tri_fill_Pinedas_rasterizer_interpolate_normal(), and setup().

3.13.2.3 normals

```
Point Tri::normals[3]
```

Optional normals (unused here).

Definition at line 122 of file Almog_Draw_Library.h.

3.13.2.4 points

```
Point Tri::points[3]
```

Triangle vertices.

Definition at line 120 of file Almog_Draw_Library.h.

Referenced by adl_quad2tris(), adl_tri_draw(), adl_tri_fill_Pinedas_rasterizer(), adl_tri_fill_Pinedas_rasterizer_interpolate_color(), adl_tri_fill_Pinedas_rasterizer_interpolate_normal(), and setup().

3.13.2.5 tex_points

```
Point Tri::tex_points[3]
```

Optional texture coordinates (unused here).

Definition at line 121 of file Almog_Draw_Library.h.

3.13.2.6 to_draw

```
bool Tri::to_draw
```

Whether to include in rendering.

Definition at line 124 of file Almog_Draw_Library.h.

Referenced by adl_quad2tris(), adl_tri_mesh_draw(), adl_tri_mesh_fill_Pinedas_rasterizer(), adl_tri_mesh_fill_Pinedas_rasterizer_int
adl_tri_mesh_fill_Pinedas_rasterizer_interpolate_normal(), and setup().

The documentation for this struct was generated from the following file:

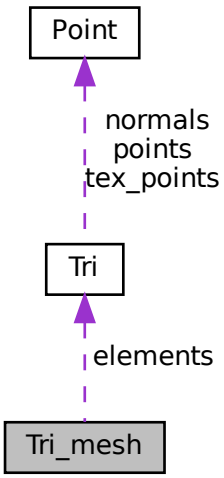
- Almog_Draw_Library.h

3.14 Tri_mesh Struct Reference

Dynamic array of triangles (triangle mesh).

`#include <Almog_Draw_Library.h>`

Collaboration diagram for Tri_mesh:



Public Attributes

- size_t length
- size_t capacity
- Tri * elements

3.14.1 Detailed Description

Dynamic array of triangles (triangle mesh).

Definition at line 148 of file Almog_Draw_Library.h.

3.14.2 Member Data Documentation

3.14.2.1 capacity

```
size_t Tri_mesh::capacity
```

Allocated capacity.

Definition at line 150 of file Almog_Draw_Library.h.

3.14.2.2 elements

```
Tri* Tri_mesh::elements
```

Triangle array.

Definition at line 151 of file Almog_Draw_Library.h.

Referenced by adl_tri_mesh_draw(), adl_tri_mesh_fill_Pinedas_rasterizer(), adl_tri_mesh_fill_Pinedas_rasterizer_interpolate_color(), and adl_tri_mesh_fill_Pinedas_rasterizer_interpolate_normal().

3.14.2.3 length

```
size_t Tri_mesh::length
```

Number of triangles used.

Definition at line 149 of file Almog_Draw_Library.h.

Referenced by adl_tri_mesh_draw(), adl_tri_mesh_fill_Pinedas_rasterizer(), adl_tri_mesh_fill_Pinedas_rasterizer_interpolate_color(), and adl_tri_mesh_fill_Pinedas_rasterizer_interpolate_normal().

The documentation for this struct was generated from the following file:

- Almog_Draw_Library.h

Chapter 4

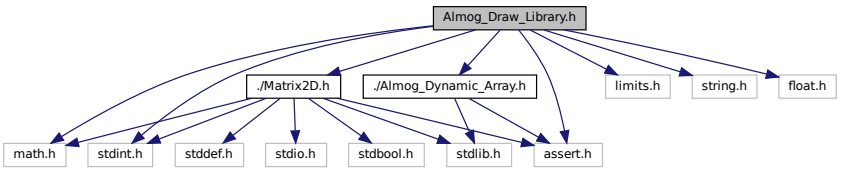
File Documentation

4.1 Almog_Draw_Library.h File Reference

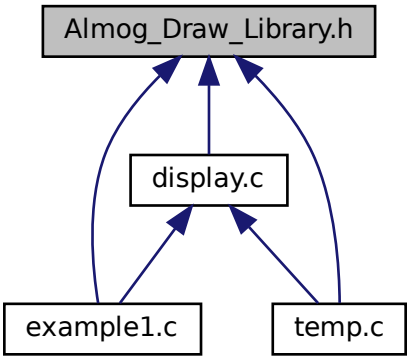
Immediate-mode 2D/3D raster helpers for drawing onto Mat2D_uint32 pixel buffers.

```
#include <math.h>
#include <stdint.h>
#include <limits.h>
#include <string.h>
#include <float.h>
#include "./Matrix2D.h"
#include "./Almog_Dynamic_Array.h"
#include <assert.h>
```

Include dependency graph for Almog_Draw_Library.h:



This graph shows which files directly or indirectly include this file:



Classes

- struct Offset_zoom_param

  Pan/zoom parameters relative to screen center.
- struct Point

  Homogeneous 2D/3D point with per-vertex depth (z) and w.
- struct Curve

  Polyline of points with a uniform color.
- struct Curve_ada

  Dynamic array of curves (polyline container).
- struct Tri

  Triangle primitive with optional per-vertex attributes.
- struct Quad

  Quad primitive with optional per-vertex attributes.
- struct Tri_mesh

  Dynamic array of triangles (triangle mesh).
- struct Quad_mesh

  Dynamic array of quads (quad mesh).
- struct Figure

  Plotting figure holding a pixel buffer, z-buffer and plot state.
- struct Grid

  Grid definition (as lines) in a chosen plane.

Macros

- #define ADL_ASSERT assert

  Assertion macro used by this header (defaults to assert).
- #define POINT
- #define CURVE
- #define CURVE_ADA

- #define TRI
- #define QUAD
- #define TRI_MESH
- #define QUAD_MESH
- #define HexARGB_RGBA(x) ((x)>>(8*2)&0xFF), ((x)>>(8*1)&0xFF), ((x)>>(8*0)&0xFF), ((x)>>(8*3)&0x↩FF)
- #define HexARGB_RGB_VAR(x, r, g, b) r = ((x)>>(8*2)&0xFF); g = ((x)>>(8*1)&0xFF); b = ((x)>>(8*0)&0xFF);
- #define HexARGB_RGBA_VAR(x, r, g, b, a) r = ((x)>>(8*2)&0xFF); g = ((x)>>(8*1)&0xFF); b = ((x)>>(8*0)&0xFF); a = ((x)>>(8*3)&0xFF)
- #define RGB_hexRGB(r, g, b) (int)(0x010000*(int)(r) + 0x000100*(int)(g) + 0x000001*(int)(b))
- #define RGBA_hexARGB(r, g, b, a) (int)(0x01000000l*(int)(fminf(a, 255)) + 0x010000*(int)(r) + 0x000100*(int)(g) + 0x000001*(int)(b))
- #define RED_hexARGB 0xFFFF0000
- #define GREEN_hexARGB 0xFF00FF00
- #define BLUE_hexARGB 0xFF0000FF
- #define PURPLE_hexARGB 0xFFFF00FF
- #define CYAN_hexARGB 0xFF00FFFF
- #define YELLOW_hexARGB 0xFFFFFF00
- #define edge_cross_point(a1, b, a2, p) (b.x-a1.x)*(p.y-a2.y)-(b.y-a1.y)*(p.x-a2.x)
- #define is_top_edge(x, y) (y == 0 && x > 0)
- #define is_left_edge(x, y) (y < 0)
- #define is_top_left(ps, pe) (is_top_edge(pe.x-ps.x, pe.y-ps.y) || is_left_edge(pe.x-ps.x, pe.y-ps.y))
- #define ADL_MAX_POINT_VAL 1e5
- #define adl_assert_point_is_valid(p) ADL_ASSERT(isfinite(p.x) && isfinite(p.y) && isfinite(p.z) && isfinite(p.↩w))
- #define adl_assert_tri_is_valid(tri)
- #define adl_assert_quad_is_valid(quad)
- #define ADL_FIGURE_PADDING_PRECENTAGE 20
- #define ADL_MAX_FIGURE_PADDING 70
- #define ADL_MIN_FIGURE_PADDING 20
- #define ADL_MAX_HEAD_SIZE 15
- #define ADL_FIGURE_HEAD_ANGLE_DEG 30
- #define ADL_FIGURE_AXIS_COLOR 0xff000000
- #define ADL_MAX_CHARACTER_OFFSET 10
- #define ADL_MIN_CHARACTER_OFFSET 5
- #define ADL_MAX_SENTENCE_LEN 256
- #define ADL_MAX_ZOOM 1e3
- #define ADL_DEFAULT_OFFSET_ZOOM (Offset_zoom_param){1,0,0,0,0}
- #define adl_offset_zoom_point(p, window_w, window_h, offset_zoom_param)
- #define adl_offset2d(i, j, ni) (j) * (ni) + (i)

Functions

- void adl_point_draw (Mat2D_uint32 screen_mat, int x, int y, uint32_t color, Offset_zoom_param offset_↩zoom_param)

  Draw a single pixel with alpha blending.
- void adl_line_draw (Mat2D_uint32 screen_mat, const float x1_input, const float y1_input, const float x2_input, const float y2_input, uint32_t color, Offset_zoom_param offset_zoom_param)

  Draw an anti-aliased-like line by vertical spans (integer grid).
- void adl_lines_draw (const Mat2D_uint32 screen_mat, const Point *points, const size_t len, const uint32_t color, Offset_zoom_param offset_zoom_param)

  Draw a polyline connecting an array of points.

- void adl_lines_loop_draw (const Mat2D_uint32 screen_mat, const Point *points, const size_t len, const uint32_t color, Offset_zoom_param offset_zoom_param)

  Draw a closed polyline (loop).
- void adl_arrow_draw (Mat2D_uint32 screen_mat, int xs, int ys, int xe, int ye, float head_size, float angle_deg, uint32_t color, Offset_zoom_param offset_zoom_param)

  Draw an arrow from start to end with a triangular head.
- void adl_character_draw (Mat2D_uint32 screen_mat, char c, int width_pixel, int hight_pixel, int x_top_left, int y_top_left, uint32_t color, Offset_zoom_param offset_zoom_param)

  Draw a vector glyph for a single ASCII character.
- void adl_sentence_draw (Mat2D_uint32 screen_mat, const char sentence[ ], size_t len, const int x_top_left, const int y_top_left, const int hight_pixel, const uint32_t color, Offset_zoom_param offset_zoom_param)

  Draw a horizontal sentence using vector glyphs.
- void adl_rectangle_draw_min_max (Mat2D_uint32 screen_mat, int min_x, int max_x, int min_y, int max_y, uint32_t color, Offset_zoom_param offset_zoom_param)

  Draw a rectangle outline defined by min/max corners (inclusive).
- void adl_rectangle_fill_min_max (Mat2D_uint32 screen_mat, int min_x, int max_x, int min_y, int max_↩ y, uint32_t color, Offset_zoom_param offset_zoom_param)

  Fill a rectangle defined by min/max corners (inclusive).
- void adl_quad_draw (Mat2D_uint32 screen_mat, Mat2D inv_z_buffer, Quad quad, uint32_t color, Offset_zoom_param offset_zoom_param)

  Draw the outline of a quad (four points, looped).
- void adl_quad_fill (Mat2D_uint32 screen_mat, Mat2D inv_z_buffer, Quad quad, uint32_t color, Offset_zoom_param offset_zoom_param)

  Fill a quad using mean-value (Barycentric) coordinates and flat base color.
- void adl_quad_fill_interpolate_normal_mean_value (Mat2D_uint32 screen_mat, Mat2D inv_z_buffer, Quad quad, uint32_t color, Offset_zoom_param offset_zoom_param)

  Fill a quad with per-pixel light interpolation (mean value coords).
- void adl_quad_fill_interpolate_color_mean_value (Mat2D_uint32 screen_mat, Mat2D inv_z_buffer, Quad quad, Offset_zoom_param offset_zoom_param)

  Fill a quad with per-vertex colors (mean value coords).
- void adl_quad_mesh_draw (Mat2D_uint32 screen_mat, Mat2D inv_z_buffer_mat, Quad_mesh mesh, uint32_t color, Offset_zoom_param offset_zoom_param)

  Draw outlines for all quads in a mesh.
- void adl_quad_mesh_fill (Mat2D_uint32 screen_mat, Mat2D inv_z_buffer_mat, Quad_mesh mesh, uint32_t color, Offset_zoom_param offset_zoom_param)

  Fill all quads in a mesh with a uniform base color.
- void adl_quad_mesh_fill_interpolate_normal (Mat2D_uint32 screen_mat, Mat2D inv_z_buffer_mat, Quad_mesh mesh, uint32_t color, Offset_zoom_param offset_zoom_param)

  Fill all quads in a mesh using interpolated lighting.
- void adl_quad_mesh_fill_interpolate_color (Mat2D_uint32 screen_mat, Mat2D inv_z_buffer_mat, Quad_mesh mesh, Offset_zoom_param offset_zoom_param)

  Fill all quads in a mesh using per-vertex colors.
- void adl_circle_draw (Mat2D_uint32 screen_mat, float center_x, float center_y, float r, uint32_t color, Offset_zoom_param offset_zoom_param)

  Draw an approximate circle outline (1px thickness).
- void adl_circle_fill (Mat2D_uint32 screen_mat, float center_x, float center_y, float r, uint32_t color, Offset_zoom_param offset_zoom_param)

  Fill a circle.
- void adl_tri_draw (Mat2D_uint32 screen_mat, Tri tri, uint32_t color, Offset_zoom_param offset_zoom_param)

  Draw the outline of a triangle.
- void adl_tri_fill_Pinedas_rasterizer (Mat2D_uint32 screen_mat, Mat2D inv_z_buffer, Tri tri, uint32_t color, Offset_zoom_param offset_zoom_param)

  Fill a triangle using Pineda's rasterizer with flat base color.

- void adl_tri_fill_Pinedas_rasterizer_interpolate_color (Mat2D_uint32 screen_mat, Mat2D inv_z_buffer, Tri tri, Offset_zoom_param offset_zoom_param)

  Fill a triangle using Pineda's rasterizer with per-vertex colors.
- void adl_tri_fill_Pinedas_rasterizer_interpolate_normal (Mat2D_uint32 screen_mat, Mat2D inv_z_buffer, Tri tri, uint32_t color, Offset_zoom_param offset_zoom_param)

  Fill a triangle with interpolated lighting over a uniform color.
- void adl_tri_mesh_draw (Mat2D_uint32 screen_mat, Tri_mesh mesh, uint32_t color, Offset_zoom_param offset_zoom_param)

  Draw outlines for all triangles in a mesh.
- void adl_tri_mesh_fill_Pinedas_rasterizer (Mat2D_uint32 screen_mat, Mat2D inv_z_buffer_mat, Tri_mesh mesh, uint32_t color, Offset_zoom_param offset_zoom_param)

  Fill all triangles in a mesh with a uniform base color.
- void adl_tri_mesh_fill_Pinedas_rasterizer_interpolate_color (Mat2D_uint32 screen_mat, Mat2D inv_z_↩ buffer_mat, Tri_mesh mesh, Offset_zoom_param offset_zoom_param)

  Fill all triangles in a mesh with a uniform base color.
- void adl_tri_mesh_fill_Pinedas_rasterizer_interpolate_normal (Mat2D_uint32 screen_mat, Mat2D inv_z_↩ buffer_mat, Tri_mesh mesh, uint32_t color, Offset_zoom_param offset_zoom_param)

  Fill all triangles in a mesh with interpolated lighting.
- float adl_tan_half_angle (Point vi, Point vj, Point p, float li, float lj)

  Compute tan(alpha/2) for the angle at point p between segments p->vi and p->vj.
- float adl_linear_map (float s, float min_in, float max_in, float min_out, float max_out)

  Affine map from one scalar range to another (no clamping).
- void adl_quad2tris (Quad quad, Tri *tri1, Tri *tri2, char split_line[])

  Split a quad into two triangles along a chosen diagonal.
- void adl_linear_sRGB_to_okLab (uint32_t hex_ARGB, float *L, float *a, float *b)

  Convert a linear sRGB color (ARGB) to Oklab components.
- void adl_okLab_to_linear_sRGB (float L, float a, float b, uint32_t *hex_ARGB)

  Convert Oklab components to a linear sRGB ARGB color.
- void adl_linear_sRGB_to_okLch (uint32_t hex_ARGB, float *L, float *c, float *h_deg)

  Convert a linear sRGB color (ARGB) to OkLch components.
- void adl_okLch_to_linear_sRGB (float L, float c, float h_deg, uint32_t *hex_ARGB)

  Convert OkLch components to a linear sRGB ARGB color.
- void adl_interpolate_ARGBcolor_on_okLch (uint32_t color1, uint32_t color2, float t, float num_of_rotations, uint32_t *color_out)

  Interpolate between two ARGB colors in OkLch space.
- Figure adl_figure_alloc (size_t rows, size_t cols, Point top_left_position)

  Allocate and initialize a Figure with an internal pixel buffer.
- void adl_figure_copy_to_screen (Mat2D_uint32 screen_mat, Figure figure)

  Blit a Figure's pixels onto a destination screen buffer.
- void adl_axis_draw_on_figure (Figure *figure)

  Draw X/Y axes with arrowheads into a Figure.
- void adl_max_min_values_draw_on_figure (Figure figure)

  Draw min/max numeric labels for the current data range.
- void adl_curve_add_to_figure (Figure *figure, Point *src_points, size_t src_len, uint32_t color)

  Add a curve (polyline) to a Figure and update its data bounds.
- void adl_curves_plot_on_figure (Figure figure)

  Render all added curves into a Figure's pixel buffer.
- void adl_2Dscalar_interp_on_figure (Figure figure, double *x_2Dmat, double *y_2Dmat, double *scalar_2↩ Dmat, int ni, int nj, char color_scale[], float num_of_rotations)

  Visualize a scalar field on a Figure by colored quads.
- Grid adl_cartesian_grid_create (float min_e1, float max_e1, float min_e2, float max_e2, int num_samples_e1, int num_samples_e2, char plane[], float third_direction_position)

Create a Cartesian grid (as curves) on one of the principal planes.

- void adl_grid_draw (Mat2D_uint32 screen_mat, Grid grid, uint32_t color, Offset_zoom_param offset_zoom↩ _param)

  Draw a previously created Grid as line segments.

4.1.1 Detailed Description

Immediate-mode 2D/3D raster helpers for drawing onto Mat2D_uint32 pixel buffers.

This single-header library provides a minimal software rasterizer for drawing into a 32-bit ARGB pixel buffer (Mat2D_uint32). It supports:

- Points, lines, circles, triangles and quads (wire and filled)
- Z-buffered triangle/quad rasterization (inverse-Z convention)
- Per-vertex color and simple light-intensity interpolation
- Basic vector-text drawing (ASCII subset)
- Plotting helper types (Figure) and utilities for curve plots and 2D scalar-field visualization using perceptual color interpolation in the OKLab/OKLch color spaces
- Cartesian grid generation in common planes

All draw calls may accept an Offset_zoom_param that enables simple pan/zoom behavior around the screen center.

Types Mat2D and Mat2D_uint32 are provided by Matrix2D.h.

Usage:

- Include this header wherever you use the API.
- In exactly one translation unit (source file) define ALMOG_DRAW_LIBRARY_IMPLEMENTATION before including this header to compile the function definitions.

Note

- Colors are ARGB in 0xAARRGGBB packed 32-bit format.
- Z buffering uses an inverse-Z buffer (bigger is closer).
- The OKLab/OKLch conversions here assume linear sRGB channels.

Definition in file Almog_Draw_Library.h.

4.1.2 Macro Definition Documentation

4.1.2.1 ADL_ASSERT

```
#define ADL_ASSERT assert
```

Assertion macro used by this header (defaults to assert).

Define ADL_ASSERT before including this file to override. When NDEBUG is defined, standard assert() is disabled.

Definition at line 55 of file Almog_Draw_Library.h.

4.1.2.2 adl_assert_point_is_valid

```
#define adl_assert_point_is_valid(
            p ) ADL_ASSERT(isfinite(p.x) && isfinite(p.y) && isfinite(p.z) && isfinite(p.w))
```

Definition at line 310 of file Almog_Draw_Library.h.

4.1.2.3 adl_assert_quad_is_valid

```
#define adl_assert_quad_is_valid(
            quad )
```

Value:

```
adl_assert_point_is_valid(quad.points[0]);   \
adl_assert_point_is_valid(quad.points[1]);                                  \
adl_assert_point_is_valid(quad.points[2]);                                  \
adl_assert_point_is_valid(quad.points[3])
```

Definition at line 314 of file Almog_Draw_Library.h.

4.1.2.4 adl_assert_tri_is_valid

```
#define adl_assert_tri_is_valid(
            tri )
```

Value:

```
adl_assert_point_is_valid(tri.points[0]); \
adl_assert_point_is_valid(tri.points[1]);                           \
adl_assert_point_is_valid(tri.points[2])
```

Definition at line 311 of file Almog_Draw_Library.h.

4.1.2.5 ADL_DEFAULT_OFFSET_ZOOM

```
#define ADL_DEFAULT_OFFSET_ZOOM (Offset_zoom_param){1,0,0,0,0}
```

Definition at line 331 of file Almog_Draw_Library.h.

4.1.2.6 ADL_FIGURE_AXIS_COLOR

```
#define ADL_FIGURE_AXIS_COLOR 0xff000000
```

Definition at line 324 of file Almog_Draw_Library.h.

4.1.2.7 ADL_FIGURE_HEAD_ANGLE_DEG

```
#define ADL_FIGURE_HEAD_ANGLE_DEG 30
```

Definition at line 323 of file Almog_Draw_Library.h.

4.1.2.8 ADL_FIGURE_PADDING_PRECENTAGE

```
#define ADL_FIGURE_PADDING_PRECENTAGE 20
```

Definition at line 319 of file Almog_Draw_Library.h.

4.1.2.9 ADL_MAX_CHARACTER_OFFSET

```
#define ADL_MAX_CHARACTER_OFFSET 10
```

Definition at line 326 of file Almog_Draw_Library.h.

4.1.2.10 ADL_MAX_FIGURE_PADDING

```
#define ADL_MAX_FIGURE_PADDING 70
```

Definition at line 320 of file Almog_Draw_Library.h.

4.1.2.11 ADL_MAX_HEAD_SIZE

```
#define ADL_MAX_HEAD_SIZE 15
```

Definition at line 322 of file Almog_Draw_Library.h.

4.1.2.12 ADL_MAX_POINT_VAL

```
#define ADL_MAX_POINT_VAL 1e5
```

Definition at line 309 of file Almog_Draw_Library.h.

4.1.2.13 ADL_MAX_SENTENCE_LEN

```
#define ADL_MAX_SENTENCE_LEN 256
```

Definition at line 328 of file Almog_Draw_Library.h.

4.1.2.14 ADL_MAX_ZOOM

```
#define ADL_MAX_ZOOM 1e3
```

Definition at line 329 of file Almog_Draw_Library.h.

4.1.2.15 ADL_MIN_CHARACTER_OFFSET

```
#define ADL_MIN_CHARACTER_OFFSET 5
```

Definition at line 327 of file Almog_Draw_Library.h.

4.1.2.16 ADL_MIN_FIGURE_PADDING

```
#define ADL_MIN_FIGURE_PADDING 20
```

Definition at line 321 of file Almog_Draw_Library.h.

4.1.2.17 adl_offset2d

```
#define adl_offset2d(
              i,
              j,
              ni ) (j) * (ni) + (i)
```

Definition at line 2294 of file Almog_Draw_Library.h.

4.1.2.18 adl_offset_zoom_point

```
#define adl_offset_zoom_point(
              p,
              window_w,
              window_h,
              offset_zoom_param )
```

Value:

```
    (p).x = ((p).x - (window_w)/2 + offset_zoom_param.offset_x) * offset_zoom_param.zoom_multiplier +
       (window_w)/2; \
    (p).y = ((p).y - (window_h)/2 + offset_zoom_param.offset_y) * offset_zoom_param.zoom_multiplier +
       (window_h)/2
```

Definition at line 332 of file Almog_Draw_Library.h.

4.1.2.19 BLUE_hexARGB

```
#define BLUE_hexARGB 0xFF0000FF
```

Definition at line 299 of file Almog_Draw_Library.h.

4.1.2.20 CURVE

```
#define CURVE
```

Definition at line 90 of file Almog_Draw_Library.h.

4.1.2.21 CURVE_ADA

```
#define CURVE_ADA
```

Definition at line 103 of file Almog_Draw_Library.h.

4.1.2.22 CYAN_hexARGB

```
#define CYAN_hexARGB 0xFF00FFFF
```

Definition at line 301 of file Almog_Draw_Library.h.

4.1.2.23 edge_cross_point

```
#define edge_cross_point(
              a1,
              b,
              a2,
              p ) (b.x-a1.x)*(p.y-a2.y)-(b.y-a1.y)*(p.x-a2.x)
```

Definition at line 304 of file Almog_Draw_Library.h.

4.1.2.24 GREEN_hexARGB

```
#define GREEN_hexARGB 0xFF00FF00
```

Definition at line 298 of file Almog_Draw_Library.h.

4.1.2.25 HexARGB_RGB_VAR

```
#define HexARGB_RGB_VAR(
              x,
              r,
              g,
              b ) r = ((x)>>(8*2)&0xFF); g = ((x)>>(8*1)&0xFF); b = ((x)>>(8*0)&0xFF);
```

Definition at line 224 of file Almog_Draw_Library.h.

4.1.2.26 HexARGB_RGBA

```
#define HexARGB_RGBA(
              x ) ((x)>>(8*2)&0xFF), ((x)>>(8*1)&0xFF), ((x)>>(8*0)&0xFF), ((x)>>(8*3)&0xFF)
```

Definition at line 221 of file Almog_Draw_Library.h.

4.1.2.27 HexARGB_RGBA_VAR

```
#define HexARGB_RGBA_VAR(
              x,
              r,
              g,
              b,
              a ) r = ((x)>>(8*2)&0xFF); g = ((x)>>(8*1)&0xFF); b = ((x)>>(8*0)&0xFF); a =
((x)>>(8*3)&0xFF)
```

Definition at line 227 of file Almog_Draw_Library.h.

4.1.2.28 is_left_edge

```
#define is_left_edge(
              x,
              y ) (y < 0)
```

Definition at line 306 of file Almog_Draw_Library.h.

4.1.2.29 is_top_edge

```
#define is_top_edge(
              x,
              y ) (y == 0 && x > 0)
```

Definition at line 305 of file Almog_Draw_Library.h.

4.1.2.30 is_top_left

```
#define is_top_left(
              ps,
              pe ) (is_top_edge(pe.x-ps.x, pe.y-ps.y) || is_left_edge(pe.x-ps.x, pe.y-ps.y))
```

Definition at line 307 of file Almog_Draw_Library.h.

4.1.2.31 POINT

```
#define POINT
```

Definition at line 74 of file Almog_Draw_Library.h.

4.1.2.32 PURPLE_hexARGB

```
#define PURPLE_hexARGB 0xFFFF00FF
```

Definition at line 300 of file Almog_Draw_Library.h.

4.1.2.33 QUAD

```
#define QUAD
```

Definition at line 130 of file Almog_Draw_Library.h.

4.1.2.34 QUAD_MESH

```
#define QUAD_MESH
```

Definition at line 156 of file Almog_Draw_Library.h.

4.1.2.35 RED_hexARGB

```
#define RED_hexARGB 0xFFFF0000
```

Definition at line 297 of file Almog_Draw_Library.h.

4.1.2.36 RGB_hexRGB

```
#define RGB_hexRGB(
              r,
              g,
              b ) (int)(0x010000*(int)(r) + 0x000100*(int)(g) + 0x000001*(int)(b))
```

Definition at line 230 of file Almog_Draw_Library.h.

4.1.2.37 RGBA_hexARGB

```
#define RGBA_hexARGB(
              r,
              g,
              b,
              a ) (int)(0x01000000l*(int)(fminf(a, 255)) + 0x010000*(int)(r) + 0x000100*(int)(g)
+ 0x000001*(int)(b))
```

Definition at line 233 of file Almog_Draw_Library.h.

4.1.2.38 TRI

```
#define TRI
```

Definition at line 115 of file Almog_Draw_Library.h.

4.1.2.39 TRI_MESH

```
#define TRI_MESH
```

Definition at line 144 of file Almog_Draw_Library.h.

4.1.2.40 YELLOW_hexARGB

```
#define YELLOW_hexARGB 0xFFFFFF00
```

Definition at line 302 of file Almog_Draw_Library.h.

4.1.3 Function Documentation

4.1.3.1 adl_2Dscalar_interp_on_figure()

```
void adl_2Dscalar_interp_on_figure (
            Figure figure,
            double * x_2Dmat,
            double * y_2Dmat,
            double * scalar_2Dmat,
            int ni,
            int nj,
            char color_scale[],
            float num_of_rotations )
```

Visualize a scalar field on a Figure by colored quads.

Treats x_2Dmat and y_2Dmat as a structured 2D grid of positions (column-major with stride ni) and colors each cell using scalar_2Dmat mapped through a two-color OkLch gradient. Also updates figure bounds from the provided data. Depth-tested inside the figure's buffers.

Parameters

figure	Figure to render into (uses its own pixel buffers).
x_2Dmat	Grid X coordinates, size ni∗nj.
y_2Dmat	Grid Y coordinates, size ni∗nj.
scalar_2Dmat	Scalar values per grid node, size ni∗nj.
ni	Number of samples along the first index (rows).
nj	Number of samples along the second index (cols).
color_scale	Two-letter code of endpoints ("b-c","b-g","b-r", "b-y","g-y","g-p","g-r","r-y").
num_of_rotations	Hue turns for the OkLch interpolation (can be fractional/negative).

Definition at line 2314 of file Almog_Draw_Library.h.

References adl_axis_draw_on_figure(), ADL_DEFAULT_OFFSET_ZOOM, adl_interpolate_ARGBcolor_on_okLch(), adl_linear_map(), adl_max_min_values_draw_on_figure(), adl_offset2d, adl_offset_zoom_point, adl_quad_fill_interpolate_color_mea Figure::background_color, BLUE_hexARGB, Quad::colors, Mat2D::cols, Mat2D_uint32::cols, CYAN_hexARGB, Mat2D::elements, GREEN_hexARGB, Figure::inv_z_buffer_mat, Quad::light_intensity, mat2D_fill_uint32(), Figure::max_x, Figure::max_x_pixel, Figure::max_y, Figure::max_y_pixel, Figure::min_x, Figure::min_x_pixel, Figure::min_y, Figure::min_y_pixel, Figure::offset_zoom_param, Figure::pixels_mat, Quad::points, PURPLE_hexARGB, RED_hexARGB, Mat2D::rows, Mat2D_uint32::rows, Quad::to_draw, Figure::to_draw_axis, Figure::to_draw_max_min_values, Point::w, Point::x, Point::y, YELLOW_hexARGB, and Point::z.

4.1.3.2 adl_arrow_draw()

```
void adl_arrow_draw (
            Mat2D_uint32 screen_mat,
            int xs,
            int ys,
            int xe,
            int ye,
            float head_size,
            float angle_deg,
            uint32_t color,
            Offset_zoom_param offset_zoom_param )
```

Draw an arrow from start to end with a triangular head.

The head is constructed by rotating around the arrow tip by +/- angle_deg and using head_size as a fraction of the shaft length.

Note

: This function is a bit complicated and expansive but this is what I could come up with

Parameters

screen_mat	Destination ARGB pixel buffer.
xs	Start X (before pan/zoom).
ys	Start Y (before pan/zoom).
xe	End X (before pan/zoom), i.e., the arrow tip.
ye	End Y (before pan/zoom), i.e., the arrow tip.
head_size	Head size as a fraction of total length in [0,1].
angle_deg	Head wing rotation angle in degrees.
color	Arrow color (0xAARRGGBB).
offset_zoom_param	Pan/zoom transform. Use ADL_DEFAULT_OFFSET_ZOOM for identity.

Definition at line 518 of file Almog_Draw_Library.h.

References adl_line_draw(), mat2D_add(), mat2D_alloc(), MAT2D_AT, mat2D_copy(), mat2D_dot(), mat2D_fill(), mat2D_free(), mat2D_set_rot_mat_z(), and mat2D_sub().

Referenced by adl_axis_draw_on_figure().

4.1.3.3 adl_axis_draw_on_figure()

```
void adl_axis_draw_on_figure (
            Figure * figure )
```

Draw X/Y axes with arrowheads into a Figure.

Uses the current figure's pixel extents and padding to place axes, and stores the computed head sizes for later label layout.

Parameters

figure	[in,out] Figure to draw onto.

Definition at line 2144 of file Almog_Draw_Library.h.

References adl_arrow_draw(), ADL_FIGURE_AXIS_COLOR, ADL_FIGURE_HEAD_ANGLE_DEG, ADL_FIGURE_PADDING_PREC ADL_MAX_FIGURE_PADDING, ADL_MAX_HEAD_SIZE, ADL_MIN_FIGURE_PADDING, Mat2D_uint32::cols, Figure::max_x_pixel, Figure::max_y_pixel, Figure::min_x_pixel, Figure::min_y_pixel, Figure::offset_zoom_param, Figure::pixels_mat, Mat2D_uint32::rows, Figure::x_axis_head_size, and Figure::y_axis_head_size.

Referenced by adl_2Dscalar_interp_on_figure(), and adl_curves_plot_on_figure().

4.1.3.4 adl_cartesian_grid_create()

```
Grid adl_cartesian_grid_create (
            float min_e1,
            float max_e1,
            float min_e2,
            float max_e2,
            int num_samples_e1,
            int num_samples_e2,
            char plane[],
            float third_direction_position )
```

Create a Cartesian grid (as curves) on one of the principal planes.

Supported planes (case-insensitive): "XY","xy","XZ","xz","YX","yx","YZ","yz","ZX","zx","ZY","zy". The third_↩ direction_position places the grid along the axis normal to the plane (e.g., Z for "XY").

Parameters

min_e1	Minimum coordinate along the first axis of the plane.
max_e1	Maximum coordinate along the first axis of the plane.
min_e2	Minimum coordinate along the second axis of the plane.
max_e2	Maximum coordinate along the second axis of the plane.
num_samples_e1	Number of segments along first axis.
num_samples_e2	Number of segments along second axis.
plane	Plane code string ("XY","xy","XZ","xz","YX","yx","YZ","yz","ZX","zx","ZY","zy").
third_direction_position	Position along the axis normal to plane.

Returns

Grid structure containing the generated curves and spacing.

Definition at line 2513 of file Almog_Draw_Library.h.

References ada_append, ada_init_array, Grid::curves, Grid::de1, Grid::de2, Grid::max_e1, Grid::max_e2, Grid::min_e1, Grid::min_e2, Grid::num_samples_e1, Grid::num_samples_e2, Grid::plane, Point::w, Point::x, Point::y, and Point::z.

4.1.3.5 adl_character_draw()

```
void adl_character_draw (
            Mat2D_uint32 screen_mat,
            char c,
            int width_pixel,
            int hight_pixel,
            int x_top_left,
            int y_top_left,
            uint32_t color,
            Offset_zoom_param offset_zoom_param )
```

Draw a vector glyph for a single ASCII character.

Only a limited set of characters is supported (A–Z, a–z, 0–9, space, '.', ':', '-', '+'). Unsupported characters are rendered as a framed box with an 'X'. Coordinates are for the character's top-left corner.

Parameters

screen_mat	Destination ARGB pixel buffer.
c	The character to draw.
width_pixel	Character box width in pixels.
hight_pixel	Character box height in pixels (spelled as in API).
x_top_left	X of top-left corner (before pan/zoom).
y_top_left	Y of top-left corner (before pan/zoom).
color	Stroke color (0xAARRGGBB).
offset_zoom_param	Pan/zoom transform. Use ADL_DEFAULT_OFFSET_ZOOM for identity.

Definition at line 586 of file Almog_Draw_Library.h.

References adl_line_draw(), adl_rectangle_draw_min_max(), and adl_rectangle_fill_min_max().

Referenced by adl_sentence_draw(), and render().

4.1.3.6 adl_circle_draw()

```
void adl_circle_draw (
            Mat2D_uint32 screen_mat,
```

```
            float center_x,
            float center_y,
            float r,
            uint32_t color,
            Offset_zoom_param offset_zoom_param )
```

Draw an approximate circle outline (1px thickness).

The outline is approximated on the integer grid by sampling a band around radius r.

Parameters

screen_mat	Destination ARGB pixel buffer.
center_x	Circle center X (before pan/zoom).
center_y	Circle center Y (before pan/zoom).
r	Circle radius in pixels.
color	Stroke color (0xAARRGGBB).
offset_zoom_param	Pan/zoom transform. Use ADL_DEFAULT_OFFSET_ZOOM for identity.

Definition at line 1427 of file Almog_Draw_Library.h.

References adl_point_draw().

4.1.3.7 adl_circle_fill()

```
void adl_circle_fill (
            Mat2D_uint32 screen_mat,
            float center_x,
            float center_y,
            float r,
            uint32_t color,
            Offset_zoom_param offset_zoom_param )
```

Fill a circle.

Parameters

screen_mat	Destination ARGB pixel buffer.
center_x	Circle center X (before pan/zoom).
center_y	Circle center Y (before pan/zoom).
r	Circle radius in pixels.
color	Fill color (0xAARRGGBB).
offset_zoom_param	Pan/zoom transform. Use ADL_DEFAULT_OFFSET_ZOOM for identity.

Definition at line 1449 of file Almog_Draw_Library.h.

References adl_point_draw().

4.1.3.8 adl_curve_add_to_figure()

```
void adl_curve_add_to_figure (
            Figure * figure,
            Point * src_points,
            size_t src_len,
            uint32_t color )
```

Add a curve (polyline) to a Figure and update its data bounds.

The input points are copied into the figure's source curve array with the given color. Figure min/max bounds are updated to include them.

Parameters

figure	[in,out] Target figure.
src_points	Array of source points (in data space).
src_len	Number of points.
color	Curve color (0xAARRGGBB).

Definition at line 2230 of file Almog_Draw_Library.h.

References ada_append, ada_init_array, Curve::color, Figure::max_x, Figure::max_y, Figure::min_x, Figure::min_y, Figure::src_curve_array, Point::x, and Point::y.

Referenced by setup().

4.1.3.9 adl_curves_plot_on_figure()

```
void adl_curves_plot_on_figure (
            Figure figure )
```

Render all added curves into a Figure's pixel buffer.

Clears the pixel buffer to background_color, draws axes if enabled, maps data-space points to pixel-space using current min/max bounds, draws the polylines, and optionally draws min/max labels.

Parameters

figure	Figure to render into (uses its own pixel buffer).

Definition at line 2265 of file Almog_Draw_Library.h.

References adl_axis_draw_on_figure(), adl_line_draw(), adl_linear_map(), adl_max_min_values_draw_on_figure(), Figure::background_color, Curve::color, Mat2D::cols, Curve::elements, Curve_ada::elements, Mat2D::elements, Figure::inv_z_buffer_mat, Curve::length, Curve_ada::length, mat2D_fill_uint32(), Figure::max_x, Figure::max_x_pixel, Figure::max_y, Figure::max_y_pixel, Figure::min_x, Figure::min_x_pixel, Figure::min_y, Figure::min_y_pixel, Figure::offset_zoom_param, Figure::pixels_mat, Mat2D::rows, Figure::src_curve_array, Figure::to_draw_axis, Figure::to_draw_max_min_values, Point::x, and Point::y.

Referenced by render().

4.1.3.10 adl_figure_alloc()

```
Figure adl_figure_alloc (
            size_t rows,
            size_t cols,
            Point top_left_position )
```

Allocate and initialize a Figure with an internal pixel buffer.

Initializes the pixel buffer (rows x cols), an inverse-Z buffer (zeroed), an empty source curve array, and default padding/axes bounds. The background_color, to_draw_axis, and to_draw_max_min_values should be set by the caller before rendering.

Parameters

rows	Height of the figure in pixels.
cols	Width of the figure in pixels.
top_left_position	Target position when copying to a screen.

Returns

A new Figure with allocated buffers.

Definition at line 2081 of file Almog_Draw_Library.h.

References ada_init_array, ADL_ASSERT, adl_assert_point_is_valid, ADL_DEFAULT_OFFSET_ZOOM, ADL_FIGURE_PADDING_PRECENTAGE, ADL_MAX_FIGURE_PADDING, Mat2D::cols, Mat2D_uint32::cols, Mat2D::elements, Figure::inv_z_buffer_mat, mat2D_alloc(), mat2D_alloc_uint32(), Figure::max_x, Figure::max_x_pixel, Figure::max_y, Figure::max_y_pixel, Figure::min_x, Figure::min_x_pixel, Figure::min_y, Figure::min_y_pixel, Figure::offset_zoom_param, Figure::pixels_mat, Mat2D::rows, Mat2D_uint32::rows, Figure::src_curve_array, and Figure::top_left_position.

Referenced by setup().

4.1.3.11 adl_figure_copy_to_screen()

```
void adl_figure_copy_to_screen (
            Mat2D_uint32 screen_mat,
            Figure figure )
```

Blit a Figure's pixels onto a destination screen buffer.

Performs per-pixel blending using adl_point_draw and the identity transform. The figure's top_left_position is used as the destination offset.

Parameters

screen_mat	Destination ARGB pixel buffer.
figure	Source figure to copy from.

Definition at line 2124 of file Almog_Draw_Library.h.

References adl_point_draw(), Mat2D_uint32::cols, MAT2D_AT_UINT32, Figure::pixels_mat, Mat2D_uint32::rows, Figure::top_left_position, Point::x, and Point::y.

Referenced by render().

4.1.3.12 adl_grid_draw()

```
void adl_grid_draw (
            Mat2D_uint32 screen_mat,
            Grid grid,
            uint32_t color,
            Offset_zoom_param offset_zoom_param )
```

Draw a previously created Grid as line segments.

Parameters

screen_mat	Destination ARGB pixel buffer.
grid	Grid to draw (curves are 2-point polylines).
color	Line color (0xAARRGGBB).
offset_zoom_param	Pan/zoom transform. Use ADL_DEFAULT_OFFSET_ZOOM for identity.

Definition at line 2791 of file Almog_Draw_Library.h.

References adl_lines_draw(), Grid::curves, Curve::elements, Curve_ada::elements, Curve::length, and Curve_ada::length.

4.1.3.13 adl_interpolate_ARGBcolor_on_okLch()

```
void adl_interpolate_ARGBcolor_on_okLch (
            uint32_t color1,
            uint32_t color2,
            float t,
            float num_of_rotations,
            uint32_t * color_out )
```

Interpolate between two ARGB colors in OkLch space.

Lightness and chroma are interpolated linearly. Hue is interpolated in degrees after adding 360∗num_of_rotations to the second hue, allowing control over the winding direction.

Parameters

color1	Start color (0xAARRGGBB).
color2	End color (0xAARRGGBB).
t	Interpolation factor in [0,1].
num_of_rotations	Number of hue turns to add to color2 (can be fractional/negative).
color_out	[out] Interpolated ARGB color (A=255).

Definition at line 2053 of file Almog_Draw_Library.h.

References adl_linear_sRGB_to_okLch(), and adl_okLch_to_linear_sRGB().

Referenced by adl_2Dscalar_interp_on_figure().

4.1.3.14 adl_line_draw()

```
void adl_line_draw (
            Mat2D_uint32 screen_mat,
            const float x1_input,
            const float y1_input,
            const float x2_input,
            const float y2_input,
            uint32_t color,
            Offset_zoom_param offset_zoom_param )
```

Draw an anti-aliased-like line by vertical spans (integer grid).

The line is rasterized with a simple integer-span approach. Pan/zoom is applied about the screen center prior to rasterization.

Parameters

screen_mat	Destination ARGB pixel buffer.
x1_input	Line start X (before pan/zoom).
y1_input	Line start Y (before pan/zoom).
x2_input	Line end X (before pan/zoom).
y2_input	Line end Y (before pan/zoom).
color	Line color (0xAARRGGBB).
offset_zoom_param	Pan/zoom transform. Use ADL_DEFAULT_OFFSET_ZOOM for identity.

Definition at line 383 of file Almog_Draw_Library.h.

References ADL_ASSERT, ADL_MAX_POINT_VAL, adl_point_draw(), Mat2D_uint32::cols, Offset_zoom_param::offset_x, Offset_zoom_param::offset_y, Mat2D_uint32::rows, and Offset_zoom_param::zoom_multiplier.

Referenced by adl_arrow_draw(), adl_character_draw(), adl_curves_plot_on_figure(), adl_lines_draw(), adl_lines_loop_draw(), adl_rectangle_draw_min_max(), adl_rectangle_fill_min_max(), and adl_tri_draw().

4.1.3.15 adl_linear_map()

```
float adl_linear_map (
            float s,
            float min_in,
            float max_in,
            float min_out,
            float max_out )
```

Affine map from one scalar range to another (no clamping).

Parameters

s	Input value.
min_in	Input range minimum.
max_in	Input range maximum.
min_out	Output range minimum.
max_out	Output range maximum.

Returns

Mapped value in the output range (may exceed if s is out-of-range).

Definition at line 1865 of file Almog_Draw_Library.h.

Referenced by adl_2Dscalar_interp_on_figure(), adl_curves_plot_on_figure(), and render().

4.1.3.16 adl_linear_sRGB_to_okLab()

```
void adl_linear_sRGB_to_okLab (
            uint32_t hex_ARGB,
            float * L,
            float * a,
            float * b )
```

Convert a linear sRGB color (ARGB) to Oklab components.

Oklab components are returned in ranges: L in [0,1], a in [-0.5,0.5], b in [-0.5,0.5] (typical). Input is assumed to be linear sRGB.

Parameters

hex_ARGB	Input color (0xAARRGGBB). Alpha is ignored.
L	[out] Perceptual lightness.
a	[out] First opponent axis.
b	[out] Second opponent axis.

Definition at line 1945 of file Almog_Draw_Library.h.

References HexARGB_RGB_VAR.

Referenced by adl_linear_sRGB_to_okLch().

4.1.3.17 adl_linear_sRGB_to_okLch()

```
void adl_linear_sRGB_to_okLch (
            uint32_t hex_ARGB,
```

```
            float * L,
            float * c,
            float * h_deg )
```

Convert a linear sRGB color (ARGB) to OkLch components.

Parameters

hex_ARGB	Input color (0xAARRGGBB). Alpha is ignored.
L	[out] Lightness in [0,1].
c	[out] Chroma (non-negative).
h_deg	[out] Hue angle in degrees [-180,180] from atan2.

Definition at line 2012 of file Almog_Draw_Library.h.

References adl_linear_sRGB_to_okLab(), and PI.

Referenced by adl_interpolate_ARGBcolor_on_okLch().

4.1.3.18 adl_lines_draw()

```
void adl_lines_draw (
            const Mat2D_uint32 screen_mat,
            const Point * points,
            const size_t len,
            const uint32_t color,
            Offset_zoom_param offset_zoom_param )
```

Draw a polyline connecting an array of points.

Draws segments between consecutive points: p[0]-p[1]-...-p[len-1].

Parameters

screen_mat	Destination ARGB pixel buffer.
points	Array of points in pixel space (before pan/zoom).
len	Number of points in the array (>= 1).
color	Line color (0xAARRGGBB).
offset_zoom_param	Pan/zoom transform. Use ADL_DEFAULT_OFFSET_ZOOM for identity.

Definition at line 470 of file Almog_Draw_Library.h.

References adl_line_draw(), and points.

Referenced by adl_grid_draw().

4.1.3.19 adl_lines_loop_draw()

```
void adl_lines_loop_draw (
            const Mat2D_uint32 screen_mat,
            const Point * points,
            const size_t len,
            const uint32_t color,
            Offset_zoom_param offset_zoom_param )
```

Draw a closed polyline (loop).

Same as adl_lines_draw, plus an extra segment from the last point back to the first point.

Parameters

screen_mat	Destination ARGB pixel buffer.
points	Array of points in pixel space (before pan/zoom).
len	Number of points in the array (>= 1).
color	Line color (0xAARRGGBB).
offset_zoom_param	Pan/zoom transform. Use ADL_DEFAULT_OFFSET_ZOOM for identity.

Definition at line 490 of file Almog_Draw_Library.h.

References adl_line_draw(), and points.

Referenced by adl_quad_draw().

4.1.3.20 adl_max_min_values_draw_on_figure()

```
void adl_max_min_values_draw_on_figure (
            Figure figure )
```

Draw min/max numeric labels for the current data range.

Renders textual min/max values for both axes inside the figure area. Assumes figure.min_x/max_x/min_y/max_y have been populated.

Parameters

figure	Figure whose labels are drawn into its own pixel buffer.

Definition at line 2170 of file Almog_Draw_Library.h.

References ADL_FIGURE_AXIS_COLOR, ADL_MAX_CHARACTER_OFFSET, ADL_MIN_CHARACTER_OFFSET, adl_sentence_draw(), Figure::max_x, Figure::max_x_pixel, Figure::max_y, Figure::max_y_pixel, Figure::min_x, Figure::min_x_pixel, Figure::min_y, Figure::min_y_pixel, Figure::offset_zoom_param, Figure::pixels_mat, Mat2D_uint32::rows, Figure::x_axis_head_size, and Figure::y_axis_head_size.

Referenced by adl_2Dscalar_interp_on_figure(), and adl_curves_plot_on_figure().

4.1.3.21 adl_okLab_to_linear_sRGB()

```
void adl_okLab_to_linear_sRGB (
            float L,
            float a,
            float b,
            uint32_t * hex_ARGB )
```

Convert Oklab components to a linear sRGB ARGB color.

Output RGB components are clamped to [0,255], alpha is set to 255.

Parameters

L	Oklab lightness.
a	Oklab a component.
b	Oklab b component.
hex_ARGB	[out] Output color (0xAARRGGBB, A=255).

Definition at line 1980 of file Almog_Draw_Library.h.

References RGBA_hexARGB.

Referenced by adl_okLch_to_linear_sRGB().

4.1.3.22 adl_okLch_to_linear_sRGB()

```
void adl_okLch_to_linear_sRGB (
            float L,
            float c,
            float h_deg,
            uint32_t * hex_ARGB )
```

Convert OkLch components to a linear sRGB ARGB color.

Hue is wrapped to [0,360). Output RGB is clamped to [0,255], alpha=255.

Parameters

L	Lightness.
c	Chroma.
h_deg	Hue angle in degrees.
hex_ARGB	[out] Output color (0xAARRGGBB, A=255).

Definition at line 2031 of file Almog_Draw_Library.h.

References adl_okLab_to_linear_sRGB(), and PI.

Referenced by adl_interpolate_ARGBcolor_on_okLch().

4.1.3.23 adl_point_draw()

```
void adl_point_draw (
            Mat2D_uint32 screen_mat,
            int x,
            int y,
            uint32_t color,
            Offset_zoom_param offset_zoom_param )
```

Draw a single pixel with alpha blending.

Applies the pan/zoom transform and writes the pixel if it falls inside the destination bounds. The source color is blended over the existing pixel using the source alpha; the stored alpha is set to 255.

Parameters

screen_mat	Destination ARGB pixel buffer.
x	X coordinate in pixels (before pan/zoom).
y	Y coordinate in pixels (before pan/zoom).
color	Source color (0xAARRGGBB).
offset_zoom_param	Pan/zoom transform. Use ADL_DEFAULT_OFFSET_ZOOM for identity.

Definition at line 350 of file Almog_Draw_Library.h.

References Mat2D_uint32::cols, HexARGB_RGBA_VAR, MAT2D_AT_UINT32, Offset_zoom_param::offset_x, Offset_zoom_param::offset_y, RGBA_hexARGB, Mat2D_uint32::rows, and Offset_zoom_param::zoom_multiplier.

Referenced by adl_circle_draw(), adl_circle_fill(), adl_figure_copy_to_screen(), adl_line_draw(), adl_quad_fill(), adl_quad_fill_interpolate_color_mean_value(), adl_quad_fill_interpolate_normal_mean_value(), adl_tri_fill_Pinedas_rasterizer(), adl_tri_fill_Pinedas_rasterizer_interpolate_color(), and adl_tri_fill_Pinedas_rasterizer_interpolate_normal().

4.1.3.24 adl_quad2tris()

```
void adl_quad2tris (
            Quad quad,
            Tri * tri1,
            Tri * tri2,
            char split_line[] )
```

Split a quad into two triangles along a chosen diagonal.

The split is controlled by split_line:

- "02" splits along diagonal from vertex 0 to vertex 2.
- "13" splits along diagonal from vertex 1 to vertex 3.

The function copies positions, per-vertex colors, light_intensity, and the to_draw flag into the output triangles.

Parameters

quad	Input quad.
tri1	[out] First output triangle.
tri2	[out] Second output triangle.
split_line	Null-terminated code: "02" or "13".

Definition at line 1885 of file Almog_Draw_Library.h.

References Tri::colors, Quad::colors, Tri::light_intensity, Quad::light_intensity, Tri::points, Quad::points, Tri::to_draw, and Quad::to_draw.

4.1.3.25 adl_quad_draw()

```
void adl_quad_draw (
            Mat2D_uint32 screen_mat,
            Mat2D inv_z_buffer,
            Quad quad,
            uint32_t color,
            Offset_zoom_param offset_zoom_param )
```

Draw the outline of a quad (four points, looped).

Depth buffer is not used in this outline variant.

Parameters

screen_mat	Destination ARGB pixel buffer.
inv_z_buffer	Unused for outline; safe to pass a dummy Mat2D.
quad	Quad to draw in pixel space (before transform).
color	Stroke color (0xAARRGGBB).
offset_zoom_param	Pan/zoom transform. Use ADL_DEFAULT_OFFSET_ZOOM for identity.

Definition at line 1010 of file Almog_Draw_Library.h.

References adl_lines_loop_draw(), and Quad::points.

Referenced by adl_quad_mesh_draw(), and render().

4.1.3.26 adl_quad_fill()

```
void adl_quad_fill (
            Mat2D_uint32 screen_mat,
            Mat2D inv_z_buffer,
            Quad quad,
```

```
            uint32_t color,
            Offset_zoom_param offset_zoom_param )
```

Fill a quad using mean-value (Barycentric) coordinates and flat base color.

Performs a depth test against inv_z_buffer and modulates the base color with the average light_intensity of the quad's vertices.

Parameters

screen_mat	Destination ARGB pixel buffer.
inv_z_buffer	Inverse-Z buffer (larger is closer).
quad	Quad in pixel space; points carry z and w for depth.
color	Base color (0xAARRGGBB).
offset_zoom_param	Pan/zoom transform. Use ADL_DEFAULT_OFFSET_ZOOM for identity.

Definition at line 1028 of file Almog_Draw_Library.h.

References adl_point_draw(), Mat2D_uint32::cols, edge_cross_point, HexARGB_RGBA_VAR, Quad::light_intensity, MAT2D_AT, Quad::points, RGBA_hexARGB, Mat2D_uint32::rows, Point::w, Point::x, Point::y, and Point::z.

Referenced by adl_quad_mesh_fill().

4.1.3.27 adl_quad_fill_interpolate_color_mean_value()

```
void adl_quad_fill_interpolate_color_mean_value (
            Mat2D_uint32 screen_mat,
            Mat2D inv_z_buffer,
            Quad quad,
            Offset_zoom_param offset_zoom_param )
```

Fill a quad with per-vertex colors (mean value coords).

Interpolates ARGB vertex colors using mean-value coordinates, optionally modulated by the average light_intensity. Depth-tested.

Parameters

screen_mat	Destination ARGB pixel buffer.
inv_z_buffer	Inverse-Z buffer (larger is closer).
quad	Quad in pixel space with quad.colors[] set.
offset_zoom_param	Pan/zoom transform. Use ADL_DEFAULT_OFFSET_ZOOM for identity.

Definition at line 1216 of file Almog_Draw_Library.h.

References adl_point_draw(), adl_tan_half_angle(), Quad::colors, Mat2D_uint32::cols, edge_cross_point, HexARGB_RGBA_VAR, Quad::light_intensity, MAT2D_AT, Quad::points, RGBA_hexARGB, Mat2D_uint32::rows, Point::w, Point::x, Point::y, and Point::z.

Referenced by adl_2Dscalar_interp_on_figure(), adl_quad_mesh_fill_interpolate_color(), and render().

4.1.3.28 adl_quad_fill_interpolate_normal_mean_value()

```
void adl_quad_fill_interpolate_normal_mean_value (
            Mat2D_uint32 screen_mat,
            Mat2D inv_z_buffer,
            Quad quad,
            uint32_t color,
            Offset_zoom_param offset_zoom_param )
```

Fill a quad with per-pixel light interpolation (mean value coords).

Interpolates light_intensity across the quad using mean-value coordinates and modulates a uniform base color. Depth-tested.

Parameters

screen_mat	Destination ARGB pixel buffer.
inv_z_buffer	Inverse-Z buffer (larger is closer).
quad	Quad in pixel space; points carry z and w for depth.
color	Base color (0xAARRGGBB).
offset_zoom_param	Pan/zoom transform. Use ADL_DEFAULT_OFFSET_ZOOM for identity.

Definition at line 1122 of file Almog_Draw_Library.h.

References adl_point_draw(), adl_tan_half_angle(), Mat2D_uint32::cols, edge_cross_point, HexARGB_RGBA_VAR, Quad::light_intensity, MAT2D_AT, Quad::points, RGBA_hexARGB, Mat2D_uint32::rows, Point::w, Point::x, Point::y, and Point::z.

Referenced by adl_quad_mesh_fill_interpolate_normal().

4.1.3.29 adl_quad_mesh_draw()

```
void adl_quad_mesh_draw (
            Mat2D_uint32 screen_mat,
            Mat2D inv_z_buffer_mat,
            Quad_mesh mesh,
            uint32_t color,
            Offset_zoom_param offset_zoom_param )
```

Draw outlines for all quads in a mesh.

Skips elements with to_draw == false. Depth buffer is not used.

Parameters

screen_mat	Destination ARGB pixel buffer.
inv_z_buffer_mat	Unused for outline; safe to pass a dummy Mat2D.
mesh	Quad mesh (array + length).
color	Stroke color (0xAARRGGBB).
offset_zoom_param	Pan/zoom transform. Use ADL_DEFAULT_OFFSET_ZOOM for identity.

Definition at line 1320 of file Almog_Draw_Library.h.

References adl_assert_quad_is_valid, adl_quad_draw(), Quad_mesh::elements, Quad_mesh::length, and Quad::to_draw.

4.1.3.30 adl_quad_mesh_fill()

```
void adl_quad_mesh_fill (
            Mat2D_uint32 screen_mat,
            Mat2D inv_z_buffer_mat,
            Quad_mesh mesh,
            uint32_t color,
            Offset_zoom_param offset_zoom_param )
```

Fill all quads in a mesh with a uniform base color.

Applies per-quad average light_intensity. Depth-tested.

Parameters

screen_mat	Destination ARGB pixel buffer.
inv_z_buffer_mat	Inverse-Z buffer (larger is closer).
mesh	Quad mesh (array + length).
color	Base color (0xAARRGGBB).
offset_zoom_param	Pan/zoom transform. Use ADL_DEFAULT_OFFSET_ZOOM for identity.

Definition at line 1344 of file Almog_Draw_Library.h.

References adl_assert_quad_is_valid, adl_quad_fill(), Quad_mesh::elements, Quad_mesh::length, and Quad::to_draw.

4.1.3.31 adl_quad_mesh_fill_interpolate_color()

```
void adl_quad_mesh_fill_interpolate_color (
            Mat2D_uint32 screen_mat,
            Mat2D inv_z_buffer_mat,
            Quad_mesh mesh,
            Offset_zoom_param offset_zoom_param )
```

Fill all quads in a mesh using per-vertex colors.

Interpolates quad.colors[] across each quad with mean-value coordinates. Depth-tested.

Parameters

screen_mat	Destination ARGB pixel buffer.
inv_z_buffer_mat	Inverse-Z buffer (larger is closer).
mesh	Quad mesh (array + length).
offset_zoom_param	Pan/zoom transform. Use ADL_DEFAULT_OFFSET_ZOOM for identity.

Definition at line 1401 of file Almog_Draw_Library.h.

References adl_assert_quad_is_valid, adl_quad_fill_interpolate_color_mean_value(), Quad_mesh::elements, Quad_mesh::length, and Quad::to_draw.

4.1.3.32 adl_quad_mesh_fill_interpolate_normal()

```
void adl_quad_mesh_fill_interpolate_normal (
            Mat2D_uint32 screen_mat,
            Mat2D inv_z_buffer_mat,
            Quad_mesh mesh,
            uint32_t color,
            Offset_zoom_param offset_zoom_param )
```

Fill all quads in a mesh using interpolated lighting.

Interpolates light_intensity across quads and modulates a uniform base color. Depth-tested.

Parameters

screen_mat	Destination ARGB pixel buffer.
inv_z_buffer_mat	Inverse-Z buffer (larger is closer).
mesh	Quad mesh (array + length).
color	Base color (0xAARRGGBB).
offset_zoom_param	Pan/zoom transform. Use ADL_DEFAULT_OFFSET_ZOOM for identity.

Definition at line 1371 of file Almog_Draw_Library.h.

References adl_assert_quad_is_valid, adl_quad_fill_interpolate_normal_mean_value(), Quad_mesh::elements, HexARGB_RGBA_VAR, Quad_mesh::length, and Quad::to_draw.

4.1.3.33 adl_rectangle_draw_min_max()

```
void adl_rectangle_draw_min_max (
            Mat2D_uint32 screen_mat,
            int min_x,
            int max_x,
            int min_y,
            int max_y,
            uint32_t color,
            Offset_zoom_param offset_zoom_param )
```

Draw a rectangle outline defined by min/max corners (inclusive).

Parameters

screen_mat	Destination ARGB pixel buffer.
min_x	Minimum X (before pan/zoom).

Parameters

max_x	Maximum X (before pan/zoom).
min_y	Minimum Y (before pan/zoom).
max_y	Maximum Y (before pan/zoom).
color	Stroke color (0xAARRGGBB).
offset_zoom_param	Pan/zoom transform. Use ADL_DEFAULT_OFFSET_ZOOM for identity.

Definition at line 973 of file Almog_Draw_Library.h.

References adl_line_draw().

Referenced by adl_character_draw().

4.1.3.34 adl_rectangle_fill_min_max()

```
void adl_rectangle_fill_min_max (
            Mat2D_uint32 screen_mat,
            int min_x,
            int max_x,
            int min_y,
            int max_y,
            uint32_t color,
            Offset_zoom_param offset_zoom_param )
```

Fill a rectangle defined by min/max corners (inclusive).

Parameters

screen_mat	Destination ARGB pixel buffer.
min_x	Minimum X (before pan/zoom).
max_x	Maximum X (before pan/zoom).
min_y	Minimum Y (before pan/zoom).
max_y	Maximum Y (before pan/zoom).
color	Fill color (0xAARRGGBB).
offset_zoom_param	Pan/zoom transform. Use ADL_DEFAULT_OFFSET_ZOOM for identity.

Definition at line 992 of file Almog_Draw_Library.h.

References adl_line_draw().

Referenced by adl_character_draw().

4.1.3.35 adl_sentence_draw()

```
void adl_sentence_draw (
            Mat2D_uint32 screen_mat,
```

```
            const char sentence[],
            size_t len,
            const int x_top_left,
            const int y_top_left,
            const int hight_pixel,
            const uint32_t color,
            Offset_zoom_param offset_zoom_param )
```

Draw a horizontal sentence using vector glyphs.

Characters are laid out left-to-right with a spacing derived from the character height. All characters share the same height.

Parameters

screen_mat	Destination ARGB pixel buffer.
sentence	ASCII string buffer.
len	Number of characters to draw from sentence.
x_top_left	X of top-left of the first character (before transform).
y_top_left	Y of top-left of the first character (before transform).
hight_pixel	Character height in pixels (spelled as in API).
color	Stroke color (0xAARRGGBB).
offset_zoom_param	Pan/zoom transform. Use ADL_DEFAULT_OFFSET_ZOOM for identity.

Definition at line 949 of file Almog_Draw_Library.h.

References adl_character_draw(), ADL_MAX_CHARACTER_OFFSET, and ADL_MIN_CHARACTER_OFFSET.

Referenced by adl_max_min_values_draw_on_figure().

4.1.3.36 adl_tan_half_angle()

```
float adl_tan_half_angle (
            Point vi,
            Point vj,
            Point p,
            float li,
            float lj )
```

Compute tan(alpha/2) for the angle at point p between segments p->vi and p->vj.

Uses the identity tan(alpha/2) = |a×b| / (|a||b| + a·b), where a = vi - p and b = vj - p. The lengths li = |a| and lj = |b| are passed in to avoid recomputation.

Parameters

vi	Vertex i.
vj	Vertex j.
p	Pivot point.
li	Precomputed |vi - p|.
lj	Precomputed |vj - p|.

Returns

tan(alpha/2) (non-negative).

Definition at line 1845 of file Almog_Draw_Library.h.

References Point::x, and Point::y.

Referenced by adl_quad_fill_interpolate_color_mean_value(), and adl_quad_fill_interpolate_normal_mean_value().

4.1.3.37 adl_tri_draw()

```
void adl_tri_draw (
            Mat2D_uint32 screen_mat,
            Tri tri,
            uint32_t color,
            Offset_zoom_param offset_zoom_param )
```

Draw the outline of a triangle.

Parameters

screen_mat	Destination ARGB pixel buffer.
tri	Triangle in pixel space (before transform).
color	Stroke color (0xAARRGGBB).
offset_zoom_param	Pan/zoom transform. Use ADL_DEFAULT_OFFSET_ZOOM for identity.

Definition at line 1469 of file Almog_Draw_Library.h.

References adl_line_draw(), Tri::points, tri, Point::x, and Point::y.

Referenced by adl_tri_mesh_draw(), and render().

4.1.3.38 adl_tri_fill_Pinedas_rasterizer()

```
void adl_tri_fill_Pinedas_rasterizer (
            Mat2D_uint32 screen_mat,
            Mat2D inv_z_buffer,
            Tri tri,
            uint32_t color,
            Offset_zoom_param offset_zoom_param )
```

Fill a triangle using Pineda's rasterizer with flat base color.

Uses the top-left fill convention and performs a depth test using inverse-Z computed from per-vertex z and w.

Parameters

screen_mat	Destination ARGB pixel buffer.
inv_z_buffer	Inverse-Z buffer (larger is closer).
tri	Triangle in pixel space; points carry z and w for depth.
color	Base color (0xAARRGGBB).
offset_zoom_param	Pan/zoom transform. Use ADL_DEFAULT_OFFSET_ZOOM for identity.

Definition at line 1492 of file Almog_Draw_Library.h.

References adl_point_draw(), Mat2D_uint32::cols, edge_cross_point, HexARGB_RGBA_VAR, is_top_left, Tri::light_intensity, MAT2D_AT, MATRIX2D_ASSERT, Tri::points, RGBA_hexARGB, Mat2D_uint32::rows, tri, Point::w, Point::x, Point::y, and Point::z.

Referenced by adl_tri_mesh_fill_Pinedas_rasterizer().

4.1.3.39 adl_tri_fill_Pinedas_rasterizer_interpolate_color()

```
void adl_tri_fill_Pinedas_rasterizer_interpolate_color (
            Mat2D_uint32 screen_mat,
            Mat2D inv_z_buffer,
            Tri tri,
            Offset_zoom_param offset_zoom_param )
```

Fill a triangle using Pineda's rasterizer with per-vertex colors.

Interpolates tri.colors[] and optionally modulates by average light_intensity. Depth-tested.

Parameters

screen_mat	Destination ARGB pixel buffer.
inv_z_buffer	Inverse-Z buffer (larger is closer).
tri	Triangle in pixel space with colors set.
offset_zoom_param	Pan/zoom transform. Use ADL_DEFAULT_OFFSET_ZOOM for identity.

Definition at line 1573 of file Almog_Draw_Library.h.

References adl_point_draw(), Tri::colors, Mat2D_uint32::cols, edge_cross_point, HexARGB_RGBA_VAR, is_top_left, Tri::light_intensity, MAT2D_AT, MATRIX2D_ASSERT, Tri::points, RGBA_hexARGB, Mat2D_uint32::rows, tri, Point::w, Point::x, Point::y, and Point::z.

Referenced by adl_tri_mesh_fill_Pinedas_rasterizer_interpolate_color(), and render().

4.1.3.40 adl_tri_fill_Pinedas_rasterizer_interpolate_normal()

```
void adl_tri_fill_Pinedas_rasterizer_interpolate_normal (
            Mat2D_uint32 screen_mat,
```

```
            Mat2D inv_z_buffer,
            Tri tri,
            uint32_t color,
            Offset_zoom_param offset_zoom_param )
```

Fill a triangle with interpolated lighting over a uniform color.

Interpolates light_intensity across the triangle and modulates a uniform base color. Depth-tested.

Parameters

screen_mat	Destination ARGB pixel buffer.
inv_z_buffer	Inverse-Z buffer (larger is closer).
tri	Triangle in pixel space; points carry z and w for depth.
color	Base color (0xAARRGGBB).
offset_zoom_param	Pan/zoom transform. Use ADL_DEFAULT_OFFSET_ZOOM for identity.

Definition at line 1664 of file Almog_Draw_Library.h.

References adl_point_draw(), Mat2D_uint32::cols, edge_cross_point, HexARGB_RGBA_VAR, is_top_left, Tri::light_intensity, MAT2D_AT, MATRIX2D_ASSERT, Tri::points, RGBA_hexARGB, Mat2D_uint32::rows, tri, Point::w, Point::x, Point::y, and Point::z.

Referenced by adl_tri_mesh_fill_Pinedas_rasterizer_interpolate_normal().

4.1.3.41 adl_tri_mesh_draw()

```
void adl_tri_mesh_draw (
            Mat2D_uint32 screen_mat,
            Tri_mesh mesh,
            uint32_t color,
            Offset_zoom_param offset_zoom_param )
```

Draw outlines for all triangles in a mesh.

Skips elements with to_draw == false.

Parameters

screen_mat	Destination ARGB pixel buffer.
mesh	Triangle mesh (array + length).
color	Stroke color (0xAARRGGBB).
offset_zoom_param	Pan/zoom transform. Use ADL_DEFAULT_OFFSET_ZOOM for identity.

Definition at line 1746 of file Almog_Draw_Library.h.

References adl_tri_draw(), Tri_mesh::elements, Tri_mesh::length, Tri::to_draw, and tri.

4.1.3.42 adl_tri_mesh_fill_Pinedas_rasterizer()

```
void adl_tri_mesh_fill_Pinedas_rasterizer (
            Mat2D_uint32 screen_mat,
            Mat2D inv_z_buffer_mat,
            Tri_mesh mesh,
            uint32_t color,
            Offset_zoom_param offset_zoom_param )
```

Fill all triangles in a mesh with a uniform base color.

Applies average light_intensity per triangle. Depth-tested.

Parameters

screen_mat	Destination ARGB pixel buffer.
inv_z_buffer_mat	Inverse-Z buffer (larger is closer).
mesh	Triangle mesh (array + length).
color	Base color (0xAARRGGBB).
offset_zoom_param	Pan/zoom transform. Use ADL_DEFAULT_OFFSET_ZOOM for identity.

Definition at line 1768 of file Almog_Draw_Library.h.

References adl_assert_tri_is_valid, adl_tri_fill_Pinedas_rasterizer(), Tri_mesh::elements, Tri_mesh::length, Tri::to_draw, and tri.

4.1.3.43 adl_tri_mesh_fill_Pinedas_rasterizer_interpolate_color()

```
void adl_tri_mesh_fill_Pinedas_rasterizer_interpolate_color (
            Mat2D_uint32 screen_mat,
            Mat2D inv_z_buffer_mat,
            Tri_mesh mesh,
            Offset_zoom_param offset_zoom_param )
```

Fill all triangles in a mesh with a uniform base color.

Applies average light_intensity per triangle. Depth-tested.

Parameters

screen_mat	Destination ARGB pixel buffer.
inv_z_buffer_mat	Inverse-Z buffer (larger is closer).
mesh	Triangle mesh (array + length).
color	Base color (0xAARRGGBB).
offset_zoom_param	Pan/zoom transform. Use ADL_DEFAULT_OFFSET_ZOOM for identity.

Definition at line 1792 of file Almog_Draw_Library.h.

References adl_assert_tri_is_valid, adl_tri_fill_Pinedas_rasterizer_interpolate_color(), Tri_mesh::elements, Tri_mesh::length, Tri::to_draw, and tri.

4.1.3.44 adl_tri_mesh_fill_Pinedas_rasterizer_interpolate_normal()

```
void adl_tri_mesh_fill_Pinedas_rasterizer_interpolate_normal (
            Mat2D_uint32 screen_mat,
            Mat2D inv_z_buffer_mat,
            Tri_mesh mesh,
            uint32_t color,
            Offset_zoom_param offset_zoom_param )
```

Fill all triangles in a mesh with interpolated lighting.

Interpolates light_intensity across each triangle and modulates a uniform base color. Depth-tested.

Parameters

screen_mat	Destination ARGB pixel buffer.
inv_z_buffer_mat	Inverse-Z buffer (larger is closer).
mesh	Triangle mesh (array + length).
color	Base color (0xAARRGGBB).
offset_zoom_param	Pan/zoom transform. Use ADL_DEFAULT_OFFSET_ZOOM for identity.

Definition at line 1817 of file Almog_Draw_Library.h.

References adl_assert_tri_is_valid, adl_tri_fill_Pinedas_rasterizer_interpolate_normal(), Tri_mesh::elements, Tri_mesh::length, Tri::to_draw, and tri.

4.2 Almog_Draw_Library.h

```
00001
00034 #ifndef ALMOG_DRAW_LIBRARY_H_
00035 #define ALMOG_DRAW_LIBRARY_H_
00036
00037 #include <math.h>
00038 #include <stdint.h>
00039 #include <limits.h>
00040 #include <string.h>
00041 #include <float.h>
00042
00043 #include "./Matrix2D.h"
00044 #include "./Almog_Dynamic_Array.h"
00045
00053 #ifndef ADL_ASSERT
00054 #include <assert.h>
00055 #define ADL_ASSERT assert
00056 #endif
00057
00065 typedef struct {
00066     float zoom_multiplier;
00067     float offset_x;
00068     float offset_y;
00069     int mouse_x;
00070     int mouse_y;
00071 } Offset_zoom_param;
00072
00073 #ifndef POINT
00074 #define POINT
00081 typedef struct {
00082     float x;
00083     float y;
00084     float z;
00085     float w;
00086 } Point ;
```

```
00087 #endif
00088
00089 #ifndef CURVE
00090 #define CURVE
00094 typedef struct {
00095     uint32_t color;
00096     size_t length;
00097     size_t capacity;
00098     Point *elements;
00099 } Curve;
00100 #endif
00101
00102 #ifndef CURVE_ADA
00103 #define CURVE_ADA
00107 typedef struct {
00108     size_t length;
00109     size_t capacity;
00110     Curve *elements;
00111 } Curve_ada;
00112 #endif
00113
00114 #ifndef TRI
00115 #define TRI
00119 typedef struct {
00120     Point points[3];
00121     Point tex_points[3];
00122     Point normals[3];
00123     uint32_t colors[3];
00124     bool to_draw;
00125     float light_intensity[3];
00126 } Tri;
00127 #endif
00128
00129 #ifndef QUAD
00130 #define QUAD
00134 typedef struct {
00135     Point points[4];
00136     Point normals[4];
00137     uint32_t colors[4];
00138     bool to_draw;
00139     float light_intensity[4];
00140 } Quad;
00141 #endif
00142
00143 #ifndef TRI_MESH
00144 #define TRI_MESH
00148 typedef struct {
00149     size_t length;
00150     size_t capacity;
00151     Tri *elements;
00152 } Tri_mesh; /* Tri ada array */
00153 #endif
00154
00155 #ifndef QUAD_MESH
00156 #define QUAD_MESH
00160 typedef struct {
00161     size_t length;
00162     size_t capacity;
00163     Quad *elements;
00164 } Quad_mesh; /* Quad ada array */
00165 #endif
00166
00174 typedef struct {
00175     int min_x_pixel;
00176     int max_x_pixel;
00177     int min_y_pixel;
00178     int max_y_pixel;
00180     float min_x;
00181     float max_x;
00182     float min_y;
00183     float max_y;
00185     int x_axis_head_size;
00186     int y_axis_head_size;
00188     Offset_zoom_param offset_zoom_param;
00189     Curve_ada src_curve_array;
00190     Point top_left_position;
00192     Mat2D_uint32 pixels_mat;
00193     Mat2D inv_z_buffer_mat;
00195     uint32_t background_color;
00196     bool to_draw_axis;
00197     bool to_draw_max_min_values;
00198 } Figure;
00199
00203 typedef struct {
00204     Curve_ada curves;
00206     float min_el;
00207     float max_el;
```

```
00208     float min_e2;
00209     float max_e2;
00211     int num_samples_e1;
00212     int num_samples_e2;
00213     float de1;
00214     float de2;
00216     char plane[3];
00217 } Grid; /* direction: e1, e2 */
00218
00219
00220 #ifndef HexARGB_RGBA
00221 #define HexARGB_RGBA(x) ((x)»(8*2)&0xFF), ((x)»(8*1)&0xFF), ((x)»(8*0)&0xFF), ((x)»(8*3)&0xFF)
00222 #endif
00223 #ifndef HexARGB_RGB_VAR
00224 #define HexARGB_RGB_VAR(x, r, g, b) r = ((x)»(8*2)&0xFF); g = ((x)»(8*1)&0xFF); b = ((x)»(8*0)&0xFF);
00225 #endif
00226 #ifndef HexARGB_RGBA_VAR
00227 #define HexARGB_RGBA_VAR(x, r, g, b, a) r = ((x)»(8*2)&0xFF); g = ((x)»(8*1)&0xFF); b =
       ((x)»(8*0)&0xFF); a = ((x)»(8*3)&0xFF)
00228 #endif
00229 #ifndef RGB_hexRGB
00230 #define RGB_hexRGB(r, g, b) (int)(0x010000*(int)(r) + 0x000100*(int)(g) + 0x000001*(int)(b))
00231 #endif
00232 #ifndef RGBA_hexARGB
00233 #define RGBA_hexARGB(r, g, b, a) (int)(0x01000000l*(int)(fminf(a, 255)) + 0x010000*(int)(r) +
       0x000100*(int)(g) + 0x000001*(int)(b))
00234 #endif
00235
00236
00237 void    adl_point_draw(Mat2D_uint32 screen_mat, int x, int y, uint32_t color, Offset_zoom_param
       offset_zoom_param);
00238 void    adl_line_draw(Mat2D_uint32 screen_mat, const float x1_input, const float y1_input, const float
       x2_input, const float y2_input, uint32_t color, Offset_zoom_param offset_zoom_param);
00239 void    adl_lines_draw(const Mat2D_uint32 screen_mat, const Point *points, const size_t len, const
       uint32_t color, Offset_zoom_param offset_zoom_param);
00240 void    adl_lines_loop_draw(const Mat2D_uint32 screen_mat, const Point *points, const size_t len,
       const uint32_t color, Offset_zoom_param offset_zoom_param);
00241 void    adl_arrow_draw(Mat2D_uint32 screen_mat, int xs, int ys, int xe, int ye, float head_size, float
       angle_deg, uint32_t color, Offset_zoom_param offset_zoom_param);
00242
00243 void    adl_character_draw(Mat2D_uint32 screen_mat, char c, int width_pixel, int hight_pixel, int
       x_top_left, int y_top_left, uint32_t color, Offset_zoom_param offset_zoom_param);
00244 void    adl_sentence_draw(Mat2D_uint32 screen_mat, const char sentence[], size_t len, const int
       x_top_left, const int y_top_left, const int hight_pixel, const uint32_t color, Offset_zoom_param
       offset_zoom_param);
00245
00246 void    adl_rectangle_draw_min_max(Mat2D_uint32 screen_mat, int min_x, int max_x, int min_y, int
       max_y, uint32_t color, Offset_zoom_param offset_zoom_param);
00247 void    adl_rectangle_fill_min_max(Mat2D_uint32 screen_mat, int min_x, int max_x, int min_y, int
       max_y, uint32_t color, Offset_zoom_param offset_zoom_param);
00248
00249 void    adl_quad_draw(Mat2D_uint32 screen_mat, Mat2D inv_z_buffer, Quad quad, uint32_t color,
       Offset_zoom_param offset_zoom_param);
00250 void    adl_quad_fill(Mat2D_uint32 screen_mat, Mat2D inv_z_buffer, Quad quad, uint32_t color,
       Offset_zoom_param offset_zoom_param);
00251 void    adl_quad_fill_interpolate_normal_mean_value(Mat2D_uint32 screen_mat, Mat2D inv_z_buffer, Quad
       quad, uint32_t color, Offset_zoom_param offset_zoom_param);
00252 void    adl_quad_fill_interpolate_color_mean_value(Mat2D_uint32 screen_mat, Mat2D inv_z_buffer, Quad
       quad, Offset_zoom_param offset_zoom_param);
00253
00254 void    adl_quad_mesh_draw(Mat2D_uint32 screen_mat, Mat2D inv_z_buffer_mat, Quad_mesh mesh, uint32_t
       color, Offset_zoom_param offset_zoom_param);
00255 void    adl_quad_mesh_fill(Mat2D_uint32 screen_mat, Mat2D inv_z_buffer_mat, Quad_mesh mesh, uint32_t
       color, Offset_zoom_param offset_zoom_param);
00256 void    adl_quad_mesh_fill_interpolate_normal(Mat2D_uint32 screen_mat, Mat2D inv_z_buffer_mat,
       Quad_mesh mesh, uint32_t color, Offset_zoom_param offset_zoom_param);
00257 void    adl_quad_mesh_fill_interpolate_color(Mat2D_uint32 screen_mat, Mat2D inv_z_buffer_mat,
       Quad_mesh mesh, Offset_zoom_param offset_zoom_param);
00258
00259 void    adl_circle_draw(Mat2D_uint32 screen_mat, float center_x, float center_y, float r, uint32_t
       color, Offset_zoom_param offset_zoom_param);
00260 void    adl_circle_fill(Mat2D_uint32 screen_mat, float center_x, float center_y, float r, uint32_t
       color, Offset_zoom_param offset_zoom_param);
00261
00262 void    adl_tri_draw(Mat2D_uint32 screen_mat, Tri tri, uint32_t color, Offset_zoom_param
       offset_zoom_param);
00263 void    adl_tri_fill_Pinedas_rasterizer(Mat2D_uint32 screen_mat, Mat2D inv_z_buffer, Tri tri, uint32_t
       color, Offset_zoom_param offset_zoom_param);
00264 void    adl_tri_fill_Pinedas_rasterizer_interpolate_color(Mat2D_uint32 screen_mat, Mat2D inv_z_buffer,
       Tri tri, Offset_zoom_param offset_zoom_param);
00265 void    adl_tri_fill_Pinedas_rasterizer_interpolate_normal(Mat2D_uint32 screen_mat, Mat2D
       inv_z_buffer, Tri tri, uint32_t color, Offset_zoom_param offset_zoom_param);
00266
00267 void    adl_tri_mesh_draw(Mat2D_uint32 screen_mat, Tri_mesh mesh, uint32_t color, Offset_zoom_param
       offset_zoom_param);
00268 void    adl_tri_mesh_fill_Pinedas_rasterizer(Mat2D_uint32 screen_mat, Mat2D inv_z_buffer_mat, Tri_mesh
       mesh, uint32_t color, Offset_zoom_param offset_zoom_param);
```

```
00269 void    adl_tri_mesh_fill_Pinedas_rasterizer_interpolate_color(Mat2D_uint32 screen_mat, Mat2D
       inv_z_buffer_mat, Tri_mesh mesh, Offset_zoom_param offset_zoom_param);
00270 void    adl_tri_mesh_fill_Pinedas_rasterizer_interpolate_normal(Mat2D_uint32 screen_mat, Mat2D
       inv_z_buffer_mat, Tri_mesh mesh, uint32_t color, Offset_zoom_param offset_zoom_param);
00271
00272 float   adl_tan_half_angle(Point vi, Point vj, Point p, float li, float lj);
00273 float   adl_linear_map(float s, float min_in, float max_in, float min_out, float max_out);
00274 void    adl_quad2tris(Quad quad, Tri *tri1, Tri *tri2, char split_line[]);
00275 void    adl_linear_sRGB_to_okLab(uint32_t hex_ARGB, float *L, float *a, float *b);
00276 void    adl_okLab_to_linear_sRGB(float L, float a, float b, uint32_t *hex_ARGB);
00277 void    adl_linear_sRGB_to_okLch(uint32_t hex_ARGB, float *L, float *c, float *h_deg);
00278 void    adl_okLch_to_linear_sRGB(float L, float c, float h_deg, uint32_t *hex_ARGB);
00279 void    adl_interpolate_ARGBcolor_on_okLch(uint32_t color1, uint32_t color2, float t, float
       num_of_rotations, uint32_t *color_out);
00280
00281 Figure  adl_figure_alloc(size_t rows, size_t cols, Point top_left_position);
00282 void    adl_figure_copy_to_screen(Mat2D_uint32 screen_mat, Figure figure);
00283 void    adl_axis_draw_on_figure(Figure *figure);
00284 void    adl_max_min_values_draw_on_figure(Figure figure);
00285 void    adl_curve_add_to_figure(Figure *figure, Point *src_points, size_t src_len, uint32_t color);
00286 void    adl_curves_plot_on_figure(Figure figure);
00287 void    adl_2Dscalar_interp_on_figure(Figure figure, double *x_2Dmat, double *y_2Dmat, double
       *scalar_2Dmat, int ni, int nj, char color_scale[], float num_of_rotations);
00288
00289 Grid    adl_cartesian_grid_create(float min_e1, float max_e1, float min_e2, float max_e2, int
       num_samples_e1, int num_samples_e2, char plane[], float third_direction_position);
00290 void    adl_grid_draw(Mat2D_uint32 screen_mat, Grid grid, uint32_t color, Offset_zoom_param
       offset_zoom_param);
00291
00292 #endif /*ALMOG_RENDER_SHAPES_H_*/
00293
00294 #ifdef ALMOG_DRAW_LIBRARY_IMPLEMENTATION
00295 #undef ALMOG_DRAW_LIBRARY_IMPLEMENTATION
00296
00297 #define RED_hexARGB    0xFFFF0000
00298 #define GREEN_hexARGB  0xFF00FF00
00299 #define BLUE_hexARGB   0xFF0000FF
00300 #define PURPLE_hexARGB 0xFFFF00FF
00301 #define CYAN_hexARGB   0xFF00FFFF
00302 #define YELLOW_hexARGB 0xFFFFFF00
00303
00304 #define edge_cross_point(a1, b, a2, p) (b.x-a1.x)*(p.y-a2.y)-(b.y-a1.y)*(p.x-a2.x)
00305 #define is_top_edge(x, y) (y == 0 && x > 0)
00306 #define is_left_edge(x, y) (y < 0)
00307 #define is_top_left(ps, pe) (is_top_edge(pe.x-ps.x, pe.y-ps.y) || is_left_edge(pe.x-ps.x, pe.y-ps.y))
00308
00309 #define ADL_MAX_POINT_VAL 1e5
00310 #define adl_assert_point_is_valid(p) ADL_ASSERT(isfinite(p.x) && isfinite(p.y) && isfinite(p.z) &&
       isfinite(p.w))
00311 #define adl_assert_tri_is_valid(tri) adl_assert_point_is_valid(tri.points[0]); \
00312         adl_assert_point_is_valid(tri.points[1]);                               \
00313         adl_assert_point_is_valid(tri.points[2])
00314 #define adl_assert_quad_is_valid(quad) adl_assert_point_is_valid(quad.points[0]);   \
00315         adl_assert_point_is_valid(quad.points[1]);                                  \
00316         adl_assert_point_is_valid(quad.points[2]);                                  \
00317         adl_assert_point_is_valid(quad.points[3])
00318
00319 #define ADL_FIGURE_PADDING_PRECENTAGE 20
00320 #define ADL_MAX_FIGURE_PADDING 70
00321 #define ADL_MIN_FIGURE_PADDING 20
00322 #define ADL_MAX_HEAD_SIZE 15
00323 #define ADL_FIGURE_HEAD_ANGLE_DEG 30
00324 #define ADL_FIGURE_AXIS_COLOR 0xff000000
00325
00326 #define ADL_MAX_CHARACTER_OFFSET 10
00327 #define ADL_MIN_CHARACTER_OFFSET 5
00328 #define ADL_MAX_SENTENCE_LEN 256
00329 #define ADL_MAX_ZOOM 1e3
00330
00331 #define ADL_DEFAULT_OFFSET_ZOOM (Offset_zoom_param){1,0,0,0,0}
00332 #define adl_offset_zoom_point(p, window_w, window_h, offset_zoom_param)
                \
00333     (p).x = ((p).x - (window_w)/2 + offset_zoom_param.offset_x) * offset_zoom_param.zoom_multiplier +
       (window_w)/2; \
00334     (p).y = ((p).y - (window_h)/2 + offset_zoom_param.offset_y) * offset_zoom_param.zoom_multiplier +
       (window_h)/2
00335
00350 void adl_point_draw(Mat2D_uint32 screen_mat, int x, int y, uint32_t color, Offset_zoom_param
       offset_zoom_param)
00351 {
00352     float window_w = (float)screen_mat.cols;
00353     float window_h = (float)screen_mat.rows;
00354
00355     x = (x - window_w/2 + offset_zoom_param.offset_x) * offset_zoom_param.zoom_multiplier +
       window_w/2;
00356     y = (y - window_h/2 + offset_zoom_param.offset_y) * offset_zoom_param.zoom_multiplier +
       window_h/2;
```

```
00357
00358     if ((x < (int)screen_mat.cols && y < (int)screen_mat.rows) && (x >= 0 && y >= 0)) { /* point is in
      screen */
00359         uint8_t r_new, g_new, b_new, a_new;
00360         uint8_t r_current, g_current, b_current, a_current;
00361         HexARGB_RGBA_VAR(MAT2D_AT_UINT32(screen_mat, y, x), r_current, g_current, b_current,
      a_current);
00362         HexARGB_RGBA_VAR(color, r_new, g_new, b_new, a_new);
00363         MAT2D_AT_UINT32(screen_mat, y, x) = RGBA_hexARGB(r_current*(1-a_new/255.0f) +
      r_new*a_new/255.0f, g_current*(1-a_new/255.0f) + g_new*a_new/255.0f, b_current*(1-a_new/255.0f) +
      b_new*a_new/255.0f, 255);
00364         (void)a_current;
00365     }
00366 }
00367
00383 void adl_line_draw(Mat2D_uint32 screen_mat, const float x1_input, const float y1_input, const float
      x2_input, const float y2_input, uint32_t color, Offset_zoom_param offset_zoom_param)
00384 {
00385     /* This function is inspired by the Olive.c function developed by 'Tsoding' on his YouTube
      channel. You can fined the video in this link:
      https://youtu.be/LmQKZmQh1ZQ?list=PLpM-Dvs8t0Va-Gb0Dp4d9t8yvNFHaKH6N&t=4683. */
00386
00387     float window_w = (float)screen_mat.cols;
00388     float window_h = (float)screen_mat.rows;
00389
00390     int x1 = (x1_input - window_w/2 + offset_zoom_param.offset_x) * offset_zoom_param.zoom_multiplier
      + window_w/2;
00391     int x2 = (x2_input - window_w/2 + offset_zoom_param.offset_x) * offset_zoom_param.zoom_multiplier
      + window_w/2;
00392     int y1 = (y1_input - window_h/2 + offset_zoom_param.offset_y) * offset_zoom_param.zoom_multiplier
      + window_h/2;
00393     int y2 = (y2_input - window_h/2 + offset_zoom_param.offset_y) * offset_zoom_param.zoom_multiplier
      + window_h/2;
00394
00395     ADL_ASSERT((int)fabsf(fabsf((float)x2) - fabsf((float)x1)) < ADL_MAX_POINT_VAL);
00396     ADL_ASSERT((int)fabsf(fabsf((float)y2) - fabsf((float)y1)) < ADL_MAX_POINT_VAL);
00397
00398     int x = x1;
00399     int y = y1;
00400     int dx, dy;
00401
00402     adl_point_draw(screen_mat, x, y, color, (Offset_zoom_param){1,0,0,0,0});
00403
00404     dx = x2 - x1;
00405     dy = y2 - y1;
00406
00407     ADL_ASSERT(dy > INT_MIN && dy < INT_MAX);
00408     ADL_ASSERT(dx > INT_MIN && dx < INT_MAX);
00409
00410     if (0 == dx && 0 == dy) return;
00411     if (0 == dx) {
00412         while (x != x2 || y != y2) {
00413             if (dy > 0) {
00414                 y++;
00415             }
00416             if (dy < 0) {
00417                 y--;
00418             }
00419             adl_point_draw(screen_mat, x, y, color, (Offset_zoom_param){1,0,0,0,0});
00420         }
00421         return;
00422     }
00423     if (0 == dy) {
00424         while (x != x2 || y != y2) {
00425             if (dx > 0) {
00426                 x++;
00427             }
00428             if (dx < 0) {
00429                 x--;
00430             }
00431             adl_point_draw(screen_mat, x, y, color, (Offset_zoom_param){1,0,0,0,0});
00432         }
00433         return;
00434     }
00435
00436     /* float m = (float)dy / dx */
00437     int b = y1 - dy * x1 / dx;
00438
00439     if (x1 > x2) {
00440         int temp_x = x1;
00441         x1 = x2;
00442         x2 = temp_x;
00443     }
00444     for (x = x1; x < x2; x++) {
00445         int sy1 = dy * x / dx + b;
00446         int sy2 = dy * (x + 1) / dx + b;
00447         if (sy1 > sy2) {
```

```
00448             int temp_y = sy1;
00449             sy1 = sy2;
00450             sy2 = temp_y;
00451         }
00452         for (y = sy1; y <= sy2; y++) {
00453             adl_point_draw(screen_mat, x, y, color, (Offset_zoom_param){1,0,0,0,0});
00454         }
00455     }
00456
00457 }
00458
00470 void adl_lines_draw(const Mat2D_uint32 screen_mat, const Point *points, const size_t len, const
      uint32_t color, Offset_zoom_param offset_zoom_param)
00471 {
00472     if (len == 0) return;
00473     for (size_t i = 0; i < len-1; i++) {
00474         adl_line_draw(screen_mat, points[i].x, points[i].y, points[i+1].x, points[i+1].y, color,
      offset_zoom_param);
00475     }
00476 }
00477
00490 void adl_lines_loop_draw(const Mat2D_uint32 screen_mat, const Point *points, const size_t len, const
      uint32_t color, Offset_zoom_param offset_zoom_param)
00491 {
00492     if (len == 0) return;
00493     for (size_t i = 0; i < len-1; i++) {
00494         adl_line_draw(screen_mat, points[i].x, points[i].y, points[i+1].x, points[i+1].y, color,
      offset_zoom_param);
00495     }
00496     adl_line_draw(screen_mat, points[len-1].x, points[len-1].y, points[0].x, points[0].y, color,
      offset_zoom_param);
00497 }
00498
00499
00518 void adl_arrow_draw(Mat2D_uint32 screen_mat, int xs, int ys, int xe, int ye, float head_size, float
      angle_deg, uint32_t color, Offset_zoom_param offset_zoom_param)
00519 {
00520     Mat2D pe = mat2D_alloc(3, 1);
00521     mat2D_fill(pe, 0);
00522     MAT2D_AT(pe, 0, 0) = xe;
00523     MAT2D_AT(pe, 1, 0) = ye;
00524     Mat2D v1 = mat2D_alloc(3, 1);
00525     mat2D_fill(v1, 0);
00526     Mat2D v2 = mat2D_alloc(3, 1);
00527     mat2D_fill(v2, 0);
00528     Mat2D temp_v = mat2D_alloc(3, 1);
00529     mat2D_fill(temp_v, 0);
00530     Mat2D DCM_p = mat2D_alloc(3, 3);
00531     mat2D_fill(DCM_p, 0);
00532     mat2D_set_rot_mat_z(DCM_p, angle_deg);
00533     Mat2D DCM_m = mat2D_alloc(3, 3);
00534     mat2D_fill(DCM_m, 0);
00535     mat2D_set_rot_mat_z(DCM_m, -angle_deg);
00536
00537     int x_center = xs*head_size + xe*(1-head_size);
00538     int y_center = ys*head_size + ye*(1-head_size);
00539
00540     MAT2D_AT(v1, 0, 0) = x_center;
00541     MAT2D_AT(v1, 1, 0) = y_center;
00542     mat2D_copy(v2, v1);
00543
00544     /* v1 */
00545     mat2D_copy(temp_v, v1);
00546     mat2D_sub(temp_v, pe);
00547     mat2D_fill(v1, 0);
00548     mat2D_dot(v1, DCM_p, temp_v);
00549     mat2D_add(v1, pe);
00550
00551     /* v2 */
00552     mat2D_copy(temp_v, v2);
00553     mat2D_sub(temp_v, pe);
00554     mat2D_fill(v2, 0);
00555     mat2D_dot(v2, DCM_m, temp_v);
00556     mat2D_add(v2, pe);
00557
00558     adl_line_draw(screen_mat, MAT2D_AT(v1, 0, 0), MAT2D_AT(v1, 1, 0), xe, ye, color,
      offset_zoom_param);
00559     adl_line_draw(screen_mat, MAT2D_AT(v2, 0, 0), MAT2D_AT(v2, 1, 0), xe, ye, color,
      offset_zoom_param);
00560     adl_line_draw(screen_mat, xs, ys, xe, ye, color, offset_zoom_param);
00561
00562     mat2D_free(pe);
00563     mat2D_free(v1);
00564     mat2D_free(v2);
00565     mat2D_free(temp_v);
00566     mat2D_free(DCM_p);
00567     mat2D_free(DCM_m);
```

```
00568 }
00569
00586 void adl_character_draw(Mat2D_uint32 screen_mat, char c, int width_pixel, int hight_pixel, int
       x_top_left, int y_top_left, uint32_t color, Offset_zoom_param offset_zoom_param)
00587 {
00588     switch (c)
00589     {
00590     case 'a':
00591     case 'A':
00592         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel, x_top_left+width_pixel/2,
      y_top_left, color, offset_zoom_param);
00593         adl_line_draw(screen_mat, x_top_left+width_pixel/2, y_top_left, x_top_left+width_pixel,
      y_top_left+hight_pixel, color, offset_zoom_param);
00594         adl_line_draw(screen_mat, x_top_left+width_pixel/6, y_top_left+2*hight_pixel/3,
      x_top_left+5*width_pixel/6, y_top_left+2*hight_pixel/3, color, offset_zoom_param);
00595         break;
00596     case 'b':
00597     case 'B':
00598         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left, y_top_left+hight_pixel, color,
      offset_zoom_param);
00599         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left+2*width_pixel/3, y_top_left,
      color, offset_zoom_param);
00600         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left, x_top_left+width_pixel,
      y_top_left+hight_pixel/6, color, offset_zoom_param);
00601         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+hight_pixel/6,
      x_top_left+width_pixel, y_top_left+hight_pixel/3, color, offset_zoom_param);
00602         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+hight_pixel/3,
      x_top_left+2*width_pixel/3, y_top_left+hight_pixel/2, color, offset_zoom_param);
00603
00604         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left+hight_pixel/2, x_top_left,
      y_top_left+hight_pixel/2, color, offset_zoom_param);
00605
00606         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left+hight_pixel/2,
      x_top_left+width_pixel, y_top_left+2*hight_pixel/3, color, offset_zoom_param);
00607         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+2*hight_pixel/3,
      x_top_left+width_pixel, y_top_left+5*hight_pixel/6, color, offset_zoom_param);
00608         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+5*hight_pixel/6,
      x_top_left+2*width_pixel/3, y_top_left+hight_pixel, color, offset_zoom_param);
00609         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left+hight_pixel, x_top_left,
      y_top_left+hight_pixel, color, offset_zoom_param);
00610         break;
00611     case 'c':
00612     case 'C':
00613         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left, x_top_left+width_pixel/3,
      y_top_left, color, offset_zoom_param);
00614         adl_line_draw(screen_mat, x_top_left+width_pixel/3, y_top_left, x_top_left,
      y_top_left+hight_pixel/6, color, offset_zoom_param);
00615         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel/6, x_top_left,
      y_top_left+5*hight_pixel/6, color, offset_zoom_param);
00616         adl_line_draw(screen_mat, x_top_left, y_top_left+5*hight_pixel/6, x_top_left+width_pixel/3,
      y_top_left+hight_pixel, color, offset_zoom_param);
00617         adl_line_draw(screen_mat, x_top_left+width_pixel/3, y_top_left+hight_pixel,
      x_top_left+width_pixel, y_top_left+hight_pixel, color, offset_zoom_param);
00618         break;
00619     case 'd':
00620     case 'D':
00621         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left+2*width_pixel/3, y_top_left,
      color, offset_zoom_param);
00622         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left, x_top_left+width_pixel,
      y_top_left+hight_pixel/6, color, offset_zoom_param);
00623         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+hight_pixel/6,
      x_top_left+width_pixel, y_top_left+5*hight_pixel/6, color, offset_zoom_param);
00624         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+5*hight_pixel/6,
      x_top_left+2*width_pixel/3, y_top_left+hight_pixel, color, offset_zoom_param);
00625         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left+hight_pixel, x_top_left,
      y_top_left+hight_pixel, color, offset_zoom_param);
00626         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel, x_top_left, y_top_left, color,
      offset_zoom_param);
00627         break;
00628     case 'e':
00629     case 'E':
00630         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left, x_top_left, y_top_left, color,
      offset_zoom_param);
00631         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left, y_top_left+hight_pixel, color,
      offset_zoom_param);
00632         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel, x_top_left+width_pixel,
      y_top_left+hight_pixel, color, offset_zoom_param);
00633
00634         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel/2, x_top_left+width_pixel,
      y_top_left+hight_pixel/2, color, offset_zoom_param);
00635         break;
00636     case 'f':
00637     case 'F':
00638         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left, x_top_left, y_top_left, color,
      offset_zoom_param);
00639         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left, y_top_left+hight_pixel, color,
      offset_zoom_param);
```

```
00640
00641         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel/2, x_top_left+width_pixel,
      y_top_left+hight_pixel/2, color, offset_zoom_param);
00642         break;
00643     case 'g':
00644     case 'G':
00645         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+hight_pixel/6,
      x_top_left+2*width_pixel/3, y_top_left, color, offset_zoom_param);
00646         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left, x_top_left+width_pixel/3,
      y_top_left, color, offset_zoom_param);
00647         adl_line_draw(screen_mat, x_top_left+width_pixel/3, y_top_left, x_top_left,
      y_top_left+hight_pixel/6, color, offset_zoom_param);
00648         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel/6, x_top_left,
      y_top_left+5*hight_pixel/6, color, offset_zoom_param);
00649         adl_line_draw(screen_mat, x_top_left, y_top_left+5*hight_pixel/6, x_top_left+width_pixel/3,
      y_top_left+hight_pixel, color, offset_zoom_param);
00650         adl_line_draw(screen_mat, x_top_left+width_pixel/3, y_top_left+hight_pixel,
      x_top_left+2*width_pixel/3, y_top_left+hight_pixel, color, offset_zoom_param);
00651         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left+hight_pixel,
      x_top_left+width_pixel, y_top_left+5*hight_pixel/6, color, offset_zoom_param);
00652         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+5*hight_pixel/6,
      x_top_left+width_pixel, y_top_left+hight_pixel/2, color, offset_zoom_param);
00653         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+hight_pixel/2,
      x_top_left+width_pixel/2, y_top_left+hight_pixel/2, color, offset_zoom_param);
00654         break;
00655     case 'h':
00656     case 'H':
00657         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left, y_top_left+hight_pixel, color,
      offset_zoom_param);
00658         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left, x_top_left+width_pixel,
      y_top_left+hight_pixel, color, offset_zoom_param);
00659         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel/2, x_top_left+width_pixel,
      y_top_left+hight_pixel/2, color, offset_zoom_param);
00660         break;
00661     case 'i':
00662     case 'I':
00663         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left+width_pixel, y_top_left, color,
      offset_zoom_param);
00664         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel, x_top_left+width_pixel,
      y_top_left+hight_pixel, color, offset_zoom_param);
00665         adl_line_draw(screen_mat, x_top_left+width_pixel/2, y_top_left, x_top_left+width_pixel/2,
      y_top_left+hight_pixel, color, offset_zoom_param);
00666         break;
00667     case 'j':
00668     case 'J':
00669         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left+width_pixel, y_top_left, color,
      offset_zoom_param);
00670         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left, x_top_left+2*width_pixel/3,
      y_top_left+5*hight_pixel/6, color, offset_zoom_param);
00671         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left+5*hight_pixel/6,
      x_top_left+width_pixel/2, y_top_left+hight_pixel, color, offset_zoom_param);
00672         adl_line_draw(screen_mat, x_top_left+width_pixel/2, y_top_left+hight_pixel,
      x_top_left+width_pixel/3, y_top_left+hight_pixel, color, offset_zoom_param);
00673         adl_line_draw(screen_mat, x_top_left+width_pixel/3, y_top_left+hight_pixel,
      x_top_left+width_pixel/6, y_top_left+5*hight_pixel/6, color, offset_zoom_param);
00674         break;
00675     case 'k':
00676     case 'K':
00677         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left, y_top_left+hight_pixel, color,
      offset_zoom_param);
00678         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel/2, x_top_left+width_pixel,
      y_top_left+hight_pixel, color, offset_zoom_param);
00679         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel/2, x_top_left+width_pixel,
      y_top_left, color, offset_zoom_param);
00680         break;
00681     case 'l':
00682     case 'L':
00683         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left, y_top_left+hight_pixel, color,
      offset_zoom_param);
00684         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel, x_top_left+width_pixel,
      y_top_left+hight_pixel, color, offset_zoom_param);
00685         break;
00686     case 'm':
00687     case 'M':
00688         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel, x_top_left, y_top_left, color,
      offset_zoom_param);
00689         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left+width_pixel/2,
      y_top_left+hight_pixel, color, offset_zoom_param);
00690         adl_line_draw(screen_mat, x_top_left+width_pixel/2, y_top_left+hight_pixel,
      x_top_left+width_pixel, y_top_left, color, offset_zoom_param);
00691         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left, x_top_left+width_pixel,
      y_top_left+hight_pixel, color, offset_zoom_param);
00692         break;
00693     case 'n':
00694     case 'N':
00695         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel, x_top_left, y_top_left, color,
      offset_zoom_param);
```

```
00696         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left+width_pixel,
      y_top_left+hight_pixel, color, offset_zoom_param);
00697         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+hight_pixel,
      x_top_left+width_pixel, y_top_left, color, offset_zoom_param);
00698         break;
00699     case 'o':
00700     case 'O':
00701         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left, x_top_left+width_pixel/3,
      y_top_left, color, offset_zoom_param);
00702         adl_line_draw(screen_mat, x_top_left+width_pixel/3, y_top_left, x_top_left,
      y_top_left+hight_pixel/6, color, offset_zoom_param);
00703         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel/6, x_top_left,
      y_top_left+5*hight_pixel/6, color, offset_zoom_param);
00704         adl_line_draw(screen_mat, x_top_left, y_top_left+5*hight_pixel/6, x_top_left+width_pixel/3,
      y_top_left+hight_pixel, color, offset_zoom_param);
00705         adl_line_draw(screen_mat, x_top_left+width_pixel/3, y_top_left+hight_pixel,
      x_top_left+2*width_pixel/3, y_top_left+hight_pixel, color, offset_zoom_param);
00706         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left+hight_pixel,
      x_top_left+width_pixel, y_top_left+5*hight_pixel/6, color, offset_zoom_param);
00707         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+5*hight_pixel/6,
      x_top_left+width_pixel, y_top_left+hight_pixel/6, color, offset_zoom_param);
00708         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+hight_pixel/6,
      x_top_left+2*width_pixel/3, y_top_left, color, offset_zoom_param);
00709         break;
00710     case 'p':
00711     case 'P':
00712         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left, y_top_left+hight_pixel, color,
      offset_zoom_param);
00713         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left+2*width_pixel/3, y_top_left,
      color, offset_zoom_param);
00714         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left, x_top_left+width_pixel,
      y_top_left+hight_pixel/6, color, offset_zoom_param);
00715         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+hight_pixel/6,
      x_top_left+width_pixel, y_top_left+hight_pixel/3, color, offset_zoom_param);
00716         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+hight_pixel/3,
      x_top_left+2*width_pixel/3, y_top_left+hight_pixel/2, color, offset_zoom_param);
00717
00718         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left+hight_pixel/2, x_top_left,
      y_top_left+hight_pixel/2, color, offset_zoom_param);
00719         break;
00720     case 'q':
00721     case 'Q':
00722         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left, x_top_left+width_pixel/3,
      y_top_left, color, offset_zoom_param);
00723         adl_line_draw(screen_mat, x_top_left+width_pixel/3, y_top_left, x_top_left,
      y_top_left+hight_pixel/6, color, offset_zoom_param);
00724         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel/6, x_top_left,
      y_top_left+5*hight_pixel/6, color, offset_zoom_param);
00725         adl_line_draw(screen_mat, x_top_left, y_top_left+5*hight_pixel/6, x_top_left+width_pixel/3,
      y_top_left+hight_pixel, color, offset_zoom_param);
00726         adl_line_draw(screen_mat, x_top_left+width_pixel/3, y_top_left+hight_pixel,
      x_top_left+2*width_pixel/3, y_top_left+hight_pixel, color, offset_zoom_param);
00727         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left+hight_pixel,
      x_top_left+width_pixel, y_top_left+5*hight_pixel/6, color, offset_zoom_param);
00728         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+5*hight_pixel/6,
      x_top_left+width_pixel, y_top_left+hight_pixel/6, color, offset_zoom_param);
00729         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+hight_pixel/6,
      x_top_left+2*width_pixel/3, y_top_left, color, offset_zoom_param);
00730
00731         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left+5*hight_pixel/6,
      x_top_left+width_pixel, y_top_left+hight_pixel, color, offset_zoom_param);
00732         break;
00733     case 'r':
00734     case 'R':
00735         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left, y_top_left+hight_pixel, color,
      offset_zoom_param);
00736         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left+2*width_pixel/3, y_top_left,
      color, offset_zoom_param);
00737         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left, x_top_left+width_pixel,
      y_top_left+hight_pixel/6, color, offset_zoom_param);
00738         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+hight_pixel/6,
      x_top_left+width_pixel, y_top_left+hight_pixel/3, color, offset_zoom_param);
00739         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+hight_pixel/3,
      x_top_left+2*width_pixel/3, y_top_left+hight_pixel/2, color, offset_zoom_param);
00740
00741         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left+hight_pixel/2, x_top_left,
      y_top_left+hight_pixel/2, color, offset_zoom_param);
00742
00743         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left+hight_pixel/2,
      x_top_left+width_pixel, y_top_left+hight_pixel, color, offset_zoom_param);
00744         break;
00745     case 's':
00746     case 'S':
00747         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+hight_pixel/6,
      x_top_left+2*width_pixel/3, y_top_left, color, offset_zoom_param);
00748         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left, x_top_left+width_pixel/3,
      y_top_left, color, offset_zoom_param);
```

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00749         adl_line_draw(screen_mat, x_top_left+width_pixel/3, y_top_left, x_top_left,
      y_top_left+hight_pixel/6, color, offset_zoom_param);
00750
00751         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel/6, x_top_left,
      y_top_left+hight_pixel/3, color, offset_zoom_param);
00752         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel/3, x_top_left+width_pixel/3,
      y_top_left+hight_pixel/2, color, offset_zoom_param);
00753         adl_line_draw(screen_mat, x_top_left+width_pixel/3, y_top_left+hight_pixel/2,
      x_top_left+2*width_pixel/3, y_top_left+hight_pixel/2, color, offset_zoom_param);
00754         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left+hight_pixel/2,
      x_top_left+width_pixel, y_top_left+2*hight_pixel/3, color, offset_zoom_param);
00755
00756         adl_line_draw(screen_mat, x_top_left, y_top_left+5*hight_pixel/6, x_top_left+width_pixel/3,
      y_top_left+hight_pixel, color, offset_zoom_param);
00757         adl_line_draw(screen_mat, x_top_left+width_pixel/3, y_top_left+hight_pixel,
      x_top_left+2*width_pixel/3, y_top_left+hight_pixel, color, offset_zoom_param);
00758         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left+hight_pixel,
      x_top_left+width_pixel, y_top_left+5*hight_pixel/6, color, offset_zoom_param);
00759         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+5*hight_pixel/6,
      x_top_left+width_pixel, y_top_left+2*hight_pixel/3, color, offset_zoom_param);
00760         break;
00761     case 't':
00762     case 'T':
00763         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left+width_pixel, y_top_left, color,
      offset_zoom_param);
00764         adl_line_draw(screen_mat, x_top_left+width_pixel/2, y_top_left, x_top_left+width_pixel/2,
      y_top_left+hight_pixel, color, offset_zoom_param);
00765         break;
00766     case 'u':
00767     case 'U':
00768         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left, y_top_left+hight_pixel/6, color,
      offset_zoom_param);
00769         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel/6, x_top_left,
      y_top_left+5*hight_pixel/6, color, offset_zoom_param);
00770         adl_line_draw(screen_mat, x_top_left, y_top_left+5*hight_pixel/6, x_top_left+width_pixel/3,
      y_top_left+hight_pixel, color, offset_zoom_param);
00771         adl_line_draw(screen_mat, x_top_left+width_pixel/3, y_top_left+hight_pixel,
      x_top_left+2*width_pixel/3, y_top_left+hight_pixel, color, offset_zoom_param);
00772         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left+hight_pixel,
      x_top_left+width_pixel, y_top_left+5*hight_pixel/6, color, offset_zoom_param);
00773         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+5*hight_pixel/6,
      x_top_left+width_pixel, y_top_left, color, offset_zoom_param);
00774         break;
00775     case 'v':
00776     case 'V':
00777         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left+width_pixel/2,
      y_top_left+hight_pixel, color, offset_zoom_param);
00778         adl_line_draw(screen_mat, x_top_left+width_pixel/2, y_top_left+hight_pixel,
      x_top_left+width_pixel, y_top_left, color, offset_zoom_param);
00779         break;
00780     case 'w':
00781     case 'W':
00782         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left+width_pixel/3,
      y_top_left+hight_pixel, color, offset_zoom_param);
00783         adl_line_draw(screen_mat, x_top_left+width_pixel/3, y_top_left+hight_pixel,
      x_top_left+width_pixel/2, y_top_left, color, offset_zoom_param);
00784         adl_line_draw(screen_mat, x_top_left+width_pixel/2, y_top_left, x_top_left+2*width_pixel/3,
      y_top_left+hight_pixel, color, offset_zoom_param);
00785         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left+hight_pixel,
      x_top_left+width_pixel, y_top_left, color, offset_zoom_param);
00786         break;
00787     case 'x':
00788     case 'X':
00789         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left+width_pixel,
      y_top_left+hight_pixel, color, offset_zoom_param);
00790         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel, x_top_left+width_pixel,
      y_top_left, color, offset_zoom_param);
00791         break;
00792     case 'y':
00793     case 'Y':
00794         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left+width_pixel/2,
      y_top_left+hight_pixel/2, color, offset_zoom_param);
00795         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left, x_top_left+width_pixel/2,
      y_top_left+hight_pixel/2, color, offset_zoom_param);
00796         adl_line_draw(screen_mat, x_top_left+width_pixel/2, y_top_left+hight_pixel/2,
      x_top_left+width_pixel/2, y_top_left+hight_pixel, color, offset_zoom_param);
00797         break;
00798     case 'z':
00799     case 'Z':
00800         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left+width_pixel, y_top_left, color,
      offset_zoom_param);
00801         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel, x_top_left+width_pixel,
      y_top_left+hight_pixel, color, offset_zoom_param);
00802         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left, x_top_left,
      y_top_left+hight_pixel, color, offset_zoom_param);
00803         break;
00804     case '.':
```

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00805         adl_rectangle_fill_min_max(screen_mat, x_top_left+width_pixel/6, x_top_left+width_pixel/3,
      y_top_left+5*hight_pixel/6, y_top_left+hight_pixel, color, offset_zoom_param);
00806         break;
00807     case ':':
00808         adl_rectangle_fill_min_max(screen_mat, x_top_left+width_pixel/6, x_top_left+width_pixel/3,
      y_top_left+5*hight_pixel/6, y_top_left+hight_pixel, color, offset_zoom_param);
00809         adl_rectangle_fill_min_max(screen_mat, x_top_left+width_pixel/6, x_top_left+width_pixel/3,
      y_top_left, y_top_left+hight_pixel/6, color, offset_zoom_param);
00810         break;
00811     case '0':
00812         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left, x_top_left+width_pixel/3,
      y_top_left, color, offset_zoom_param);
00813         adl_line_draw(screen_mat, x_top_left+width_pixel/3, y_top_left, x_top_left,
      y_top_left+hight_pixel/6, color, offset_zoom_param);
00814         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel/6, x_top_left,
      y_top_left+5*hight_pixel/6, color, offset_zoom_param);
00815         adl_line_draw(screen_mat, x_top_left, y_top_left+5*hight_pixel/6, x_top_left+width_pixel/3,
      y_top_left+hight_pixel, color, offset_zoom_param);
00816         adl_line_draw(screen_mat, x_top_left+width_pixel/3, y_top_left+hight_pixel,
      x_top_left+2*width_pixel/3, y_top_left+hight_pixel, color, offset_zoom_param);
00817         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left+hight_pixel,
      x_top_left+width_pixel, y_top_left+5*hight_pixel/6, color, offset_zoom_param);
00818         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+5*hight_pixel/6,
      x_top_left+width_pixel, y_top_left+hight_pixel/6, color, offset_zoom_param);
00819         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+hight_pixel/6,
      x_top_left+2*width_pixel/3, y_top_left, color, offset_zoom_param);
00820
00821         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+hight_pixel/6, x_top_left,
      y_top_left+5*hight_pixel/6, color, offset_zoom_param);
00822         break;
00823     case '1':
00824         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel/6, x_top_left+width_pixel/2,
      y_top_left, color, offset_zoom_param);
00825         adl_line_draw(screen_mat, x_top_left+width_pixel/2, y_top_left, x_top_left+width_pixel/2,
      y_top_left+hight_pixel, color, offset_zoom_param);
00826         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel, x_top_left+width_pixel,
      y_top_left+hight_pixel, color, offset_zoom_param);
00827         break;
00828     case '2':
00829         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel/6, x_top_left+width_pixel/3,
      y_top_left, color, offset_zoom_param);
00830         adl_line_draw(screen_mat, x_top_left+width_pixel/3, y_top_left, x_top_left+2*width_pixel/3,
      y_top_left, color, offset_zoom_param);
00831         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left, x_top_left+width_pixel,
      y_top_left+hight_pixel/6, color, offset_zoom_param);
00832         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+hight_pixel/6,
      x_top_left+width_pixel, y_top_left+hight_pixel/3, color, offset_zoom_param);
00833         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+hight_pixel/3, x_top_left,
      y_top_left+hight_pixel, color, offset_zoom_param);
00834         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel, x_top_left+width_pixel,
      y_top_left+hight_pixel, color, offset_zoom_param);
00835         break;
00836     case '3':
00837         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel/6, x_top_left+width_pixel/3,
      y_top_left, color, offset_zoom_param);
00838         adl_line_draw(screen_mat, x_top_left+width_pixel/3, y_top_left, x_top_left+2*width_pixel/3,
      y_top_left, color, offset_zoom_param);
00839         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left, x_top_left+width_pixel,
      y_top_left+hight_pixel/6, color, offset_zoom_param);
00840         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+hight_pixel/6,
      x_top_left+width_pixel, y_top_left+hight_pixel/3, color, offset_zoom_param);
00841         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+hight_pixel/3,
      x_top_left+2*width_pixel/3, y_top_left+hight_pixel/2, color, offset_zoom_param);
00842
00843         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left+hight_pixel/2,
      x_top_left+width_pixel/3, y_top_left+hight_pixel/2, color, offset_zoom_param);
00844
00845         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left+hight_pixel/2,
      x_top_left+width_pixel, y_top_left+2*hight_pixel/3, color, offset_zoom_param);
00846         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+2*hight_pixel/3,
      x_top_left+width_pixel, y_top_left+5*hight_pixel/6, color, offset_zoom_param);
00847         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+5*hight_pixel/6,
      x_top_left+2*width_pixel/3, y_top_left+hight_pixel, color, offset_zoom_param);
00848         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left+hight_pixel,
      x_top_left+width_pixel/3, y_top_left+hight_pixel, color, offset_zoom_param);
00849         adl_line_draw(screen_mat, x_top_left+width_pixel/3, y_top_left+hight_pixel, x_top_left,
      y_top_left+5*hight_pixel/6, color, offset_zoom_param);
00850         break;
00851     case '4':
00852         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left+hight_pixel,
      x_top_left+2*width_pixel/3, y_top_left, color, offset_zoom_param);
00853         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left, x_top_left,
      y_top_left+2*hight_pixel/3, color, offset_zoom_param);
00854         adl_line_draw(screen_mat, x_top_left, y_top_left+2*hight_pixel/3, x_top_left+width_pixel,
      y_top_left+2*hight_pixel/3, color, offset_zoom_param);
00855         break;
00856     case '5':
```

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00857         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left, x_top_left, y_top_left, color,
      offset_zoom_param);
00858         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left, y_top_left+hight_pixel/2, color,
      offset_zoom_param);
00859
00860         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel/2, x_top_left+2*width_pixel/3,
      y_top_left+hight_pixel/2, color, offset_zoom_param);
00861         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left+hight_pixel/2,
      x_top_left+width_pixel, y_top_left+2*hight_pixel/3, color, offset_zoom_param);
00862
00863         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel, x_top_left+2*width_pixel/3,
      y_top_left+hight_pixel, color, offset_zoom_param);
00864         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left+hight_pixel,
      x_top_left+width_pixel, y_top_left+5*hight_pixel/6, color, offset_zoom_param);
00865         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+5*hight_pixel/6,
      x_top_left+width_pixel, y_top_left+2*hight_pixel/3, color, offset_zoom_param);
00866         break;
00867     case '6':
00868         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+hight_pixel/6,
      x_top_left+2*width_pixel/3, y_top_left, color, offset_zoom_param);
00869         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left, x_top_left+width_pixel/3,
      y_top_left, color, offset_zoom_param);
00870         adl_line_draw(screen_mat, x_top_left+width_pixel/3, y_top_left, x_top_left,
      y_top_left+hight_pixel/6, color, offset_zoom_param);
00871
00872         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel/6, x_top_left,
      y_top_left+5*hight_pixel/6, color, offset_zoom_param);
00873         adl_line_draw(screen_mat, x_top_left, y_top_left+5*hight_pixel/6, x_top_left+width_pixel/3,
      y_top_left+hight_pixel, color, offset_zoom_param);
00874         adl_line_draw(screen_mat, x_top_left+width_pixel/3, y_top_left+hight_pixel,
      x_top_left+2*width_pixel/3, y_top_left+hight_pixel, color, offset_zoom_param);
00875         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left+hight_pixel,
      x_top_left+width_pixel, y_top_left+5*hight_pixel/6, color, offset_zoom_param);
00876         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+5*hight_pixel/6,
      x_top_left+width_pixel, y_top_left+2*hight_pixel/3, color, offset_zoom_param);
00877         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+2*hight_pixel/3,
      x_top_left+2*width_pixel/3, y_top_left+hight_pixel/2, color, offset_zoom_param);
00878         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left+hight_pixel/2,
      x_top_left+width_pixel/3, y_top_left+hight_pixel/2, color, offset_zoom_param);
00879         adl_line_draw(screen_mat, x_top_left+width_pixel/3, y_top_left+hight_pixel/2, x_top_left,
      y_top_left+2*hight_pixel/3, color, offset_zoom_param);
00880         break;
00881     case '7':
00882         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left+width_pixel, y_top_left, color,
      offset_zoom_param);
00883         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left, x_top_left+width_pixel/3,
      y_top_left+hight_pixel, color, offset_zoom_param);
00884         break;
00885     case '8':
00886         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left+hight_pixel/2,
      x_top_left+width_pixel, y_top_left+hight_pixel/3, color, offset_zoom_param);
00887         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+hight_pixel/3,
      x_top_left+width_pixel, y_top_left+hight_pixel/6, color, offset_zoom_param);
00888         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+hight_pixel/6,
      x_top_left+2*width_pixel/3, y_top_left, color, offset_zoom_param);
00889         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left, x_top_left+width_pixel/3,
      y_top_left, color, offset_zoom_param);
00890         adl_line_draw(screen_mat, x_top_left+width_pixel/3, y_top_left, x_top_left,
      y_top_left+hight_pixel/6, color, offset_zoom_param);
00891
00892         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel/6, x_top_left,
      y_top_left+hight_pixel/3, color, offset_zoom_param);
00893         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel/3, x_top_left+width_pixel/3,
      y_top_left+hight_pixel/2, color, offset_zoom_param);
00894         adl_line_draw(screen_mat, x_top_left+width_pixel/3, y_top_left+hight_pixel/2,
      x_top_left+2*width_pixel/3, y_top_left+hight_pixel/2, color, offset_zoom_param);
00895         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left+hight_pixel/2,
      x_top_left+width_pixel, y_top_left+2*hight_pixel/3, color, offset_zoom_param);
00896
00897         adl_line_draw(screen_mat, x_top_left+width_pixel/3, y_top_left+hight_pixel/2, x_top_left,
      y_top_left+2*hight_pixel/3, color, offset_zoom_param);
00898         adl_line_draw(screen_mat, x_top_left, y_top_left+2*hight_pixel/3, x_top_left,
      y_top_left+5*hight_pixel/6, color, offset_zoom_param);
00899         adl_line_draw(screen_mat, x_top_left, y_top_left+5*hight_pixel/6, x_top_left+width_pixel/3,
      y_top_left+hight_pixel, color, offset_zoom_param);
00900         adl_line_draw(screen_mat, x_top_left+width_pixel/3, y_top_left+hight_pixel,
      x_top_left+2*width_pixel/3, y_top_left+hight_pixel, color, offset_zoom_param);
00901         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left+hight_pixel,
      x_top_left+width_pixel, y_top_left+5*hight_pixel/6, color, offset_zoom_param);
00902         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+5*hight_pixel/6,
      x_top_left+width_pixel, y_top_left+2*hight_pixel/3, color, offset_zoom_param);
00903         break;
00904     case '9':
00905         adl_line_draw(screen_mat, x_top_left, y_top_left+5*hight_pixel/6, x_top_left+width_pixel/3,
      y_top_left+hight_pixel, color, offset_zoom_param);
00906         adl_line_draw(screen_mat, x_top_left+width_pixel/3, y_top_left+hight_pixel,
      x_top_left+2*width_pixel/3, y_top_left+hight_pixel, color, offset_zoom_param);
```

```
00907         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left+hight_pixel,
      x_top_left+width_pixel, y_top_left+5*hight_pixel/6, color, offset_zoom_param);
00908         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+5*hight_pixel/6,
      x_top_left+width_pixel, y_top_left+hight_pixel/6, color, offset_zoom_param);
00909         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left+hight_pixel/6,
      x_top_left+2*width_pixel/3, y_top_left, color, offset_zoom_param);
00910         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left, x_top_left+width_pixel/3,
      y_top_left, color, offset_zoom_param);
00911         adl_line_draw(screen_mat, x_top_left+width_pixel/3, y_top_left, x_top_left,
      y_top_left+hight_pixel/6, color, offset_zoom_param);
00912         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel/6, x_top_left,
      y_top_left+hight_pixel/3, color, offset_zoom_param);
00913         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel/3, x_top_left+width_pixel/3,
      y_top_left+hight_pixel/2, color, offset_zoom_param);
00914         adl_line_draw(screen_mat, x_top_left+width_pixel/3, y_top_left+hight_pixel/2,
      x_top_left+2*width_pixel/3, y_top_left+hight_pixel/2, color, offset_zoom_param);
00915         adl_line_draw(screen_mat, x_top_left+2*width_pixel/3, y_top_left+hight_pixel/2,
      x_top_left+width_pixel, y_top_left+hight_pixel/3, color, offset_zoom_param);
00916         break;
00917     case '-':
00918         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel/2, x_top_left+width_pixel,
      y_top_left+hight_pixel/2, color, offset_zoom_param);
00919         break;
00920     case '+':
00921         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel/2, x_top_left+width_pixel,
      y_top_left+hight_pixel/2, color, offset_zoom_param);
00922         adl_line_draw(screen_mat, x_top_left+width_pixel/2, y_top_left, x_top_left+width_pixel/2,
      y_top_left+hight_pixel, color, offset_zoom_param);
00923         break;
00924     case ' ':
00925         break;
00926     default:
00927         adl_rectangle_draw_min_max(screen_mat, x_top_left, x_top_left+width_pixel, y_top_left,
      y_top_left+hight_pixel, color, offset_zoom_param);
00928         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left+width_pixel,
      y_top_left+hight_pixel, color, offset_zoom_param);
00929         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel, x_top_left+width_pixel,
      y_top_left, color, offset_zoom_param);
00930         break;
00931     }
00932 }
00933
00949 void adl_sentence_draw(Mat2D_uint32 screen_mat, const char sentence[], size_t len, const int
      x_top_left, const int y_top_left, const int hight_pixel, const uint32_t color, Offset_zoom_param
      offset_zoom_param)
00950 {
00951     int character_width_pixel = hight_pixel/2;
00952     int current_x_top_left = x_top_left;
00953     int character_x_offset = (int)fmaxf(fminf(ADL_MAX_CHARACTER_OFFSET, character_width_pixel / 5),
      ADL_MIN_CHARACTER_OFFSET);
00954
00955     for (size_t char_index = 0; char_index < len; char_index++) {
00956         adl_character_draw(screen_mat, sentence[char_index], character_width_pixel, hight_pixel,
      current_x_top_left, y_top_left, color, offset_zoom_param);
00957         current_x_top_left += character_width_pixel + character_x_offset;
00958     }
00959
00960 }
00961
00973 void adl_rectangle_draw_min_max(Mat2D_uint32 screen_mat, int min_x, int max_x, int min_y, int max_y,
      uint32_t color, Offset_zoom_param offset_zoom_param)
00974 {
00975     adl_line_draw(screen_mat, min_x, min_y, max_x, min_y, color, offset_zoom_param);
00976     adl_line_draw(screen_mat, min_x, max_y, max_x, max_y, color, offset_zoom_param);
00977     adl_line_draw(screen_mat, min_x, min_y, min_x, max_y, color, offset_zoom_param);
00978     adl_line_draw(screen_mat, max_x, min_y, max_x, max_y, color, offset_zoom_param);
00979 }
00980
00992 void adl_rectangle_fill_min_max(Mat2D_uint32 screen_mat, int min_x, int max_x, int min_y, int max_y,
      uint32_t color, Offset_zoom_param offset_zoom_param)
00993 {
00994     for (int y = min_y; y <= max_y; y++) {
00995         adl_line_draw(screen_mat, min_x, y, max_x, y, color, offset_zoom_param);
00996     }
00997 }
00998
01010 void adl_quad_draw(Mat2D_uint32 screen_mat, Mat2D inv_z_buffer, Quad quad, uint32_t color,
      Offset_zoom_param offset_zoom_param)
01011 {
01012     (void)inv_z_buffer;
01013     adl_lines_loop_draw(screen_mat, quad.points, 4, color, offset_zoom_param);
01014 }
01015
01028 void adl_quad_fill(Mat2D_uint32 screen_mat, Mat2D inv_z_buffer, Quad quad, uint32_t color,
      Offset_zoom_param offset_zoom_param)
01029 {
01030     Point p0 = quad.points[0];
```

```
01031     Point p1 = quad.points[1];
01032     Point p2 = quad.points[2];
01033     Point p3 = quad.points[3];
01034 
01035     int x_min = fminf(p0.x, fminf(p1.x, fminf(p2.x, p3.x)));
01036     int x_max = fmaxf(p0.x, fmaxf(p1.x, fmaxf(p2.x, p3.x)));
01037     int y_min = fminf(p0.y, fminf(p1.y, fminf(p2.y, p3.y)));
01038     int y_max = fmaxf(p0.y, fmaxf(p1.y, fmaxf(p2.y, p3.y)));
01039 
01040     if (x_min < 0) x_min = 0;
01041     if (y_min < 0) y_min = 0;
01042     if (x_max >= (int)screen_mat.cols) x_max = (int)screen_mat.cols - 1;
01043     if (y_max >= (int)screen_mat.rows) y_max = (int)screen_mat.rows - 1;
01044 
01045     float w = edge_cross_point(p0, p1, p1, p2) + edge_cross_point(p2, p3, p3, p0);
01046     if (fabs(w) < 1e-6) {
01047         // adl_quad_draw(screen_mat, inv_z_buffer, quad, quad.colors[0], offset_zoom_param);
01048         return;
01049     }
01050 
01051     float size_p3_to_p0 = sqrt((p0.x - p3.x)*(p0.x - p3.x) + (p0.y - p3.y)*(p0.y - p3.y));
01052     float size_p0_to_p1 = sqrt((p1.x - p0.x)*(p1.x - p0.x) + (p1.y - p0.y)*(p1.y - p0.y));
01053     float size_p1_to_p2 = sqrt((p2.x - p1.x)*(p2.x - p1.x) + (p2.y - p1.y)*(p2.y - p1.y));
01054     float size_p2_to_p3 = sqrt((p3.x - p2.x)*(p3.x - p2.x) + (p3.y - p2.y)*(p3.y - p2.y));
01055 
01056     int r, g, b, a;
01057     HexARGB_RGBA_VAR(color, r, g, b, a);
01058     float light_intensity = (quad.light_intensity[0] + quad.light_intensity[1] +
      quad.light_intensity[2] + quad.light_intensity[3]) / 4;
01059     uint8_t base_r = (uint8_t)fmaxf(0, fminf(255, r * light_intensity));
01060     uint8_t base_g = (uint8_t)fmaxf(0, fminf(255, g * light_intensity));
01061     uint8_t base_b = (uint8_t)fmaxf(0, fminf(255, b * light_intensity));
01062 
01063     for (int y = y_min; y <= y_max; y++) {
01064         for (int x = x_min; x <= x_max; x++) {
01065             Point p = {.x = x, .y = y, .z = 0};
01066             bool in_01, in_12, in_23, in_30;
01067 
01068             in_01 = (edge_cross_point(p0, p1, p0, p) >= 0) != (w < 0);
01069             in_12 = (edge_cross_point(p1, p2, p1, p) >= 0) != (w < 0);
01070             in_23 = (edge_cross_point(p2, p3, p2, p) >= 0) != (w < 0);
01071             in_30 = (edge_cross_point(p3, p0, p3, p) >= 0) != (w < 0);
01072 
01073             /* https://www.mn.uio.no/math/english/people/aca/michaelf/papers/mv3d.pdf. */
01074             float size_p_to_p0 = sqrt((p0.x - p.x)*(p0.x - p.x) + (p0.y - p.y)*(p0.y - p.y));
01075             float size_p_to_p1 = sqrt((p1.x - p.x)*(p1.x - p.x) + (p1.y - p.y)*(p1.y - p.y));
01076             float size_p_to_p2 = sqrt((p2.x - p.x)*(p2.x - p.x) + (p2.y - p.y)*(p2.y - p.y));
01077             float size_p_to_p3 = sqrt((p3.x - p.x)*(p3.x - p.x) + (p3.y - p.y)*(p3.y - p.y));
01078 
01079             /* tangent of half the angle directly using vector math */
01080             float tan_theta_3_over_2 = size_p3_to_p0 / (size_p_to_p3 + size_p_to_p0);
01081             float tan_theta_0_over_2 = size_p0_to_p1 / (size_p_to_p0 + size_p_to_p1);
01082             float tan_theta_1_over_2 = size_p1_to_p2 / (size_p_to_p1 + size_p_to_p2);
01083             float tan_theta_2_over_2 = size_p2_to_p3 / (size_p_to_p2 + size_p_to_p3);
01084             float w0 = (tan_theta_3_over_2 + tan_theta_0_over_2) / size_p_to_p0;
01085             float w1 = (tan_theta_0_over_2 + tan_theta_1_over_2) / size_p_to_p1;
01086             float w2 = (tan_theta_1_over_2 + tan_theta_2_over_2) / size_p_to_p2;
01087             float w3 = (tan_theta_2_over_2 + tan_theta_3_over_2) / size_p_to_p3;
01088 
01089             float inv_w_tot = 1.0f / (w0 + w1 + w2 + w3);
01090             float alpha = w0 * inv_w_tot;
01091             float beta  = w1 * inv_w_tot;
01092             float gamma = w2 * inv_w_tot;
01093             float delta = w3 * inv_w_tot;
01094 
01095             if (in_01 && in_12 && in_23 && in_30) {
01096 
01097                 double inv_w = alpha * (1.0f / p0.w) + beta  * (1.0f / p1.w) + gamma * (1.0f / p2.w) +
      delta * (1.0f / p3.w);
01098                 double z_over_w = alpha * (p0.z / p0.w) + beta  * (p1.z / p1.w) + gamma * (p2.z /
      p2.w) + delta * (p3.z / p3.w);
01099                 double inv_z = inv_w / z_over_w;
01100 
01101                 if (inv_z >= MAT2D_AT(inv_z_buffer, y, x)) {
01102                     adl_point_draw(screen_mat, x, y, RGBA_hexARGB(base_r, base_g, base_b, a),
      offset_zoom_param);
01103                     MAT2D_AT(inv_z_buffer, y, x) = inv_z;
01104                 }
01105             }
01106         }
01107     }
01108 }
01109 
01122 void adl_quad_fill_interpolate_normal_mean_value(Mat2D_uint32 screen_mat, Mat2D inv_z_buffer, Quad
      quad, uint32_t color, Offset_zoom_param offset_zoom_param)
01123 {
01124     Point p0 = quad.points[0];
```

```
01125     Point p1 = quad.points[1];
01126     Point p2 = quad.points[2];
01127     Point p3 = quad.points[3];
01128 
01129     int x_min = fminf(p0.x, fminf(p1.x, fminf(p2.x, p3.x)));
01130     int x_max = fmaxf(p0.x, fmaxf(p1.x, fmaxf(p2.x, p3.x)));
01131     int y_min = fminf(p0.y, fminf(p1.y, fminf(p2.y, p3.y)));
01132     int y_max = fmaxf(p0.y, fmaxf(p1.y, fmaxf(p2.y, p3.y)));
01133 
01134     if (x_min < 0) x_min = 0;
01135     if (y_min < 0) y_min = 0;
01136     if (x_max >= (int)screen_mat.cols) x_max = (int)screen_mat.cols - 1;
01137     if (y_max >= (int)screen_mat.rows) y_max = (int)screen_mat.rows - 1;
01138 
01139     float w = edge_cross_point(p0, p1, p1, p2) + edge_cross_point(p2, p3, p3, p0);
01140     if (fabs(w) < 1e-6) {
01141         // adl_quad_draw(screen_mat, inv_z_buffer, quad, quad.colors[0], offset_zoom_param);
01142         return;
01143     }
01144 
01145     int r, g, b, a;
01146     HexARGB_RGBA_VAR(color, r, g, b, a);
01147 
01148     for (int y = y_min; y <= y_max; y++) {
01149         for (int x = x_min; x <= x_max; x++) {
01150             Point p = {.x = x, .y = y, .z = 0};
01151             bool in_01, in_12, in_23, in_30;
01152 
01153             in_01 = (edge_cross_point(p0, p1, p0, p) >= 0) != (w < 0);
01154             in_12 = (edge_cross_point(p1, p2, p1, p) >= 0) != (w < 0);
01155             in_23 = (edge_cross_point(p2, p3, p2, p) >= 0) != (w < 0);
01156             in_30 = (edge_cross_point(p3, p0, p3, p) >= 0) != (w < 0);
01157 
01158             /* using 'mean value coordinates'
01159              * https://www.mn.uio.no/math/english/people/aca/michaelf/papers/mv3d.pdf. */
01160             float size_p_to_p0 = sqrt((p0.x - p.x)*(p0.x - p.x) + (p0.y - p.y)*(p0.y - p.y));
01161             float size_p_to_p1 = sqrt((p1.x - p.x)*(p1.x - p.x) + (p1.y - p.y)*(p1.y - p.y));
01162             float size_p_to_p2 = sqrt((p2.x - p.x)*(p2.x - p.x) + (p2.y - p.y)*(p2.y - p.y));
01163             float size_p_to_p3 = sqrt((p3.x - p.x)*(p3.x - p.x) + (p3.y - p.y)*(p3.y - p.y));
01164 
01165             /* calculating the tangent of half the angle directly using vector math */
01166             float t0 = adl_tan_half_angle(p0, p1, p, size_p_to_p0, size_p_to_p1);
01167             float t1 = adl_tan_half_angle(p1, p2, p, size_p_to_p1, size_p_to_p2);
01168             float t2 = adl_tan_half_angle(p2, p3, p, size_p_to_p2, size_p_to_p3);
01169             float t3 = adl_tan_half_angle(p3, p0, p, size_p_to_p3, size_p_to_p0);
01170 
01171             float w0 = (t3 + t0) / size_p_to_p0;
01172             float w1 = (t0 + t1) / size_p_to_p1;
01173             float w2 = (t1 + t2) / size_p_to_p2;
01174             float w3 = (t2 + t3) / size_p_to_p3;
01175 
01176             float inv_w_tot = 1.0f / (w0 + w1 + w2 + w3);
01177             float alpha = w0 * inv_w_tot;
01178             float beta  = w1 * inv_w_tot;
01179             float gamma = w2 * inv_w_tot;
01180             float delta = w3 * inv_w_tot;
01181 
01182             if (in_01 && in_12 && in_23 && in_30) {
01183                 float light_intensity = quad.light_intensity[0]*alpha + quad.light_intensity[1]*beta +
      quad.light_intensity[2]*gamma + quad.light_intensity[3]*delta;
01184 
01185                 float rf = r * light_intensity;
01186                 float gf = g * light_intensity;
01187                 float bf = b * light_intensity;
01188                 uint8_t r8 = (uint8_t)fmaxf(0, fminf(255, rf));
01189                 uint8_t g8 = (uint8_t)fmaxf(0, fminf(255, gf));
01190                 uint8_t b8 = (uint8_t)fmaxf(0, fminf(255, bf));
01191 
01192                 double inv_w = alpha * (1.0f / p0.w) + beta  * (1.0f / p1.w) + gamma * (1.0f / p2.w) +
      delta * (1.0f / p3.w);
01193                 double z_over_w = alpha * (p0.z / p0.w) + beta  * (p1.z / p1.w) + gamma * (p2.z /
      p2.w) + delta * (p3.z / p3.w);
01194                 double inv_z = inv_w / z_over_w;
01195 
01196                 if (inv_z >= MAT2D_AT(inv_z_buffer, y, x)) {
01197                     adl_point_draw(screen_mat, x, y, RGBA_hexARGB(r8, g8, b8, a), offset_zoom_param);
01198                     MAT2D_AT(inv_z_buffer, y, x) = inv_z;
01199                 }
01200             }
01201         }
01202     }
01203 }
01204 
01216 void adl_quad_fill_interpolate_color_mean_value(Mat2D_uint32 screen_mat, Mat2D inv_z_buffer, Quad
      quad, Offset_zoom_param offset_zoom_param)
01217 {
01218     Point p0 = quad.points[0];
```

```
01219     Point p1 = quad.points[1];
01220     Point p2 = quad.points[2];
01221     Point p3 = quad.points[3];
01222 
01223     int x_min = fminf(p0.x, fminf(p1.x, fminf(p2.x, p3.x)));
01224     int x_max = fmaxf(p0.x, fmaxf(p1.x, fmaxf(p2.x, p3.x)));
01225     int y_min = fminf(p0.y, fminf(p1.y, fminf(p2.y, p3.y)));
01226     int y_max = fmaxf(p0.y, fmaxf(p1.y, fmaxf(p2.y, p3.y)));
01227 
01228     if (x_min < 0) x_min = 0;
01229     if (y_min < 0) y_min = 0;
01230     if (x_max >= (int)screen_mat.cols) x_max = (int)screen_mat.cols - 1;
01231     if (y_max >= (int)screen_mat.rows) y_max = (int)screen_mat.rows - 1;
01232 
01233     float w = edge_cross_point(p0, p1, p1, p2) + edge_cross_point(p2, p3, p3, p0);
01234     if (fabs(w) < 1e-6) {
01235         // adl_quad_draw(screen_mat, inv_z_buffer, quad, quad.colors[0], offset_zoom_param);
01236         return;
01237     }
01238 
01239     for (int y = y_min; y <= y_max; y++) {
01240         for (int x = x_min; x <= x_max; x++) {
01241             Point p = {.x = x, .y = y, .z = 0};
01242             bool in_01, in_12, in_23, in_30;
01243 
01244             in_01 = (edge_cross_point(p0, p1, p0, p) >= 0) != (w < 0);
01245             in_12 = (edge_cross_point(p1, p2, p1, p) >= 0) != (w < 0);
01246             in_23 = (edge_cross_point(p2, p3, p2, p) >= 0) != (w < 0);
01247             in_30 = (edge_cross_point(p3, p0, p3, p) >= 0) != (w < 0);
01248 
01249             /* using 'mean value coordinates'
01250              * https://www.mn.uio.no/math/english/people/aca/michaelf/papers/mv3d.pdf. */
01251             float size_p_to_p0 = sqrt((p0.x - p.x)*(p0.x - p.x) + (p0.y - p.y)*(p0.y - p.y));
01252             float size_p_to_p1 = sqrt((p1.x - p.x)*(p1.x - p.x) + (p1.y - p.y)*(p1.y - p.y));
01253             float size_p_to_p2 = sqrt((p2.x - p.x)*(p2.x - p.x) + (p2.y - p.y)*(p2.y - p.y));
01254             float size_p_to_p3 = sqrt((p3.x - p.x)*(p3.x - p.x) + (p3.y - p.y)*(p3.y - p.y));
01255 
01256             /* calculating the tangent of half the angle directly using vector math */
01257             float t0 = adl_tan_half_angle(p0, p1, p, size_p_to_p0, size_p_to_p1);
01258             float t1 = adl_tan_half_angle(p1, p2, p, size_p_to_p1, size_p_to_p2);
01259             float t2 = adl_tan_half_angle(p2, p3, p, size_p_to_p2, size_p_to_p3);
01260             float t3 = adl_tan_half_angle(p3, p0, p, size_p_to_p3, size_p_to_p0);
01261 
01262             float w0 = (t3 + t0) / size_p_to_p0;
01263             float w1 = (t0 + t1) / size_p_to_p1;
01264             float w2 = (t1 + t2) / size_p_to_p2;
01265             float w3 = (t2 + t3) / size_p_to_p3;
01266 
01267             float inv_w_tot = 1.0f / (w0 + w1 + w2 + w3);
01268             float alpha = w0 * inv_w_tot;
01269             float beta  = w1 * inv_w_tot;
01270             float gamma = w2 * inv_w_tot;
01271             float delta = w3 * inv_w_tot;
01272 
01273             if (in_01 && in_12 && in_23 && in_30) {
01274                 int r0, g0, b0, a0;
01275                 int r1, g1, b1, a1;
01276                 int r2, g2, b2, a2;
01277                 int r3, g3, b3, a3;
01278                 HexARGB_RGBA_VAR(quad.colors[0], r0, g0, b0, a0);
01279                 HexARGB_RGBA_VAR(quad.colors[1], r1, g1, b1, a1);
01280                 HexARGB_RGBA_VAR(quad.colors[2], r2, g2, b2, a2);
01281                 HexARGB_RGBA_VAR(quad.colors[3], r3, g3, b3, a3);
01282 
01283                 uint8_t current_r = r0*alpha + r1*beta + r2*gamma + r3*delta;
01284                 uint8_t current_g = g0*alpha + g1*beta + g2*gamma + g3*delta;
01285                 uint8_t current_b = b0*alpha + b1*beta + b2*gamma + b3*delta;
01286                 uint8_t current_a = a0*alpha + a1*beta + a2*gamma + a3*delta;
01287 
01288                 float light_intensity = (quad.light_intensity[0] + quad.light_intensity[1] +
      quad.light_intensity[2] + quad.light_intensity[3]) / 4;
01289                 float rf = current_r * light_intensity;
01290                 float gf = current_g * light_intensity;
01291                 float bf = current_b * light_intensity;
01292                 uint8_t r8 = (uint8_t)fmaxf(0, fminf(255, rf));
01293                 uint8_t g8 = (uint8_t)fmaxf(0, fminf(255, gf));
01294                 uint8_t b8 = (uint8_t)fmaxf(0, fminf(255, bf));
01295 
01296                 double inv_w = alpha * (1.0f / p0.w) + beta  * (1.0f / p1.w) + gamma * (1.0f / p2.w) +
      delta * (1.0f / p3.w);
01297                 double z_over_w = alpha * (p0.z / p0.w) + beta  * (p1.z / p1.w) + gamma * (p2.z /
      p2.w) + delta * (p3.z / p3.w);
01298                 double inv_z = inv_w / z_over_w;
01299 
01300                 if (inv_z >= MAT2D_AT(inv_z_buffer, y, x)) {
01301                     adl_point_draw(screen_mat, x, y, RGBA_hexARGB(r8, g8, b8, current_a),
      offset_zoom_param);
```

```
01302                     MAT2D_AT(inv_z_buffer, y, x) = inv_z;
01303                 }
01304             }
01305         }
01306     }
01307 }
01308
01320 void adl_quad_mesh_draw(Mat2D_uint32 screen_mat, Mat2D inv_z_buffer_mat, Quad_mesh mesh, uint32_t
       color, Offset_zoom_param offset_zoom_param)
01321 {
01322     for (size_t i = 0; i < mesh.length; i++) {
01323         Quad quad = mesh.elements[i];
01324         /* Reject invalid quad */
01325         adl_assert_quad_is_valid(quad);
01326
01327         if (!quad.to_draw) continue;
01328
01329         adl_quad_draw(screen_mat, inv_z_buffer_mat, quad, color, offset_zoom_param);
01330     }
01331 }
01332
01344 void adl_quad_mesh_fill(Mat2D_uint32 screen_mat, Mat2D inv_z_buffer_mat, Quad_mesh mesh, uint32_t
       color, Offset_zoom_param offset_zoom_param)
01345 {
01346     for (size_t i = 0; i < mesh.length; i++) {
01347         Quad quad = mesh.elements[i];
01348         /* Reject invalid quad */
01349         adl_assert_quad_is_valid(quad);
01350
01351         if (!quad.to_draw) continue;
01352
01353         // color = rand_double() * 0xFFFFFFFF;
01354
01355         adl_quad_fill(screen_mat, inv_z_buffer_mat, quad, color, offset_zoom_param);
01356     }
01357 }
01358
01371 void adl_quad_mesh_fill_interpolate_normal(Mat2D_uint32 screen_mat, Mat2D inv_z_buffer_mat, Quad_mesh
       mesh, uint32_t color, Offset_zoom_param offset_zoom_param)
01372 {
01373     for (size_t i = 0; i < mesh.length; i++) {
01374         Quad quad = mesh.elements[i];
01375         /* Reject invalid quad */
01376         adl_assert_quad_is_valid(quad);
01377
01378         uint8_t a, r, g, b;
01379         HexARGB_RGBA_VAR(color, a, r, g, b);
01380         (void)r;
01381         (void)g;
01382         (void)b;
01383
01384         if (!quad.to_draw && a == 255) continue;
01385
01386         adl_quad_fill_interpolate_normal_mean_value(screen_mat, inv_z_buffer_mat, quad, color,
       offset_zoom_param);
01387     }
01388 }
01389
01401 void adl_quad_mesh_fill_interpolate_color(Mat2D_uint32 screen_mat, Mat2D inv_z_buffer_mat, Quad_mesh
       mesh, Offset_zoom_param offset_zoom_param)
01402 {
01403     for (size_t i = 0; i < mesh.length; i++) {
01404         Quad quad = mesh.elements[i];
01405         /* Reject invalid quad */
01406         adl_assert_quad_is_valid(quad);
01407
01408         if (!quad.to_draw) continue;
01409
01410         adl_quad_fill_interpolate_color_mean_value(screen_mat, inv_z_buffer_mat, quad,
       offset_zoom_param);
01411     }
01412 }
01413
01427 void adl_circle_draw(Mat2D_uint32 screen_mat, float center_x, float center_y, float r, uint32_t color,
       Offset_zoom_param offset_zoom_param)
01428 {
01429     for (int dy = -r; dy <= r; dy++) {
01430         for (int dx = -r; dx <= r; dx ++) {
01431             float diff = dx * dx + dy * dy - r * r;
01432             if (diff < 0 && diff > -r*2) {
01433                 adl_point_draw(screen_mat, center_x + dx, center_y + dy, color, offset_zoom_param);
01434             }
01435         }
01436     }
01437 }
01438
01449 void adl_circle_fill(Mat2D_uint32 screen_mat, float center_x, float center_y, float r, uint32_t color,
```

```
      Offset_zoom_param offset_zoom_param)
01450 {
01451     for (int dy = -r; dy <= r; dy++) {
01452         for (int dx = -r; dx <= r; dx ++) {
01453             float diff = dx * dx + dy * dy - r * r;
01454             if (diff < 0) {
01455                 adl_point_draw(screen_mat, center_x + dx, center_y + dy, color, offset_zoom_param);
01456             }
01457         }
01458     }
01459 }
01460
01469 void adl_tri_draw(Mat2D_uint32 screen_mat, Tri tri, uint32_t color, Offset_zoom_param
      offset_zoom_param)
01470 {
01471     adl_line_draw(screen_mat, tri.points[0].x, tri.points[0].y, tri.points[1].x, tri.points[1].y,
      color, offset_zoom_param);
01472     adl_line_draw(screen_mat, tri.points[1].x, tri.points[1].y, tri.points[2].x, tri.points[2].y,
      color, offset_zoom_param);
01473     adl_line_draw(screen_mat, tri.points[2].x, tri.points[2].y, tri.points[0].x, tri.points[0].y,
      color, offset_zoom_param);
01474
01475     // adl_draw_arrow(screen_mat, tri.points[0].x, tri.points[0].y, tri.points[1].x, tri.points[1].y,
      0.3, 22, color);
01476     // adl_draw_arrow(screen_mat, tri.points[1].x, tri.points[1].y, tri.points[2].x, tri.points[2].y,
      0.3, 22, color);
01477     // adl_draw_arrow(screen_mat, tri.points[2].x, tri.points[2].y, tri.points[0].x, tri.points[0].y,
      0.3, 22, color);
01478 }
01479
01492 void adl_tri_fill_Pinedas_rasterizer(Mat2D_uint32 screen_mat, Mat2D inv_z_buffer, Tri tri, uint32_t
      color, Offset_zoom_param offset_zoom_param)
01493 {
01494     /* This function follows the rasterizer of 'Pikuma' shown in his YouTube video. You can fine the
      video in this link: https://youtu.be/k5wtuKWmV48. */
01495
01496     Point p0, p1, p2;
01497     p0 = tri.points[0];
01498     p1 = tri.points[1];
01499     p2 = tri.points[2];
01500
01501     /* finding bounding box */
01502     int x_min = fmin(p0.x, fmin(p1.x, p2.x));
01503     int x_max = fmax(p0.x, fmax(p1.x, p2.x));
01504     int y_min = fmin(p0.y, fmin(p1.y, p2.y));
01505     int y_max = fmax(p0.y, fmax(p1.y, p2.y));
01506
01507     /* Clamp to screen bounds */
01508     if (x_min < 0) x_min = 0;
01509     if (y_min < 0) y_min = 0;
01510     if (x_max >= (int)screen_mat.cols) x_max = screen_mat.cols - 1;
01511     if (y_max >= (int)screen_mat.rows) y_max = screen_mat.rows - 1;
01512
01513     /* draw only outline of the tri if there is no area */
01514     float w = edge_cross_point(p0, p1, p1, p2);
01515     if (fabsf(w) < 1e-6) {
01516         // adl_tri_draw(screen_mat, tri, tri.colors[0], offset_zoom_param);
01517         return;
01518     }
01519     MATRIX2D_ASSERT(fabsf(w) > 1e-6 && "triangle must have area");
01520
01521     /* fill conventions */
01522     int bias0 = is_top_left(p0, p1) ? 0 : -1;
01523     int bias1 = is_top_left(p1, p2) ? 0 : -1;
01524     int bias2 = is_top_left(p2, p0) ? 0 : -1;
01525
01526     for (int y = y_min; y <= y_max; y++) {
01527         for (int x = x_min; x <= x_max; x++) {
01528             Point p = {.x = x, .y = y, .z = 0};
01529
01530             float w0 = edge_cross_point(p0, p1, p0, p) + bias0;
01531             float w1 = edge_cross_point(p1, p2, p1, p) + bias1;
01532             float w2 = edge_cross_point(p2, p0, p2, p) + bias2;
01533
01534             float alpha = fabs(w1 / w);
01535             float beta  = fabs(w2 / w);
01536             float gamma = fabs(w0 / w);
01537
01538             if (w0 * w >= 0 && w1 * w >= 0 &&  w2 * w >= 0) {
01539                 int r, b, g, a;
01540                 HexARGB_RGBA_VAR(color, r, g, b, a);
01541                 float light_intensity = (tri.light_intensity[0] + tri.light_intensity[1] +
      tri.light_intensity[2]) / 3;
01542                 float rf = r * light_intensity;
01543                 float gf = g * light_intensity;
01544                 float bf = b * light_intensity;
01545                 uint8_t r8 = (uint8_t)fmaxf(0, fminf(255, rf));
```

```
01546                 uint8_t g8 = (uint8_t)fmaxf(0, fminf(255, gf));
01547                 uint8_t b8 = (uint8_t)fmaxf(0, fminf(255, bf));
01548 
01549                 double inv_w = alpha * (1.0 / p0.w) + beta  * (1.0 / p1.w) + gamma * (1.0 / p2.w);
01550                 double z_over_w = alpha * (p0.z / p0.w) + beta  * (p1.z / p1.w) + gamma * (p2.z /
      p2.w);
01551                 double inv_z = inv_w / z_over_w;
01552 
01553                 if (inv_z >= MAT2D_AT(inv_z_buffer, y, x)) {
01554                     adl_point_draw(screen_mat, x, y, RGBA_hexARGB(r8, g8, b8, a), offset_zoom_param);
01555                     MAT2D_AT(inv_z_buffer, y, x) = inv_z;
01556                 }
01557             }
01558         }
01559     }
01560 }
01561 
01573 void adl_tri_fill_Pinedas_rasterizer_interpolate_color(Mat2D_uint32 screen_mat, Mat2D inv_z_buffer,
      Tri tri, Offset_zoom_param offset_zoom_param)
01574 {
01575     /* This function follows the rasterizer of 'Pikuma' shown in his YouTube video. You can fine the
      video in this link: https://youtu.be/k5wtuKWmV48. */
01576     Point p0, p1, p2;
01577     p0 = tri.points[0];
01578     p1 = tri.points[1];
01579     p2 = tri.points[2];
01580 
01581     float w = edge_cross_point(p0, p1, p1, p2);
01582     if (fabsf(w) < 1e-6) {
01583         // adl_tri_draw(screen_mat, tri, tri.colors[0], offset_zoom_param);
01584         return;
01585     }
01586     MATRIX2D_ASSERT(w != 0 && "triangle has area");
01587 
01588     /* fill conventions */
01589     int bias0 = is_top_left(p0, p1) ? 0 : -1;
01590     int bias1 = is_top_left(p1, p2) ? 0 : -1;
01591     int bias2 = is_top_left(p2, p0) ? 0 : -1;
01592 
01593     /* finding bounding box */
01594     int x_min = fmin(p0.x, fmin(p1.x, p2.x));
01595     int x_max = fmax(p0.x, fmax(p1.x, p2.x));
01596     int y_min = fmin(p0.y, fmin(p1.y, p2.y));
01597     int y_max = fmax(p0.y, fmax(p1.y, p2.y));
01598     // printf("xmin: %d, xmax: %d || ymin: %d, ymax: %d\n", x_min, x_max, y_min, y_max);
01599 
01600     /* Clamp to screen bounds */
01601     if (x_min < 0) x_min = 0;
01602     if (y_min < 0) y_min = 0;
01603     if (x_max >= (int)screen_mat.cols) x_max = screen_mat.cols - 1;
01604     if (y_max >= (int)screen_mat.rows) y_max = screen_mat.rows - 1;
01605 
01606     for (int y = y_min; y <= y_max; y++) {
01607         for (int x = x_min; x <= x_max; x++) {
01608             Point p = {.x = x, .y = y, .z = 0};
01609 
01610             float w0 = edge_cross_point(p0, p1, p0, p) + bias0;
01611             float w1 = edge_cross_point(p1, p2, p1, p) + bias1;
01612             float w2 = edge_cross_point(p2, p0, p2, p) + bias2;
01613 
01614             float alpha = fabs(w1 / w);
01615             float beta  = fabs(w2 / w);
01616             float gamma = fabs(w0 / w);
01617 
01618             if (w0 * w >= 0 && w1 * w >= 0 &&  w2 * w >= 0) {
01619                 int r0, b0, g0, a0;
01620                 int r1, b1, g1, a1;
01621                 int r2, b2, g2, a2;
01622                 HexARGB_RGBA_VAR(tri.colors[0], r0, g0, b0, a0);
01623                 HexARGB_RGBA_VAR(tri.colors[1], r1, g1, b1, a1);
01624                 HexARGB_RGBA_VAR(tri.colors[2], r2, g2, b2, a2);
01625 
01626                 uint8_t current_r = r0*alpha + r1*beta + r2*gamma;
01627                 uint8_t current_g = g0*alpha + g1*beta + g2*gamma;
01628                 uint8_t current_b = b0*alpha + b1*beta + b2*gamma;
01629                 uint8_t current_a = a0*alpha + a1*beta + a2*gamma;
01630 
01631                 float light_intensity = (tri.light_intensity[0] + tri.light_intensity[1] +
      tri.light_intensity[2]) / 3;
01632                 float rf = current_r * light_intensity;
01633                 float gf = current_g * light_intensity;
01634                 float bf = current_b * light_intensity;
01635                 uint8_t r8 = (uint8_t)fmaxf(0, fminf(255, rf));
01636                 uint8_t g8 = (uint8_t)fmaxf(0, fminf(255, gf));
01637                 uint8_t b8 = (uint8_t)fmaxf(0, fminf(255, bf));
01638 
01639                 double inv_w = alpha * (1.0 / p0.w) + beta  * (1.0 / p1.w) + gamma * (1.0 / p2.w);
```

```
01640                 double z_over_w = alpha * (p0.z / p0.w) + beta  * (p1.z / p1.w) + gamma * (p2.z /
      p2.w);
01641                 double inv_z = inv_w / z_over_w;
01642 
01643                 if (inv_z >= MAT2D_AT(inv_z_buffer, y, x)) {
01644                     adl_point_draw(screen_mat, x, y, RGBA_hexARGB(r8, g8, b8, current_a),
      offset_zoom_param);
01645                     MAT2D_AT(inv_z_buffer, y, x) = inv_z;
01646                 }
01647             }
01648         }
01649     }
01650 }
01651 
01664 void adl_tri_fill_Pinedas_rasterizer_interpolate_normal(Mat2D_uint32 screen_mat, Mat2D inv_z_buffer,
      Tri tri, uint32_t color, Offset_zoom_param offset_zoom_param)
01665 {
01666     /* This function follows the rasterizer of 'Pikuma' shown in his YouTube video. You can fine the
      video in this link: https://youtu.be/k5wtuKWmV48. */
01667     Point p0, p1, p2;
01668     p0 = tri.points[0];
01669     p1 = tri.points[1];
01670     p2 = tri.points[2];
01671 
01672     float w = edge_cross_point(p0, p1, p1, p2);
01673     if (fabsf(w) < 1e-6) {
01674         // adl_tri_draw(screen_mat, tri, tri.colors[0], offset_zoom_param);
01675         return;
01676     }
01677     MATRIX2D_ASSERT(w != 0 && "triangle has area");
01678 
01679     /* fill conventions */
01680     int bias0 = is_top_left(p0, p1) ? 0 : -1;
01681     int bias1 = is_top_left(p1, p2) ? 0 : -1;
01682     int bias2 = is_top_left(p2, p0) ? 0 : -1;
01683 
01684     /* finding bounding box */
01685     int x_min = fmin(p0.x, fmin(p1.x, p2.x));
01686     int x_max = fmax(p0.x, fmax(p1.x, p2.x));
01687     int y_min = fmin(p0.y, fmin(p1.y, p2.y));
01688     int y_max = fmax(p0.y, fmax(p1.y, p2.y));
01689     // printf("xmin: %d, xmax: %d || ymin: %d, ymax: %d\n", x_min, x_max, y_min, y_max);
01690 
01691     /* Clamp to screen bounds */
01692     if (x_min < 0) x_min = 0;
01693     if (y_min < 0) y_min = 0;
01694     if (x_max >= (int)screen_mat.cols) x_max = screen_mat.cols - 1;
01695     if (y_max >= (int)screen_mat.rows) y_max = screen_mat.rows - 1;
01696 
01697     int r, b, g, a;
01698     HexARGB_RGBA_VAR(color, r, g, b, a);
01699 
01700     for (int y = y_min; y <= y_max; y++) {
01701         for (int x = x_min; x <= x_max; x++) {
01702             Point p = {.x = x, .y = y, .z = 0};
01703 
01704             float w0 = edge_cross_point(p0, p1, p0, p) + bias0;
01705             float w1 = edge_cross_point(p1, p2, p1, p) + bias1;
01706             float w2 = edge_cross_point(p2, p0, p2, p) + bias2;
01707 
01708             float alpha = fabs(w1 / w);
01709             float beta  = fabs(w2 / w);
01710             float gamma = fabs(w0 / w);
01711 
01712             if (w0 * w >= 0 && w1 * w >= 0 &&  w2 * w >= 0) {
01713 
01714                 float light_intensity = tri.light_intensity[0]*alpha + tri.light_intensity[1]*beta +
      tri.light_intensity[2]*gamma;
01715 
01716                 float rf = r * light_intensity;
01717                 float gf = g * light_intensity;
01718                 float bf = b * light_intensity;
01719                 uint8_t r8 = (uint8_t)fmaxf(0, fminf(255, rf));
01720                 uint8_t g8 = (uint8_t)fmaxf(0, fminf(255, gf));
01721                 uint8_t b8 = (uint8_t)fmaxf(0, fminf(255, bf));
01722 
01723                 double inv_w = alpha * (1.0 / p0.w) + beta  * (1.0 / p1.w) + gamma * (1.0 / p2.w);
01724                 double z_over_w = alpha * (p0.z / p0.w) + beta  * (p1.z / p1.w) + gamma * (p2.z /
      p2.w);
01725                 double inv_z = inv_w / z_over_w;
01726 
01727                 if (inv_z >= MAT2D_AT(inv_z_buffer, y, x)) {
01728                     adl_point_draw(screen_mat, x, y, RGBA_hexARGB(r8, g8, b8, a), offset_zoom_param);
01729                     MAT2D_AT(inv_z_buffer, y, x) = inv_z;
01730                 }
01731             }
01732         }
```

```
01733     }
01734 }
01735
01746 void adl_tri_mesh_draw(Mat2D_uint32 screen_mat, Tri_mesh mesh, uint32_t color, Offset_zoom_param
       offset_zoom_param)
01747 {
01748     for (size_t i = 0; i < mesh.length; i++) {
01749         Tri tri = mesh.elements[i];
01750         if (tri.to_draw) {
01751             // color = rand_double() * 0xFFFFFFFF;
01752             adl_tri_draw(screen_mat, tri, color, offset_zoom_param);
01753         }
01754     }
01755 }
01756
01768 void adl_tri_mesh_fill_Pinedas_rasterizer(Mat2D_uint32 screen_mat, Mat2D inv_z_buffer_mat, Tri_mesh
       mesh, uint32_t color, Offset_zoom_param offset_zoom_param)
01769 {
01770     for (size_t i = 0; i < mesh.length; i++) {
01771         Tri tri = mesh.elements[i];
01772         /* Reject invalid triangles */
01773         adl_assert_tri_is_valid(tri);
01774
01775         if (!tri.to_draw) continue;
01776
01777         adl_tri_fill_Pinedas_rasterizer(screen_mat, inv_z_buffer_mat, tri, color, offset_zoom_param);
01778     }
01779 }
01780
01792 void adl_tri_mesh_fill_Pinedas_rasterizer_interpolate_color(Mat2D_uint32 screen_mat, Mat2D
       inv_z_buffer_mat, Tri_mesh mesh, Offset_zoom_param offset_zoom_param)
01793 {
01794     for (size_t i = 0; i < mesh.length; i++) {
01795         Tri tri = mesh.elements[i];
01796         /* Reject invalid triangles */
01797         adl_assert_tri_is_valid(tri);
01798
01799         if (!tri.to_draw) continue;
01800
01801         adl_tri_fill_Pinedas_rasterizer_interpolate_color(screen_mat, inv_z_buffer_mat, tri,
       offset_zoom_param);
01802     }
01803 }
01804
01817 void adl_tri_mesh_fill_Pinedas_rasterizer_interpolate_normal(Mat2D_uint32 screen_mat, Mat2D
       inv_z_buffer_mat, Tri_mesh mesh, uint32_t color, Offset_zoom_param offset_zoom_param)
01818 {
01819     for (size_t i = 0; i < mesh.length; i++) {
01820         Tri tri = mesh.elements[i];
01821         /* Reject invalid triangles */
01822         adl_assert_tri_is_valid(tri);
01823
01824         if (!tri.to_draw) continue;
01825
01826         adl_tri_fill_Pinedas_rasterizer_interpolate_normal(screen_mat, inv_z_buffer_mat, tri, color,
       offset_zoom_param);
01827     }
01828 }
01829
01845 float adl_tan_half_angle(Point vi, Point vj, Point p, float li, float lj)
01846 {
01847     float ax = vi.x - p.x, ay = vi.y - p.y;
01848     float bx = vj.x - p.x, by = vj.y - p.y;
01849     float dot = ax * bx + ay * by;
01850     float cross = ax * by - ay * bx;              // signed 2D cross (scalar)
01851     float denom = dot + li * lj;                   // = |a||b|(1 + cos(alpha))
01852     return fabsf(cross) / fmaxf(1e-20f, denom);    // tan(alpha/2)
01853 }
01854
01865 float adl_linear_map(float s, float min_in, float max_in, float min_out, float max_out)
01866 {
01867     return (min_out + ((s-min_in)*(max_out-min_out))/(max_in-min_in));
01868 }
01869
01885 void adl_quad2tris(Quad quad, Tri *tri1, Tri *tri2, char split_line[])
01886 {
01887     if (!strncmp(split_line, "02", 2)) {
01888         tri1->points[0] = quad.points[0];
01889         tri1->points[1] = quad.points[1];
01890         tri1->points[2] = quad.points[2];
01891         tri1->to_draw = quad.to_draw;
01892         tri1->light_intensity[0] = quad.light_intensity[0];
01893         tri1->light_intensity[1] = quad.light_intensity[1];
01894         tri1->light_intensity[2] = quad.light_intensity[2];
01895         tri1->colors[0] = quad.colors[0];
01896         tri1->colors[1] = quad.colors[1];
01897         tri1->colors[2] = quad.colors[2];
```

```
01898
01899         tri2->points[0] = quad.points[2];
01900         tri2->points[1] = quad.points[3];
01901         tri2->points[2] = quad.points[0];
01902         tri2->to_draw = quad.to_draw;
01903         tri1->light_intensity[0] = quad.light_intensity[2];
01904         tri1->light_intensity[1] = quad.light_intensity[3];
01905         tri1->light_intensity[2] = quad.light_intensity[0];
01906         tri2->colors[0] = quad.colors[2];
01907         tri2->colors[1] = quad.colors[3];
01908         tri2->colors[2] = quad.colors[0];
01909     } else if (!strncmp(split_line, "13", 2)) {
01910         tri1->points[0] = quad.points[1];
01911         tri1->points[1] = quad.points[2];
01912         tri1->points[2] = quad.points[3];
01913         tri1->to_draw = quad.to_draw;
01914         tri1->light_intensity[0] = quad.light_intensity[1];
01915         tri1->light_intensity[1] = quad.light_intensity[2];
01916         tri1->light_intensity[2] = quad.light_intensity[3];
01917         tri1->colors[0] = quad.colors[1];
01918         tri1->colors[1] = quad.colors[2];
01919         tri1->colors[2] = quad.colors[3];
01920
01921         tri2->points[0] = quad.points[3];
01922         tri2->points[1] = quad.points[0];
01923         tri2->points[2] = quad.points[1];
01924         tri2->to_draw = quad.to_draw;
01925         tri1->light_intensity[0] = quad.light_intensity[3];
01926         tri1->light_intensity[1] = quad.light_intensity[0];
01927         tri1->light_intensity[2] = quad.light_intensity[1];
01928         tri2->colors[0] = quad.colors[3];
01929         tri2->colors[1] = quad.colors[0];
01930         tri2->colors[2] = quad.colors[1];
01931     }
01932 }
01933
01945 void adl_linear_sRGB_to_okLab(uint32_t hex_ARGB, float *L, float *a, float *b)
01946 {
01947     /* https://bottosson.github.io/posts/oklab/
01948        https://en.wikipedia.org/wiki/Oklab_color_space */
01949     int R_255, G_255, B_255;
01950     HexARGB_RGB_VAR(hex_ARGB, R_255, G_255, B_255);
01951
01952     float R = R_255;
01953     float G = G_255;
01954     float B = B_255;
01955
01956     float l = 0.4122214705f * R + 0.5363325363f * G + 0.0514459929f * B;
01957     float m = 0.2119034982f * R + 0.6806995451f * G + 0.1073969566f * B;
01958     float s = 0.0883024619f * R + 0.2817188376f * G + 0.6299787005f * B;
01959
01960     float l_ = cbrtf(l);
01961     float m_ = cbrtf(m);
01962     float s_ = cbrtf(s);
01963
01964     *L = 0.2104542553f * l_ + 0.7936177850f * m_ - 0.0040720468f * s_;
01965     *a = 1.9779984951f * l_ - 2.4285922050f * m_ + 0.4505937099f * s_;
01966     *b = 0.0259040371f * l_ + 0.7827717662f * m_ - 0.8086757660f * s_;
01967
01968 }
01969
01980 void adl_okLab_to_linear_sRGB(float L, float a, float b, uint32_t *hex_ARGB)
01981 {
01982     /* https://bottosson.github.io/posts/oklab/
01983        https://en.wikipedia.org/wiki/Oklab_color_space */
01984
01985     float l_ = L + 0.3963377774f * a + 0.2158037573f * b;
01986     float m_ = L - 0.1055613458f * a - 0.0638541728f * b;
01987     float s_ = L - 0.0894841775f * a - 1.2914855480f * b;
01988
01989     float l = l_ * l_ * l_;
01990     float m = m_ * m_ * m_;
01991     float s = s_ * s_ * s_;
01992
01993     float R = + 4.0767416621f * l - 3.3077115913f * m + 0.2309699292f * s;
01994     float G = - 1.2684380046f * l + 2.6097574011f * m - 0.3413193965f * s;
01995     float B = - 0.0041960863f * l - 0.7034186147f * m + 1.7076147010f * s;
01996
01997     R = fmaxf(fminf(R, 255), 0);
01998     G = fmaxf(fminf(G, 255), 0);
01999     B = fmaxf(fminf(B, 255), 0);
02000
02001     *hex_ARGB = RGBA_hexARGB(R, G, B, 0xFF);
02002 }
02003
02012 void adl_linear_sRGB_to_okLch(uint32_t hex_ARGB, float *L, float *c, float *h_deg)
02013 {
```

```
02014     float a, b;
02015     adl_linear_sRGB_to_okLab(hex_ARGB, L, &a, &b);
02016
02017     *c = sqrtf(a * a + b * b);
02018     *h_deg = atan2f(b, a) * 180 / PI;
02019 }
02020
02031 void adl_okLch_to_linear_sRGB(float L, float c, float h_deg, uint32_t *hex_ARGB)
02032 {
02033     h_deg = fmodf((h_deg + 360), 360);
02034     float a = c * cosf(h_deg * PI / 180);
02035     float b = c * sinf(h_deg * PI / 180);
02036     adl_okLab_to_linear_sRGB(L, a, b, hex_ARGB);
02037 }
02038
02053 void adl_interpolate_ARGBcolor_on_okLch(uint32_t color1, uint32_t color2, float t, float
      num_of_rotations, uint32_t *color_out)
02054 {
02055     float L_1, c_1, h_1;
02056     float L_2, c_2, h_2;
02057     adl_linear_sRGB_to_okLch(color1, &L_1, &c_1, &h_1);
02058     adl_linear_sRGB_to_okLch(color2, &L_2, &c_2, &h_2);
02059     h_2 = h_2 + 360 * num_of_rotations;
02060
02061     float L, c, h;
02062     L = L_1 * (1 - t) + L_2 * (t);
02063     c = c_1 * (1 - t) + c_2 * (t);
02064     h = h_1 * (1 - t) + h_2 * (t);
02065     adl_okLch_to_linear_sRGB(L, c, h, color_out);
02066 }
02067
02081 Figure adl_figure_alloc(size_t rows, size_t cols, Point top_left_position)
02082 {
02083     ADL_ASSERT(rows && cols);
02084     adl_assert_point_is_valid(top_left_position);
02085
02086     Figure figure = {0};
02087     figure.pixels_mat = mat2D_alloc_uint32(rows, cols);
02088     figure.inv_z_buffer_mat = mat2D_alloc(rows, cols);
02089     memset(figure.inv_z_buffer_mat.elements, 0x0, sizeof(double) * figure.inv_z_buffer_mat.rows *
      figure.inv_z_buffer_mat.cols);
02090     ada_init_array(Curve, figure.src_curve_array);
02091
02092     figure.top_left_position = top_left_position;
02093
02094     int max_i    = (int)(figure.pixels_mat.rows);
02095     int max_j    = (int)(figure.pixels_mat.cols);
02096     int offset_i = (int)fminf(figure.pixels_mat.rows * ADL_FIGURE_PADDING_PRECENTAGE / 100.0f,
      ADL_MAX_FIGURE_PADDING);
02097     int offset_j = (int)fminf(figure.pixels_mat.cols * ADL_FIGURE_PADDING_PRECENTAGE / 100.0f,
      ADL_MAX_FIGURE_PADDING);
02098
02099     figure.min_x_pixel = offset_j;
02100     figure.max_x_pixel = max_j - offset_j;
02101     figure.min_y_pixel = offset_i;
02102     figure.max_y_pixel = max_i - offset_i;
02103
02104     figure.min_x = + FLT_MAX;
02105     figure.max_x = - FLT_MAX;
02106     figure.min_y = + FLT_MAX;
02107     figure.max_y = - FLT_MAX;
02108
02109     figure.offset_zoom_param = ADL_DEFAULT_OFFSET_ZOOM;
02110
02111     return figure;
02112 }
02113
02124 void adl_figure_copy_to_screen(Mat2D_uint32 screen_mat, Figure figure)
02125 {
02126     for (size_t i = 0; i < figure.pixels_mat.rows; i++) {
02127         for (size_t j = 0; j < figure.pixels_mat.cols; j++) {
02128             int offset_i = figure.top_left_position.y;
02129             int offset_j = figure.top_left_position.x;
02130
02131             adl_point_draw(screen_mat, offset_j+j, offset_i+i, MAT2D_AT_UINT32(figure.pixels_mat, i,
      j), (Offset_zoom_param){1,0,0,0,0});
02132         }
02133     }
02134 }
02135
02144 void adl_axis_draw_on_figure(Figure *figure)
02145 {
02146     int max_i    = (int)(figure->pixels_mat.rows);
02147     int max_j    = (int)(figure->pixels_mat.cols);
02148     int offset_i = (int)fmaxf(fminf(figure->pixels_mat.rows * ADL_FIGURE_PADDING_PRECENTAGE / 100.0f,
      ADL_MAX_FIGURE_PADDING), ADL_MIN_FIGURE_PADDING);
02149     int offset_j = (int)fmaxf(fminf(figure->pixels_mat.cols * ADL_FIGURE_PADDING_PRECENTAGE / 100.0f,
```

```
      ADL_MAX_FIGURE_PADDING), ADL_MIN_FIGURE_PADDING);
02150
02151     int arrow_head_size_x = (int)fminf(ADL_MAX_HEAD_SIZE, ADL_FIGURE_PADDING_PRECENTAGE / 100.0f *
      (max_j - 2 * offset_j));
02152     int arrow_head_size_y = (int)fminf(ADL_MAX_HEAD_SIZE, ADL_FIGURE_PADDING_PRECENTAGE / 100.0f *
      (max_i - 2 * offset_i));
02153
02154     adl_arrow_draw(figure->pixels_mat, figure->min_x_pixel, figure->max_y_pixel, figure->max_x_pixel,
      figure->max_y_pixel, (float)arrow_head_size_x / (max_j-2*offset_j), ADL_FIGURE_HEAD_ANGLE_DEG,
      ADL_FIGURE_AXIS_COLOR, figure->offset_zoom_param);
02155     adl_arrow_draw(figure->pixels_mat, figure->min_x_pixel, figure->max_y_pixel, figure->min_x_pixel,
      figure->min_y_pixel, (float)arrow_head_size_y / (max_i-2*offset_i), ADL_FIGURE_HEAD_ANGLE_DEG,
      ADL_FIGURE_AXIS_COLOR, figure->offset_zoom_param);
02156     // adl_draw_rectangle_min_max(figure->pixels_mat, figure->min_x_pixel, figure->max_x_pixel,
      figure->min_y_pixel, figure->max_y_pixel, 0);
02157
02158     figure->x_axis_head_size = arrow_head_size_x;
02159     figure->y_axis_head_size = arrow_head_size_y;
02160 }
02161
02170 void adl_max_min_values_draw_on_figure(Figure figure)
02171 {
02172     char x_min_sentence[256];
02173     char x_max_sentence[256];
02174     snprintf(x_min_sentence, 256, "%g", figure.min_x);
02175     snprintf(x_max_sentence, 256, "%g", figure.max_x);
02176
02177     int x_sentence_hight_pixel = (figure.pixels_mat.rows - figure.max_y_pixel -
      ADL_MIN_CHARACTER_OFFSET * 3);
02178     int x_min_char_width_pixel = x_sentence_hight_pixel / 2;
02179     int x_max_char_width_pixel = x_sentence_hight_pixel / 2;
02180
02181     int x_min_sentence_width_pixel = (int)fminf((figure.max_x_pixel - figure.min_x_pixel)/2,
      (x_min_char_width_pixel + ADL_MAX_CHARACTER_OFFSET)*strlen(x_min_sentence));
02182     x_min_char_width_pixel = x_min_sentence_width_pixel / strlen(x_min_sentence) -
      ADL_MIN_CHARACTER_OFFSET;
02183
02184     int x_max_sentence_width_pixel = (int)fminf((figure.max_x_pixel - figure.min_x_pixel)/2,
      (x_max_char_width_pixel + ADL_MAX_CHARACTER_OFFSET)*strlen(x_max_sentence)) -
      figure.x_axis_head_size;
02185     x_max_char_width_pixel = (x_max_sentence_width_pixel + figure.x_axis_head_size) /
      strlen(x_max_sentence) - ADL_MIN_CHARACTER_OFFSET;
02186
02187     int x_min_sentence_hight_pixel = (int)fminf(x_min_char_width_pixel * 2, x_sentence_hight_pixel);
02188     int x_max_sentence_hight_pixel = (int)fminf(x_max_char_width_pixel * 2, x_sentence_hight_pixel);
02189
02190     x_min_sentence_hight_pixel = (int)fminf(x_min_sentence_hight_pixel, x_max_sentence_hight_pixel);
02191     x_max_sentence_hight_pixel = x_min_sentence_hight_pixel;
02192
02193     int x_max_x_top_left = figure.max_x_pixel - strlen(x_max_sentence) * (x_max_sentence_hight_pixel /
      2 + ADL_MIN_CHARACTER_OFFSET) - figure.x_axis_head_size;
02194
02195     adl_sentence_draw(figure.pixels_mat, x_min_sentence, strlen(x_min_sentence), figure.min_x_pixel,
      figure.max_y_pixel+ADL_MIN_CHARACTER_OFFSET*2, x_min_sentence_hight_pixel, ADL_FIGURE_AXIS_COLOR,
      figure.offset_zoom_param);
02196     adl_sentence_draw(figure.pixels_mat, x_max_sentence, strlen(x_max_sentence), x_max_x_top_left,
      figure.max_y_pixel+ADL_MIN_CHARACTER_OFFSET*2, x_max_sentence_hight_pixel, ADL_FIGURE_AXIS_COLOR,
      figure.offset_zoom_param);
02197
02198     char y_min_sentence[256];
02199     char y_max_sentence[256];
02200     snprintf(y_min_sentence, 256, "%g", figure.min_y);
02201     snprintf(y_max_sentence, 256, "%g", figure.max_y);
02202
02203     int y_sentence_width_pixel = figure.min_x_pixel - ADL_MAX_CHARACTER_OFFSET -
      figure.y_axis_head_size;
02204     int y_max_char_width_pixel = y_sentence_width_pixel;
02205     y_max_char_width_pixel /= strlen(y_max_sentence);
02206     int y_max_sentence_hight_pixel = y_max_char_width_pixel * 2;
02207
02208     int y_min_char_width_pixel = y_sentence_width_pixel;
02209     y_min_char_width_pixel /= strlen(y_min_sentence);
02210     int y_min_sentence_hight_pixel = y_min_char_width_pixel * 2;
02211
02212     y_min_sentence_hight_pixel = (int)fmaxf(fminf(y_min_sentence_hight_pixel,
      y_max_sentence_hight_pixel), 1);
02213     y_max_sentence_hight_pixel = y_min_sentence_hight_pixel;
02214
02215     adl_sentence_draw(figure.pixels_mat, y_max_sentence, strlen(y_max_sentence),
      ADL_MAX_CHARACTER_OFFSET/2, figure.min_y_pixel, y_max_sentence_hight_pixel, ADL_FIGURE_AXIS_COLOR,
      figure.offset_zoom_param);
02216     adl_sentence_draw(figure.pixels_mat, y_min_sentence, strlen(y_min_sentence),
      ADL_MAX_CHARACTER_OFFSET/2, figure.max_y_pixel-y_min_sentence_hight_pixel,
      y_min_sentence_hight_pixel, ADL_FIGURE_AXIS_COLOR, figure.offset_zoom_param);
02217 }
02218
02230 void adl_curve_add_to_figure(Figure *figure, Point *src_points, size_t src_len, uint32_t color)
```

```
02231 {
02232     Curve src_points_ada;
02233     ada_init_array(Point, src_points_ada);
02234     src_points_ada.color = color;
02235 
02236     for (size_t i = 0; i < src_len; i++) {
02237         Point current_point = src_points[i];
02238         if (current_point.x > figure->max_x) {
02239             figure->max_x = current_point.x;
02240         }
02241         if (current_point.y > figure->max_y) {
02242             figure->max_y = current_point.y;
02243         }
02244         if (current_point.x < figure->min_x) {
02245             figure->min_x = current_point.x;
02246         }
02247         if (current_point.y < figure->min_y) {
02248             figure->min_y = current_point.y;
02249         }
02250         ada_append(Point, src_points_ada, current_point);
02251     }
02252 
02253     ada_append(Curve, figure->src_curve_array, src_points_ada);
02254 }
02255 
02265 void adl_curves_plot_on_figure(Figure figure)
02266 {
02267     mat2D_fill_uint32(figure.pixels_mat, figure.background_color);
02268     memset(figure.inv_z_buffer_mat.elements, 0x0, sizeof(double) * figure.inv_z_buffer_mat.rows *
       figure.inv_z_buffer_mat.cols);
02269     if (figure.to_draw_axis) adl_axis_draw_on_figure(&figure);
02270 
02271     for (size_t curve_index = 0; curve_index < figure.src_curve_array.length; curve_index++) {
02272         size_t src_len = figure.src_curve_array.elements[curve_index].length;
02273         Point *src_points = figure.src_curve_array.elements[curve_index].elements;
02274         for (size_t i = 0; i < src_len-1; i++) {
02275             Point src_start = src_points[i];
02276             Point src_end   = src_points[i+1];
02277             Point des_start = {0};
02278             Point des_end = {0};
02279 
02280             des_start.x = adl_linear_map(src_start.x, figure.min_x, figure.max_x, figure.min_x_pixel,
       figure.max_x_pixel);
02281             des_start.y = ((figure.max_y_pixel + figure.min_y_pixel) - adl_linear_map(src_start.y,
       figure.min_y, figure.max_y, figure.min_y_pixel, figure.max_y_pixel));
02282 
02283             des_end.x = adl_linear_map(src_end.x, figure.min_x, figure.max_x, figure.min_x_pixel,
       figure.max_x_pixel);
02284             des_end.y = ((figure.max_y_pixel + figure.min_y_pixel) - adl_linear_map(src_end.y,
       figure.min_y, figure.max_y, figure.min_y_pixel, figure.max_y_pixel));
02285 
02286             adl_line_draw(figure.pixels_mat, des_start.x, des_start.y, des_end.x, des_end.y,
       figure.src_curve_array.elements[curve_index].color, figure.offset_zoom_param);
02287         }
02288     }
02289 
02290     if (figure.to_draw_max_min_values) adl_max_min_values_draw_on_figure(figure);
02291 }
02292 
02293 /* check offset2D. might convert it to a Mat2D */
02294 #define adl_offset2d(i, j, ni) (j) * (ni) + (i)
02314 void adl_2Dscalar_interp_on_figure(Figure figure, double *x_2Dmat, double *y_2Dmat, double
       *scalar_2Dmat, int ni, int nj, char color_scale[], float num_of_rotations)
02315 {
02316     mat2D_fill_uint32(figure.pixels_mat, figure.background_color);
02317     memset(figure.inv_z_buffer_mat.elements, 0x0, sizeof(double) * figure.inv_z_buffer_mat.rows *
       figure.inv_z_buffer_mat.cols);
02318     if (figure.to_draw_axis) adl_axis_draw_on_figure(&figure);
02319 
02320     float min_scalar = FLT_MAX;
02321     float max_scalar = FLT_MIN;
02322     for (int i = 0; i < ni; i++) {
02323         for (int j = 0; j < nj; j++) {
02324             float val = scalar_2Dmat[adl_offset2d(i, j, ni)];
02325             if (val > max_scalar) max_scalar = val;
02326             if (val < min_scalar) min_scalar = val;
02327             float current_x = x_2Dmat[adl_offset2d(i, j, ni)];
02328             float current_y = y_2Dmat[adl_offset2d(i, j, ni)];
02329             if (current_x > figure.max_x) {
02330                 figure.max_x = current_x;
02331             }
02332             if (current_y > figure.max_y) {
02333                 figure.max_y = current_y;
02334             }
02335             if (current_x < figure.min_x) {
02336                 figure.min_x = current_x;
02337             }
```

```
02338             if (current_y < figure.min_y) {
02339                 figure.min_y = current_y;
02340             }
02341         }
02342     }
02343
02344     float window_w = (float)figure.pixels_mat.cols;
02345     float window_h = (float)figure.pixels_mat.rows;
02346
02347     for (int i = 0; i < ni-1; i++) {
02348         for (int j = 0; j < nj-1; j++) {
02349             Quad quad = {0};
02350             quad.light_intensity[0] = 1;
02351             quad.light_intensity[1] = 1;
02352             quad.light_intensity[2] = 1;
02353             quad.light_intensity[3] = 1;
02354             quad.to_draw = 1;
02355
02356             quad.points[3].x = x_2Dmat[adl_offset2d(i  , j  , ni)];
02357             quad.points[3].y = y_2Dmat[adl_offset2d(i  , j  , ni)];
02358             quad.points[2].x = x_2Dmat[adl_offset2d(i+1, j  , ni)];
02359             quad.points[2].y = y_2Dmat[adl_offset2d(i+1, j  , ni)];
02360             quad.points[1].x = x_2Dmat[adl_offset2d(i+1, j+1, ni)];
02361             quad.points[1].y = y_2Dmat[adl_offset2d(i+1, j+1, ni)];
02362             quad.points[0].x = x_2Dmat[adl_offset2d(i  , j+1, ni)];
02363             quad.points[0].y = y_2Dmat[adl_offset2d(i  , j+1, ni)];
02364
02365             for (int p_index = 0; p_index < 4; p_index++) {
02366                 quad.points[p_index].z = 1;
02367                 quad.points[p_index].w = 1;
02368                 quad.points[p_index].x = adl_linear_map(quad.points[p_index].x, figure.min_x,
    figure.max_x, figure.min_x_pixel, figure.max_x_pixel);
02369                 quad.points[p_index].y = ((figure.max_y_pixel + figure.min_y_pixel) -
    adl_linear_map(quad.points[p_index].y, figure.min_y, figure.max_y, figure.min_y_pixel,
    figure.max_y_pixel));
02370
02371                 adl_offset_zoom_point(quad.points[p_index], window_w, window_h,
    figure.offset_zoom_param);
02372             }
02373
02374             float t3 = adl_linear_map(scalar_2Dmat[adl_offset2d(i  , j  , ni)], min_scalar,
    max_scalar, 0, 1);
02375             float t2 = adl_linear_map(scalar_2Dmat[adl_offset2d(i+1, j  , ni)], min_scalar,
    max_scalar, 0, 1);
02376             float t1 = adl_linear_map(scalar_2Dmat[adl_offset2d(i+1, j+1, ni)], min_scalar,
    max_scalar, 0, 1);
02377             float t0 = adl_linear_map(scalar_2Dmat[adl_offset2d(  i, j+1, ni)], min_scalar,
    max_scalar, 0, 1);
02378
02379             /* https://en.wikipedia.org/wiki/Oklab_color_space */
02380             if (!strcmp(color_scale, "b-c")) {
02381                 uint32_t color = 0, color1 = BLUE_hexARGB, color2 = CYAN_hexARGB;
02382                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t0, num_of_rotations, &color);
02383                 quad.colors[0] = color;
02384
02385                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t1, num_of_rotations, &color);
02386                 quad.colors[1] = color;
02387
02388                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t2, num_of_rotations, &color);
02389                 quad.colors[2] = color;
02390
02391                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t3, num_of_rotations, &color);
02392                 quad.colors[3] = color;
02393             } else if (!strcmp(color_scale, "b-g")) {
02394                 uint32_t color = 0, color1 = BLUE_hexARGB, color2 = GREEN_hexARGB;
02395                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t0, num_of_rotations, &color);
02396                 quad.colors[0] = color;
02397
02398                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t1, num_of_rotations, &color);
02399                 quad.colors[1] = color;
02400
02401                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t2, num_of_rotations, &color);
02402                 quad.colors[2] = color;
02403
02404                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t3, num_of_rotations, &color);
02405                 quad.colors[3] = color;
02406             } else if (!strcmp(color_scale, "b-r")) {
02407                 uint32_t color = 0, color1 = BLUE_hexARGB, color2 = RED_hexARGB;
02408                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t0, num_of_rotations, &color);
02409                 quad.colors[0] = color;
02410
02411                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t1, num_of_rotations, &color);
02412                 quad.colors[1] = color;
02413
02414                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t2, num_of_rotations, &color);
02415                 quad.colors[2] = color;
02416
```

```
02417                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t3, num_of_rotations, &color);
02418                 quad.colors[3] = color;
02419             } else if (!strcmp(color_scale, "b-y")) {
02420                 uint32_t color = 0, color1 = BLUE_hexARGB, color2 = YELLOW_hexARGB;
02421                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t0, num_of_rotations, &color);
02422                 quad.colors[0] = color;
02423 
02424                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t1, num_of_rotations, &color);
02425                 quad.colors[1] = color;
02426 
02427                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t2, num_of_rotations, &color);
02428                 quad.colors[2] = color;
02429 
02430                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t3, num_of_rotations, &color);
02431                 quad.colors[3] = color;
02432             } else if (!strcmp(color_scale, "g-y")) {
02433                 uint32_t color = 0, color1 = GREEN_hexARGB, color2 = YELLOW_hexARGB;
02434                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t0, num_of_rotations, &color);
02435                 quad.colors[0] = color;
02436 
02437                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t1, num_of_rotations, &color);
02438                 quad.colors[1] = color;
02439 
02440                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t2, num_of_rotations, &color);
02441                 quad.colors[2] = color;
02442 
02443                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t3, num_of_rotations, &color);
02444                 quad.colors[3] = color;
02445             } else if (!strcmp(color_scale, "g-p")) {
02446                 uint32_t color = 0, color1 = GREEN_hexARGB, color2 = PURPLE_hexARGB;
02447                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t0, num_of_rotations, &color);
02448                 quad.colors[0] = color;
02449 
02450                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t1, num_of_rotations, &color);
02451                 quad.colors[1] = color;
02452 
02453                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t2, num_of_rotations, &color);
02454                 quad.colors[2] = color;
02455 
02456                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t3, num_of_rotations, &color);
02457                 quad.colors[3] = color;
02458             } else if (!strcmp(color_scale, "g-r")) {
02459                 uint32_t color = 0, color1 = GREEN_hexARGB, color2 = RED_hexARGB;
02460                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t0, num_of_rotations, &color);
02461                 quad.colors[0] = color;
02462 
02463                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t1, num_of_rotations, &color);
02464                 quad.colors[1] = color;
02465 
02466                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t2, num_of_rotations, &color);
02467                 quad.colors[2] = color;
02468 
02469                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t3, num_of_rotations, &color);
02470                 quad.colors[3] = color;
02471             } else if (!strcmp(color_scale, "r-y")) {
02472                 uint32_t color = 0, color1 = RED_hexARGB, color2 = YELLOW_hexARGB;
02473                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t0, num_of_rotations, &color);
02474                 quad.colors[0] = color;
02475 
02476                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t1, num_of_rotations, &color);
02477                 quad.colors[1] = color;
02478 
02479                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t2, num_of_rotations, &color);
02480                 quad.colors[2] = color;
02481 
02482                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t3, num_of_rotations, &color);
02483                 quad.colors[3] = color;
02484             }
02485 
02486             adl_quad_fill_interpolate_color_mean_value(figure.pixels_mat, figure.inv_z_buffer_mat,
      quad, ADL_DEFAULT_OFFSET_ZOOM);
02487         }
02488     }
02489 
02490     if (figure.to_draw_max_min_values) {
02491         adl_max_min_values_draw_on_figure(figure);
02492     }
02493 
02494 }
02495 
02513 Grid adl_cartesian_grid_create(float min_e1, float max_e1, float min_e2, float max_e2, int
      num_samples_e1, int num_samples_e2, char plane[], float third_direction_position)
02514 {
02515     Grid grid;
02516     ada_init_array(Curve, grid.curves);
02517 
02518     grid.min_e1 = min_e1;
```

```
02519     grid.max_e1 = max_e1;
02520     grid.min_e2 = min_e2;
02521     grid.max_e2 = max_e2;
02522     grid.num_samples_e1 = num_samples_e1;
02523     grid.num_samples_e2 = num_samples_e2;
02524     strncpy(grid.plane, plane, 2);
02525
02526     float del_e1 = (max_e1 - min_e1) / num_samples_e1;
02527     float del_e2 = (max_e2 - min_e2) / num_samples_e2;
02528
02529     grid.de1 = del_e1;
02530     grid.de2 = del_e2;
02531
02532     if (!strncmp(plane, "XY", 3) || !strncmp(plane, "xy", 3)) {
02533         for (int e1_index = 0; e1_index <= num_samples_e1; e1_index++) {
02534             Curve curve;
02535             ada_init_array(Point, curve);
02536             Point point_max = {0}, point_min = {0};
02537
02538             point_min.x = min_e1 + e1_index * del_e1;
02539             point_min.y = min_e2;
02540             point_min.z = third_direction_position;
02541             point_min.w = 1;
02542
02543             point_max.x = min_e1 + e1_index * del_e1;
02544             point_max.y = max_e2;
02545             point_max.z = third_direction_position;
02546             point_max.w = 1;
02547
02548             ada_append(Point, curve, point_min);
02549             ada_append(Point, curve, point_max);
02550
02551             ada_append(Curve, grid.curves, curve);
02552         }
02553         for (int e2_index = 0; e2_index <= num_samples_e2; e2_index++) {
02554             Curve curve;
02555             ada_init_array(Point, curve);
02556             Point point_max = {0}, point_min = {0};
02557
02558             point_min.x = min_e1;
02559             point_min.y = min_e2 + e2_index * del_e2;
02560             point_min.z = third_direction_position;
02561             point_min.w = 1;
02562
02563             point_max.x = max_e1;
02564             point_max.y = min_e2 + e2_index * del_e2;
02565             point_max.z = third_direction_position;
02566             point_max.w = 1;
02567
02568             ada_append(Point, curve, point_min);
02569             ada_append(Point, curve, point_max);
02570
02571             ada_append(Curve, grid.curves, curve);
02572         }
02573     } else if (!strncmp(plane, "XZ", 3) || !strncmp(plane, "xz", 3)) {
02574         for (int e1_index = 0; e1_index <= num_samples_e1; e1_index++) {
02575             Curve curve;
02576             ada_init_array(Point, curve);
02577             Point point_max = {0}, point_min = {0};
02578
02579             point_min.x = min_e1 + e1_index * del_e1;
02580             point_min.y = third_direction_position;
02581             point_min.z = min_e2;
02582             point_min.w = 1;
02583
02584             point_max.x = min_e1 + e1_index * del_e1;
02585             point_max.y = third_direction_position;
02586             point_max.z = max_e2;
02587             point_max.w = 1;
02588
02589             ada_append(Point, curve, point_min);
02590             ada_append(Point, curve, point_max);
02591
02592             ada_append(Curve, grid.curves, curve);
02593         }
02594         for (int e2_index = 0; e2_index <= num_samples_e2; e2_index++) {
02595             Curve curve;
02596             ada_init_array(Point, curve);
02597             Point point_max = {0}, point_min = {0};
02598
02599             point_min.x = min_e1;
02600             point_min.y = third_direction_position;
02601             point_min.z = min_e2 + e2_index * del_e2;
02602             point_min.w = 1;
02603
02604             point_max.x = max_e1;
02605             point_max.y = third_direction_position;
```

```
02606             point_max.z = min_e2 + e2_index * del_e2;
02607             point_max.w = 1;
02608 
02609             ada_append(Point, curve, point_min);
02610             ada_append(Point, curve, point_max);
02611 
02612             ada_append(Curve, grid.curves, curve);
02613         }
02614     } else if (!strncmp(plane, "YX", 3) || !strncmp(plane, "yx", 3)) {
02615         for (int e1_index = 0; e1_index <= num_samples_e1; e1_index++) {
02616             Curve curve;
02617             ada_init_array(Point, curve);
02618             Point point_max = {0}, point_min = {0};
02619 
02620             point_min.x = min_e2;
02621             point_min.y = min_e1 + e1_index * del_e1;
02622             point_min.z = third_direction_position;
02623             point_min.w = 1;
02624 
02625             point_max.x = max_e2;
02626             point_max.y = min_e1 + e1_index * del_e1;
02627             point_max.z = third_direction_position;
02628             point_max.w = 1;
02629 
02630             ada_append(Point, curve, point_min);
02631             ada_append(Point, curve, point_max);
02632 
02633             ada_append(Curve, grid.curves, curve);
02634         }
02635         for (int e2_index = 0; e2_index <= num_samples_e2; e2_index++) {
02636             Curve curve;
02637             ada_init_array(Point, curve);
02638             Point point_max = {0}, point_min = {0};
02639 
02640             point_min.x = min_e2 + e2_index * del_e2;
02641             point_min.y = min_e1;
02642             point_min.z = third_direction_position;
02643             point_min.w = 1;
02644 
02645             point_max.x = min_e2 + e2_index * del_e2;
02646             point_max.y = max_e1;
02647             point_max.z = third_direction_position;
02648             point_max.w = 1;
02649 
02650             ada_append(Point, curve, point_min);
02651             ada_append(Point, curve, point_max);
02652 
02653             ada_append(Curve, grid.curves, curve);
02654         }
02655     } else if (!strncmp(plane, "YZ", 3) || !strncmp(plane, "yz", 3)) {
02656         for (int e1_index = 0; e1_index <= num_samples_e1; e1_index++) {
02657             Curve curve;
02658             ada_init_array(Point, curve);
02659             Point point_max = {0}, point_min = {0};
02660 
02661             point_min.x = third_direction_position;
02662             point_min.y = min_e1 + e1_index * del_e1;
02663             point_min.z = min_e2;
02664             point_min.w = 1;
02665 
02666             point_max.x = third_direction_position;
02667             point_max.y = min_e1 + e1_index * del_e1;
02668             point_max.z = max_e2;
02669             point_max.w = 1;
02670 
02671             ada_append(Point, curve, point_min);
02672             ada_append(Point, curve, point_max);
02673 
02674             ada_append(Curve, grid.curves, curve);
02675         }
02676         for (int e2_index = 0; e2_index <= num_samples_e2; e2_index++) {
02677             Curve curve;
02678             ada_init_array(Point, curve);
02679             Point point_max = {0}, point_min = {0};
02680 
02681             point_min.x = third_direction_position;
02682             point_min.y = min_e1;
02683             point_min.z = min_e2 + e2_index * del_e2;
02684             point_min.w = 1;
02685 
02686             point_max.x = third_direction_position;
02687             point_max.y = max_e1;
02688             point_max.z = min_e2 + e2_index * del_e2;
02689             point_max.w = 1;
02690 
02691             ada_append(Point, curve, point_min);
02692             ada_append(Point, curve, point_max);
```

```
02693
02694             ada_append(Curve, grid.curves, curve);
02695         }
02696     } else if (!strncmp(plane, "ZX", 3) || !strncmp(plane, "zx", 3)) {
02697         for (int e1_index = 0; e1_index <= num_samples_e1; e1_index++) {
02698             Curve curve;
02699             ada_init_array(Point, curve);
02700             Point point_max = {0}, point_min = {0};
02701
02702             point_min.x = min_e2;
02703             point_min.y = third_direction_position;
02704             point_min.z = min_e1 + e1_index * del_e1;
02705             point_min.w = 1;
02706
02707             point_max.x = max_e2;
02708             point_max.y = third_direction_position;
02709             point_max.z = min_e1 + e1_index * del_e1;
02710             point_max.w = 1;
02711
02712             ada_append(Point, curve, point_min);
02713             ada_append(Point, curve, point_max);
02714
02715             ada_append(Curve, grid.curves, curve);
02716         }
02717         for (int e2_index = 0; e2_index <= num_samples_e2; e2_index++) {
02718             Curve curve;
02719             ada_init_array(Point, curve);
02720             Point point_max = {0}, point_min = {0};
02721
02722             point_min.x = min_e2 + e2_index * del_e2;
02723             point_min.y = third_direction_position;
02724             point_min.z = min_e1;
02725             point_min.w = 1;
02726
02727             point_max.x = min_e2 + e2_index * del_e2;
02728             point_max.y = third_direction_position;
02729             point_max.z = max_e1;
02730             point_max.w = 1;
02731
02732             ada_append(Point, curve, point_min);
02733             ada_append(Point, curve, point_max);
02734
02735             ada_append(Curve, grid.curves, curve);
02736         }
02737     } else if (!strncmp(plane, "ZY", 3) || !strncmp(plane, "zy", 3)) {
02738         for (int e1_index = 0; e1_index <= num_samples_e1; e1_index++) {
02739             Curve curve;
02740             ada_init_array(Point, curve);
02741             Point point_max = {0}, point_min = {0};
02742
02743             point_min.x = third_direction_position;
02744             point_min.y = min_e2;
02745             point_min.z = min_e1 + e1_index * del_e1;
02746             point_min.w = 1;
02747
02748             point_max.x = third_direction_position;
02749             point_max.y = max_e2;
02750             point_max.z = min_e1 + e1_index * del_e1;
02751             point_max.w = 1;
02752
02753             ada_append(Point, curve, point_min);
02754             ada_append(Point, curve, point_max);
02755
02756             ada_append(Curve, grid.curves, curve);
02757         }
02758         for (int e2_index = 0; e2_index <= num_samples_e2; e2_index++) {
02759             Curve curve;
02760             ada_init_array(Point, curve);
02761             Point point_max = {0}, point_min = {0};
02762
02763             point_min.x = third_direction_position;
02764             point_min.y = min_e2 + e2_index * del_e2;
02765             point_min.z = min_e1;
02766             point_min.w = 1;
02767
02768             point_max.x = third_direction_position;
02769             point_max.y = min_e2 + e2_index * del_e2;
02770             point_max.z = max_e1;
02771             point_max.w = 1;
02772
02773             ada_append(Point, curve, point_min);
02774             ada_append(Point, curve, point_max);
02775
02776             ada_append(Curve, grid.curves, curve);
02777         }
02778     }
02779
```

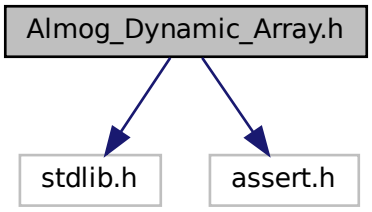
```
02780     return grid;
02781 }
02782
02791 void adl_grid_draw(Mat2D_uint32 screen_mat, Grid grid, uint32_t color, Offset_zoom_param
       offset_zoom_param)
02792 {
02793     for (size_t curve_index = 0; curve_index < grid.curves.length; curve_index++) {
02794         adl_lines_draw(screen_mat, grid.curves.elements[curve_index].elements,
       grid.curves.elements[curve_index].length, color, offset_zoom_param);
02795     }
02796 }
02797
02798 #endif /*ALMOG_DRAW_LIBRARY_IMPLEMENTATION*/
```

4.3 Almog_Dynamic_Array.h File Reference

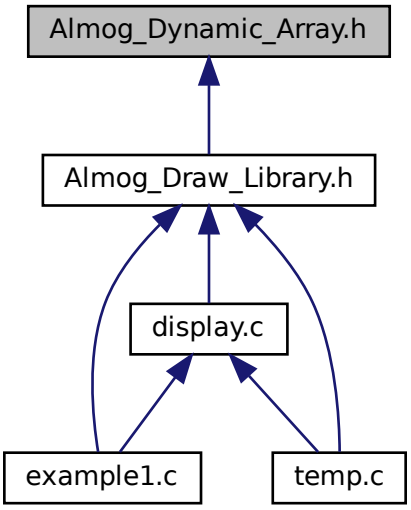
Header-only C macros that implement a simple dynamic array.

```
#include <stdlib.h>
#include <assert.h>
```

Include dependency graph for Almog_Dynamic_Array.h:



This graph shows which files directly or indirectly include this file:



Macros

- #define ADA_INIT_CAPACITY 10

  Default initial capacity used by ada_init_array.
- #define ADA_MALLOC malloc

  Allocation function used by this header (defaults to malloc).
- #define ADA_REALLOC realloc

  Reallocation function used by this header (defaults to realloc).
- #define ADA_ASSERT assert

  Assertion macro used by this header (defaults to assert).
- #define ada_init_array(type, header)

  Initialize an array header and allocate its initial storage.
- #define ada_resize(type, header, new_capacity)

  Resize the underlying storage to hold new_capacity elements.
- #define ada_append(type, header, value)

  Append a value to the end of the array, growing if necessary.
- #define ada_insert(type, header, value, index)

  Insert value at position index, preserving order (O(n)).
- #define ada_insert_unordered(type, header, value, index)

  Insert value at index without preserving order (O(1) amortized).
- #define ada_remove(type, header, index)

  Remove element at index, preserving order (O(n)).
- #define ada_remove_unordered(type, header, index)

  Remove element at index by moving the last element into its place (O(1)); order is not preserved.

4.3.1 Detailed Description

Header-only C macros that implement a simple dynamic array.

This header provides a minimal, macro-based dynamic array for POD-like types. The array "header" is a user-defined struct with three fields:

- size_t length; current number of elements
- size_t capacity; allocated capacity (in elements)
- T* elements; pointer to contiguous storage of elements (type T)

How to use: 1) Define a header struct with length/capacity/elements fields. 2) Initialize it with ada_init_array(T, header). 3) Modify it with ada_append (append), ada_insert, remove variants, etc. 4) When done, free(header.elements) (or your custom deallocator).

Customization:

- Define ADA_MALLOC, ADA_REALLOC, and ADA_ASSERT before including this header to override allocation and assertion behavior.

Complexity (n = number of elements):

- Append: amortized O(1)
- Ordered insert/remove: O(n)
- Unordered insert/remove: O(1)

Notes and limitations:

- These are macros; arguments may be evaluated multiple times. Pass only simple lvalues (no side effects).
- Index checks rely on ADA_ASSERT; with NDEBUG they may be compiled out.
- ada_resize exits the process (exit(1)) if reallocation fails.
- ada_insert reads header.elements[header.length - 1] internally; inserting into an empty array via ada_insert is undefined behavior. Use ada_append or ada_insert_unordered for that case.
- No automatic shrinking; you may call ada_resize manually.

Example: typedef struct { size_t length; size_t capacity; int* elements; } ada_int_array;

ada_int_array arr; ada_init_array(int, arr); ada_append(int, arr, 42); ada_insert(int, arr, 7, 0); // requires arr.length > 0 ada_remove(int, arr, 1); free(arr.elements);

Definition in file Almog_Dynamic_Array.h.

4.3.2 Macro Definition Documentation

4.3.2.1 ada_append

```
#define ada_append(
                type,
                header,
                value )
```

Value:

```
        do {                          \
        if (header.length >= header.capacity) {                     \
            ada_resize(type, header, (int)(header.capacity*1.5));   \
        }                                                           \
        header.elements[header.length] = value;                     \
        header.length++;                                            \
    } while (0)
```

Append a value to the end of the array, growing if necessary.

Parameters

type	Element type stored in the array.
header	Lvalue of the header struct.
value	Value to append.

Postcondition

header.length is incremented by 1; the last element equals value.

Note

Growth factor is (int)(header.capacity ∗ 1.5). Because of truncation, very small capacities may not grow (e.g., from 1 to 1). With the default INIT_CAPACITY=10 this is typically not an issue unless you manually shrink capacity. Ensure growth always increases capacity by at least 1 if you customize this macro.

Definition at line 169 of file Almog_Dynamic_Array.h.

4.3.2.2 ADA_ASSERT

```
#define ADA_ASSERT assert
```

Assertion macro used by this header (defaults to assert).

Define ADA_ASSERT before including this file to override. When NDEBUG is defined, standard assert() is disabled.

Definition at line 96 of file Almog_Dynamic_Array.h.

4.3.2.3 ada_init_array

```
#define ada_init_array(
                type,
                header )
```

Value:

```
        do {                                    \
        header.capacity = ADA_INIT_CAPACITY;                                        \
        header.length = 0;                                                          \
        header.elements = (type *)ADA_MALLOC(sizeof(type) * header.capacity);       \
        ADA_ASSERT(header.elements != NULL);                                        \
    } while (0)
```

Initialize an array header and allocate its initial storage.

Parameters

type	Element type stored in the array (e.g., int).
header	Lvalue of the header struct containing fields: length, capacity, and elements.

Precondition

header is a modifiable lvalue; header.elements is uninitialized or ignored and will be overwritten.

Postcondition

header.length == 0, header.capacity == INIT_CAPACITY, header.elements != NULL (or ADA_ASSERT fails).

Note

Allocation uses ADA_MALLOC and is checked via ADA_ASSERT.

Definition at line 120 of file Almog_Dynamic_Array.h.

4.3.2.4 ADA_INIT_CAPACITY

```
#define ADA_INIT_CAPACITY 10
```

Default initial capacity used by ada_init_array.

You may override this by defining INIT_CAPACITY before including this file.

Definition at line 64 of file Almog_Dynamic_Array.h.

4.3.2.5 ada_insert

```
#define ada_insert(
                type,
                header,
                value,
                index )
```

Value:

```
    do {                                                                \
    ADA_ASSERT((int)(index) >= 0);
        \
    ADA_ASSERT((float)(index) - (int)(index) == 0);
        \
    ada_append(type, header, header.elements[header.length-1]);
        \
    for (size_t ada_for_loop_index = header.length-2; ada_for_loop_index > (index); ada_for_loop_index--) {
        \
         header.elements[ada_for_loop_index] = header.elements [ada_for_loop_index-1];
        \
    }
        \
    header.elements[(index)] = value;
        \
} while (0)
```

Insert value at position index, preserving order (O(n)).

Parameters

type	Element type stored in the array.
header	Lvalue of the header struct.
value	Value to insert.
index	Destination index in the range [0, header.length].

Precondition

0 <= index <= header.length.

header.length > 0 if index == header.length (this macro reads the last element internally). For inserting into an empty array, use ada_append or ada_insert_unordered.

Postcondition

Element is inserted at index; subsequent elements are shifted right; header.length is incremented by 1.

Note

This macro asserts index is non-negative and an integer value using ADA_ASSERT. No explicit upper-bound assert is performed.

Definition at line 196 of file Almog_Dynamic_Array.h.

4.3.2.6 ada_insert_unordered

```
#define ada_insert_unordered(
               type,
               header,
               value,
               index )
```

Value:

```
    do {   \
    ADA_ASSERT((int)(index) >= 0);                                  \
    ADA_ASSERT((float)(index) - (int)(index) == 0);                 \
    if ((size_t)(index) == header.length) {                         \
        ada_append(type, header, value);                            \
    } else {                                                        \
        ada_append(type, header, header.elements[(index)]);         \
        header.elements[(index)] = value;                           \
    }                                                               \
} while (0)
```

Insert value at index without preserving order (O(1) amortized).

If index == header.length, this behaves like an append. Otherwise, the current element at index is moved to the end, and value is written at index.

Parameters

type	Element type stored in the array.
header	Lvalue of the header struct.
value	Value to insert.
index	Index in the range [0, header.length].

Precondition

0 <= index <= header.length.

Postcondition

header.length is incremented by 1; array order is not preserved.

Definition at line 222 of file Almog_Dynamic_Array.h.

4.3.2.7 ADA_MALLOC

```
#define ADA_MALLOC malloc
```

Allocation function used by this header (defaults to malloc).

Define ADA_MALLOC to a compatible allocator before including this file to override the default.

Definition at line 74 of file Almog_Dynamic_Array.h.

4.3.2.8 ADA_REALLOC

```
#define ADA_REALLOC realloc
```

Reallocation function used by this header (defaults to realloc).

Define ADA_REALLOC to a compatible reallocator before including this file to override the default.

Definition at line 85 of file Almog_Dynamic_Array.h.

4.3.2.9 ada_remove

```
#define ada_remove(
              type,
              header,
              index )
```

Value:

```
    do {                                                                \
    ADA_ASSERT((int)(index) >= 0);
       \
    ADA_ASSERT((float)(index) - (int)(index) == 0);
       \
    for (size_t ada_for_loop_index = (index); ada_for_loop_index < header.length-1; ada_for_loop_index++) {
       \
        header.elements[ada_for_loop_index] = header.elements[ada_for_loop_index+1];
       \
    }
       \
    header.length--;
       \
} while (0)
```

Remove element at index, preserving order (O(n)).

Parameters

type	Element type stored in the array.
header	Lvalue of the header struct.
index	Index in the range [0, header.length - 1].

Precondition

0 <= index < header.length.

Postcondition

header.length is decremented by 1; subsequent elements are shifted left by one position. The element beyond the new length is left uninitialized.

Definition at line 246 of file Almog_Dynamic_Array.h.

4.3.2.10 ada_remove_unordered

```
#define ada_remove_unordered(
              type,
              header,
              index )
```

Value:

```
    do {          \
    ADA_ASSERT((int)(index) >= 0);                                  \
    ADA_ASSERT((float)(index) - (int)(index) == 0);                 \
    header.elements[index] = header.elements[header.length-1];  \
    header.length--;                                                \
} while (0)
```

Remove element at index by moving the last element into its place (O(1)); order is not preserved.

Parameters

type	Element type stored in the array.
header	Lvalue of the header struct.
index	Index in the range [0, header.length - 1].

Precondition

0 <= index < header.length and header.length > 0.

Postcondition

header.length is decremented by 1; array order is not preserved.

Definition at line 267 of file Almog_Dynamic_Array.h.

4.3.2.11 ada_resize

```
#define ada_resize(
               type,
               header,
               new_capacity )
```

Value:

```
        do {                                                                \
        type *ada_temp_pointer = (type *)ADA_REALLOC((void *)(header.elements), new_capacity*sizeof(type));
       \
        if (ada_temp_pointer == NULL) {
       \
            exit(1);
       \
        }
       \
        header.elements = ada_temp_pointer;
       \
        ADA_ASSERT(header.elements != NULL);
       \
        header.capacity = new_capacity;
       \
    } while (0)
```

Resize the underlying storage to hold new_capacity elements.

Parameters

type	Element type stored in the array.
header	Lvalue of the header struct.
new_capacity	New capacity in number of elements.

Precondition

new_capacity >= header.length (otherwise elements beyond new_capacity are lost and length will not be adjusted).

Postcondition

header.capacity == new_capacity and header.elements points to a block large enough for new_capacity elements.

Warning

On allocation failure, this macro calls exit(1).

Note

Reallocation uses ADA_REALLOC and is also checked via ADA_ASSERT.

Definition at line 143 of file Almog_Dynamic_Array.h.

4.4 Almog_Dynamic_Array.h

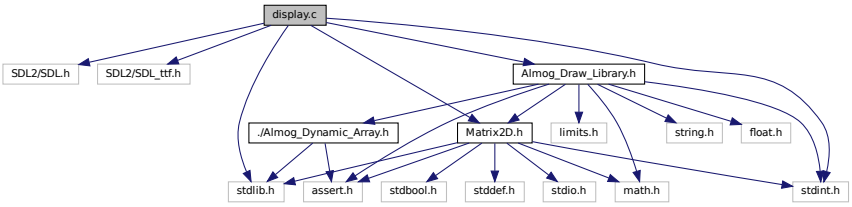
```
00001
00051 #ifndef ALMOG_DYNAMIC_ARRAY_H_
00052 #define ALMOG_DYNAMIC_ARRAY_H_
00053
00054 #include <stdlib.h>
00055 #include <assert.h>
00056
00057
00064 #define ADA_INIT_CAPACITY 10
00065
00073 #ifndef ADA_MALLOC
00074 #define ADA_MALLOC malloc
00075 #endif /*ADA_MALLOC*/
00076
00084 #ifndef ADA_REALLOC
00085 #define ADA_REALLOC realloc
00086 #endif /*ADA_REALLOC*/
00087
00095 #ifndef ADA_ASSERT
00096 #define ADA_ASSERT assert
00097 #endif /*ADA_ASSERT*/
00098
00099 /* typedef struct {
00100     size_t length;
00101     size_t capacity;
00102     int* elements;
00103 } ada_int_array; */
00104
00120 #define ada_init_array(type, header) do {                                       \
00121         header.capacity = ADA_INIT_CAPACITY;                                        \
00122         header.length = 0;                                                      \
00123         header.elements = (type *)ADA_MALLOC(sizeof(type) * header.capacity);   \
00124         ADA_ASSERT(header.elements != NULL);                                    \
00125     } while (0)
00126
00143 #define ada_resize(type, header, new_capacity) do {
        \
00144         type *ada_temp_pointer = (type *)ADA_REALLOC((void *)(header.elements),
       new_capacity*sizeof(type)); \
00145         if (ada_temp_pointer == NULL) {
        \
00146             exit(1);
        \
00147         }
        \
00148         header.elements = ada_temp_pointer;
        \
00149         ADA_ASSERT(header.elements != NULL);
        \
00150         header.capacity = new_capacity;
        \
00151     } while (0)
00152
00169 #define ada_append(type, header, value) do {                        \
00170         if (header.length >= header.capacity) {                     \
00171             ada_resize(type, header, (int)(header.capacity*1.5));   \
00172         }                                                           \
00173         header.elements[header.length] = value;                     \
00174         header.length++;                                            \
00175     } while (0)
00176
00196 #define ada_insert(type, header, value, index) do {
        \
00197     ADA_ASSERT((int)(index) >= 0);
        \
00198     ADA_ASSERT((float)(index) - (int)(index) == 0);
        \
00199     ada_append(type, header, header.elements[header.length-1]);
        \
00200     for (size_t ada_for_loop_index = header.length-2; ada_for_loop_index > (index);
       ada_for_loop_index--) { \
00201         header.elements[ada_for_loop_index] = header.elements [ada_for_loop_index-1];
        \
00202     }
        \
00203     header.elements[(index)] = value;
        \
00204 } while (0)
00205
00206
00222 #define ada_insert_unordered(type, header, value, index) do {   \
00223     ADA_ASSERT((int)(index) >= 0);                              \
00224     ADA_ASSERT((float)(index) - (int)(index) == 0);             \
00225     if ((size_t)(index) == header.length) {                     \
00226         ada_append(type, header, value);                        \
```

```
00227     } else {                                                    \
00228         ada_append(type, header, header.elements[(index)]);     \
00229         header.elements[(index)] = value;                       \
00230     }                                                           \
00231 } while (0)
00232
00246 #define ada_remove(type, header, index) do {
        \
00247     ADA_ASSERT((int)(index) >= 0);
        \
00248     ADA_ASSERT((float)(index) - (int)(index) == 0);
        \
00249     for (size_t ada_for_loop_index = (index); ada_for_loop_index < header.length-1;
      ada_for_loop_index++) { \
00250         header.elements[ada_for_loop_index] = header.elements[ada_for_loop_index+1];
        \
00251     }
        \
00252     header.length--;
        \
00253 } while (0)
00254
00267 #define ada_remove_unordered(type, header, index) do {          \
00268     ADA_ASSERT((int)(index) >= 0);                              \
00269     ADA_ASSERT((float)(index) - (int)(index) == 0);             \
00270     header.elements[index] = header.elements[header.length-1];  \
00271     header.length--;                                            \
00272 } while (0)
00273
00274
00275 #endif /*ALMOG_DYNAMIC_ARRAY_H_*/
```

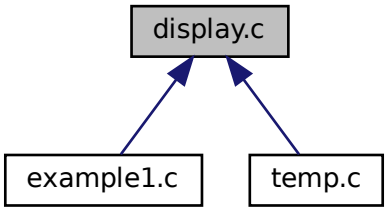
4.5 display.c File Reference

```
#include <SDL2/SDL.h>
#include <SDL2/SDL_ttf.h>
#include "Matrix2D.h"
#include <stdlib.h>
#include <stdint.h>
#include "Almog_Draw_Library.h"
```

Include dependency graph for display.c:



This graph shows which files directly or indirectly include this file:



Classes

- struct game_state_t

Macros

- #define WINDOW_WIDTH (16 ∗ 80)
- #define WINDOW_HEIGHT (9 ∗ 80)
- #define FPS 100
- #define FRAME_TARGET_TIME (1000 / FPS)
- #define dprintSTRING(expr) printf(#expr " = %s\n", expr)
- #define dprintCHAR(expr) printf(#expr " = %c\n", expr)
- #define dprintINT(expr) printf(#expr " = %d\n", expr)
- #define dprintD(expr) printf(#expr " = %g\n", expr)
- #define dprintSIZE_T(expr) printf(#expr " = %zu\n", expr)
- #define SETUP
- #define UPDATE
- #define RENDER

Functions

- int initialize_window (game_state_t ∗game_state)
- void setup_window (game_state_t ∗game_state)
- void process_input_window (game_state_t ∗game_state)
- void update_window (game_state_t ∗game_state)
- void render_window (game_state_t ∗game_state)
- void destroy_window (game_state_t ∗game_state)
- void fix_framerate (game_state_t ∗game_state)
- void setup (game_state_t ∗game_state)
- void update (game_state_t ∗game_state)
- void render (game_state_t ∗game_state)
- void check_window_mat_size (game_state_t ∗game_state)
- void copy_mat_to_surface_RGB (game_state_t ∗game_state)
- int main ()

4.5.1 Macro Definition Documentation

4.5.1.1 dprintCHAR

```
#define dprintCHAR(
              expr ) printf(#expr " = %c\n", expr)
```

Definition at line 25 of file display.c.

4.5.1.2 dprintD

```
#define dprintD(
              expr ) printf(#expr " = %g\n", expr)
```

Definition at line 27 of file display.c.

4.5.1.3 dprintINT

```
#define dprintINT(
              expr ) printf(#expr " = %d\n", expr)
```

Definition at line 26 of file display.c.

4.5.1.4 dprintSIZE_T

```
#define dprintSIZE_T(
              expr ) printf(#expr " = %zu\n", expr)
```

Definition at line 28 of file display.c.

4.5.1.5 dprintSTRING

```
#define dprintSTRING(
              expr ) printf(#expr " = %s\n", expr)
```

Definition at line 24 of file display.c.

4.5.1.6 FPS

```
#define FPS 100
```

Definition at line 17 of file display.c.

4.5.1.7 FRAME_TARGET_TIME

```
#define FRAME_TARGET_TIME (1000 / FPS)
```

Definition at line 21 of file display.c.

4.5.1.8 RENDER

```
#define RENDER
```

Definition at line 351 of file display.c.

4.5.1.9 SETUP

```
#define SETUP
```

Definition at line 341 of file display.c.

4.5.1.10 UPDATE

```
#define UPDATE
```

Definition at line 346 of file display.c.

4.5.1.11 WINDOW_HEIGHT

```
#define WINDOW_HEIGHT (9 * 80)
```

Definition at line 13 of file display.c.

4.5.1.12 WINDOW_WIDTH

```
#define WINDOW_WIDTH (16 * 80)
```

Definition at line 9 of file display.c.

4.5.2 Function Documentation

4.5.2.1 check_window_mat_size()

```
void check_window_mat_size (
            game_state_t * game_state )
```

Definition at line 355 of file display.c.

References Mat2D_uint32::cols, game_state_t::inv_z_buffer_mat, mat2D_alloc(), mat2D_alloc_uint32(), mat2D_free(), mat2D_free_uint32(), Mat2D_uint32::rows, game_state_t::window, game_state_t::window_h, game_state_t::window_pixels_mat, game_state_t::window_surface, and game_state_t::window_w.

Referenced by update_window().

4.5.2.2 copy_mat_to_surface_RGB()

```
void copy_mat_to_surface_RGB (
            game_state_t * game_state )
```

Definition at line 369 of file display.c.

References Mat2D_uint32::cols, Mat2D_uint32::elements, Mat2D_uint32::rows, game_state_t::window_pixels_mat, and game_state_t::window_surface.

Referenced by render_window().

4.5.2.3 destroy_window()

```
void destroy_window (
            game_state_t * game_state )
```

Definition at line 312 of file display.c.

References mat2D_free_uint32(), game_state_t::renderer, game_state_t::window, game_state_t::window_pixels_mat, game_state_t::window_surface, and game_state_t::window_texture.

Referenced by main().

4.5.2.4 fix_framerate()

```
void fix_framerate (
            game_state_t * game_state )
```

Definition at line 327 of file display.c.

References game_state_t::delta_time, game_state_t::frame_target_time, game_state_t::previous_frame_time, and game_state_t::to_limit_fps.

Referenced by update_window().

4.5.2.5 initialize_window()

```
int initialize_window (
            game_state_t * game_state )
```

Definition at line 141 of file display.c.

References game_state_t::renderer, game_state_t::window, game_state_t::window_h, and game_state_t::window_w.

Referenced by main().

4.5.2.6 main()

```
int main ( )
```

Definition at line 89 of file display.c.

References game_state_t::a_was_pressed, game_state_t::const_fps, game_state_t::d_was_pressed, game_state_t::delta_time, destroy_window(), game_state_t::e_was_pressed, game_state_t::elapsed_time, game_state_t::font, FPS, game_state_t::fps, FRAME_TARGET_TIME, game_state_t::frame_target_time, game_state_t::game_is_running, initialize_window(), game_state_t::left_button_pressed, game_state_t::offset_zoom_param, game_state_t::previous_frame_time, process_input_window(), game_state_t::q_was_pressed, render_window(), game_state_t::renderer, game_state_t::s_was_pressed, setup_window(), game_state_t::space_bar_was_pressed, game_state_t::to_clear_renderer, game_state_t::to_limit_fps, game_state_t::to_render, game_state_t::to_update, update_window(), game_state_t::w_was_pressed, game_state_t::window, game_state_t::window_h, WINDOW_HEIGHT, game_state_t::window_w, WINDOW_WIDTH, and Offset_zoom_param::zoom_multipl

4.5.2.7 process_input_window()

```
void process_input_window (
            game_state_t * game_state )
```

Definition at line 196 of file display.c.

References ADL_MAX_ZOOM, game_state_t::game_is_running, game_state_t::left_button_pressed, Offset_zoom_param::offset_x, Offset_zoom_param::offset_y, game_state_t::offset_zoom_param, game_state_t::previous_frame_time, game_state_t::space_bar_w game_state_t::to_render, game_state_t::to_update, and Offset_zoom_param::zoom_multiplier.

Referenced by main().

4.5.2.8 render()

```
void render (
            game_state_t * game_state )
```

Definition at line 352 of file display.c.

Referenced by render_window().

4.5.2.9 render_window()

```
void render_window (
            game_state_t * game_state )
```

Definition at line 291 of file display.c.

References Mat2D::cols, Mat2D_uint32::cols, copy_mat_to_surface_RGB(), Mat2D::elements, Mat2D_uint32::elements, game_state_t::inv_z_buffer_mat, render(), Mat2D::rows, Mat2D_uint32::rows, game_state_t::to_clear_renderer, game_state_t::window, and game_state_t::window_pixels_mat.

Referenced by main().

4.5.2.10 setup()

```
void setup (
            game_state_t * game_state )
```

Definition at line 342 of file display.c.

Referenced by setup_window().

4.5.2.11 setup_window()

```
void setup_window (
            game_state_t * game_state )
```

Definition at line 182 of file display.c.

References game_state_t::inv_z_buffer_mat, mat2D_alloc(), mat2D_alloc_uint32(), setup(), game_state_t::window, game_state_t::window_h, game_state_t::window_pixels_mat, game_state_t::window_surface, and game_state_t::window_w.

Referenced by main().

4.5.2.12 update()

```
void update (
            game_state_t * game_state )
```

Definition at line 347 of file display.c.

Referenced by update_window().

4.5.2.13 update_window()

```
void update_window (
            game_state_t * game_state )
```

Definition at line 263 of file display.c.

References check_window_mat_size(), game_state_t::const_fps, game_state_t::delta_time, game_state_t::elapsed_time, fix_framerate(), game_state_t::fps, game_state_t::frame_target_time, game_state_t::to_limit_fps, update(), game_state_t::window, game_state_t::window_h, and game_state_t::window_w.

Referenced by main().

4.6 display.c

```
00001 #include <SDL2/SDL.h>
00002 #include <SDL2/SDL_ttf.h>
00003 #include "Matrix2D.h"
00004 #include <stdlib.h>
00005 #include <stdint.h>
00006 #include "Almog_Draw_Library.h"
00007
00008 #ifndef WINDOW_WIDTH
00009 #define WINDOW_WIDTH (16 * 80)
00010 #endif
00011
00012 #ifndef WINDOW_HEIGHT
00013 #define WINDOW_HEIGHT (9 * 80)
00014 #endif
00015
00016 #ifndef FPS
00017 #define FPS 100
00018 #endif
00019
00020 #ifndef FRAME_TARGET_TIME
00021 #define FRAME_TARGET_TIME (1000 / FPS)
00022 #endif
00023
00024 #define dprintSTRING(expr) printf(#expr " = %s\n", expr)
00025 #define dprintCHAR(expr) printf(#expr " = %c\n", expr)
00026 #define dprintINT(expr) printf(#expr " = %d\n", expr)
00027 #define dprintD(expr) printf(#expr " = %g\n", expr)
00028 #define dprintSIZE_T(expr) printf(#expr " = %zu\n", expr)
00029
00030 #ifndef PI
00031     #ifndef __USE_MISC
00032     #define __USE_MISC
00033     #endif
00034     #include <math.h>
00035     #define PI M_PI
00036 #endif
00037
00038 typedef struct {
00039     int game_is_running;
00040     float delta_time;
00041     float elapsed_time;
00042     float const_fps;
00043     float fps;
```

```
00044     float frame_target_time;
00045     int to_render;
00046     int to_update;
00047     size_t previous_frame_time;
00048     int left_button_pressed;
00049     int to_limit_fps;
00050     int to_clear_renderer;
00051 
00052     int space_bar_was_pressed;
00053     int w_was_pressed;
00054     int s_was_pressed;
00055     int a_was_pressed;
00056     int d_was_pressed;
00057     int e_was_pressed;
00058     int q_was_pressed;
00059 
00060     SDL_Window *window;
00061     int window_w;
00062     int window_h;
00063     SDL_Renderer *renderer;
00064     TTF_Font *font;
00065 
00066     SDL_Surface *window_surface;
00067     SDL_Texture *window_texture;
00068 
00069     Mat2D_uint32 window_pixels_mat;
00070     Mat2D inv_z_buffer_mat;
00071 
00072     Offset_zoom_param offset_zoom_param;
00073 } game_state_t;
00074 
00075 int initialize_window(game_state_t *game_state);
00076 void setup_window(game_state_t *game_state);
00077 void process_input_window(game_state_t *game_state);
00078 void update_window(game_state_t *game_state);
00079 void render_window(game_state_t *game_state);
00080 void destroy_window(game_state_t *game_state);
00081 void fix_framerate(game_state_t *game_state);
00082 void setup(game_state_t *game_state);
00083 void update(game_state_t *game_state);
00084 void render(game_state_t *game_state);
00085 
00086 void check_window_mat_size(game_state_t *game_state);
00087 void copy_mat_to_surface_RGB(game_state_t *game_state);
00088 
00089 int main()
00090 {
00091     game_state_t game_state = {0};
00092 
00093     game_state.game_is_running = 0;
00094     game_state.delta_time = 0;
00095     game_state.elapsed_time = 0;
00096     game_state.const_fps = FPS;
00097     game_state.fps = 0;
00098     game_state.frame_target_time = FRAME_TARGET_TIME;
00099 
00100     game_state.space_bar_was_pressed = 0;
00101     game_state.w_was_pressed = 0;
00102     game_state.s_was_pressed = 0;
00103     game_state.a_was_pressed = 0;
00104     game_state.d_was_pressed = 0;
00105     game_state.e_was_pressed = 0;
00106     game_state.q_was_pressed = 0;
00107 
00108     game_state.to_render = 1;
00109     game_state.to_update = 1;
00110     game_state.previous_frame_time = 0;
00111     game_state.left_button_pressed = 0;
00112     game_state.to_limit_fps = 1;
00113     game_state.to_clear_renderer = 1;
00114     game_state.window = NULL;
00115     game_state.window_w = WINDOW_WIDTH;
00116     game_state.window_h = WINDOW_HEIGHT;
00117     game_state.renderer = NULL;
00118     game_state.font = NULL;
00119 
00120     game_state.offset_zoom_param.zoom_multiplier = 1;
00121 
00122     game_state.game_is_running = !initialize_window(&game_state);
00123 
00124     setup_window(&game_state);
00125 
00126     while (game_state.game_is_running) {
00127         process_input_window(&game_state);
00128         if (game_state.to_update) {
00129             update_window(&game_state);
00130         }
```

```
00131         if (game_state.to_render) {
00132             render_window(&game_state);
00133         }
00134 
00135     }
00136     destroy_window(&game_state);
00137 
00138     return 0;
00139 }
00140 
00141 int initialize_window(game_state_t *game_state)
00142 {
00143     if (SDL_Init(SDL_INIT_EVERYTHING) != 0) {
00144         fprintf(stderr, "%s:%d: [Error] initializing SDL.\n", __FILE__, __LINE__);
00145         return -1;
00146     }
00147 
00148     game_state->window = SDL_CreateWindow(NULL,
00149                                 SDL_WINDOWPOS_CENTERED,
00150                                 SDL_WINDOWPOS_CENTERED,
00151                                 game_state->window_w,
00152                                 game_state->window_h,
00153                                 SDL_WINDOW_RESIZABLE
00154                                 );
00155     if (!game_state->window) {
00156         fprintf(stderr, "%s:%d: [Error] creating SDL window.\n", __FILE__, __LINE__);
00157         return -1;
00158     }
00159 
00160     game_state->renderer = SDL_CreateRenderer(game_state->window, -1, 0);
00161     if (!game_state->renderer) {
00162         fprintf(stderr, "%s:%d: [Error] creating SDL renderer.\n", __FILE__, __LINE__);
00163         return -1;
00164     }
00165 
00166     if (TTF_Init() == -1) {
00167         fprintf(stderr, "%s:%d: [Error] initializing SDL_ttf.\n", __FILE__, __LINE__);
00168         return -1;
00169     }
00170 
00171     // game_state->font = TTF_OpenFont("./font/Gabriely Black.ttf",32);
00172     // if (!game_state->font) {
00173     //     fprintf(stderr, "%s:%d: [Error] loading font.\n", __FILE__, __LINE__);
00174     //     return -1;
00175     // }
00176 
00177     (void)game_state;
00178 
00179     return 0;
00180 }
00181 
00182 void setup_window(game_state_t *game_state)
00183 {
00184 
00185     game_state->window_surface = SDL_GetWindowSurface(game_state->window);
00186 
00187     game_state->window_pixels_mat = mat2D_alloc_uint32(game_state->window_h, game_state->window_w);
00188     game_state->inv_z_buffer_mat = mat2D_alloc(game_state->window_h, game_state->window_w);
00189 
00190     /*-----------------------------------*/
00191 
00192     setup(game_state);
00193 
00194 }
00195 
00196 void process_input_window(game_state_t *game_state)
00197 {
00198     SDL_Event event;
00199     while (SDL_PollEvent(&event)) {
00200         switch (event.type) {
00201             case SDL_QUIT:
00202                 game_state->game_is_running = 0;
00203                 break;
00204             case SDL_KEYDOWN:
00205                 if (event.key.keysym.sym == SDLK_ESCAPE) {
00206                     game_state->game_is_running = 0;
00207                 }
00208                 if (event.key.keysym.sym == SDLK_SPACE) {
00209                     if (!game_state->space_bar_was_pressed) {
00210                         game_state->to_render = 0;
00211                         game_state->to_update = 0;
00212                         game_state->space_bar_was_pressed = 1;
00213                         break;
00214                     }
00215                     if (game_state->space_bar_was_pressed) {
00216                         game_state->to_render = 1;
00217                         game_state->to_update = 1;
```

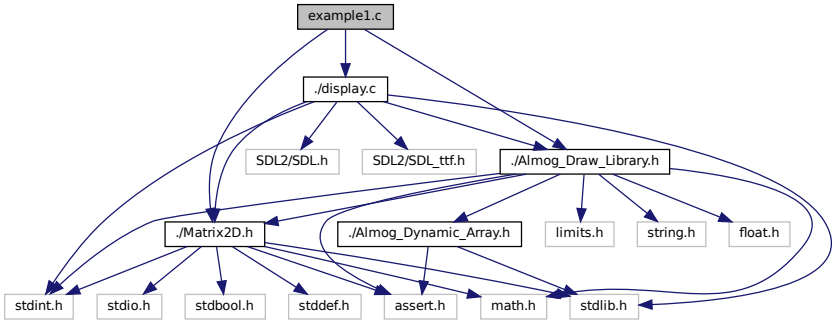
```
00218                         game_state->previous_frame_time = SDL_GetTicks();
00219                         game_state->space_bar_was_pressed = 0;
00220                         break;
00221                     }
00222                 }
00223                 if (event.key.keysym.sym == SDLK_w) {
00224                     game_state->offset_zoom_param.offset_y +=
      5/game_state->offset_zoom_param.zoom_multiplier;
00225                 }
00226                 if (event.key.keysym.sym == SDLK_s) {
00227                     game_state->offset_zoom_param.offset_y -=
      5/game_state->offset_zoom_param.zoom_multiplier;
00228                 }
00229                 if (event.key.keysym.sym == SDLK_a) {
00230                     game_state->offset_zoom_param.offset_x +=
      5/game_state->offset_zoom_param.zoom_multiplier;
00231                 }
00232                 if (event.key.keysym.sym == SDLK_d) {
00233                     game_state->offset_zoom_param.offset_x -=
      5/game_state->offset_zoom_param.zoom_multiplier;
00234                 }
00235                 if (event.key.keysym.sym == SDLK_e) {
00236                     game_state->offset_zoom_param.zoom_multiplier +=
      0.1*game_state->offset_zoom_param.zoom_multiplier;
00237                     game_state->offset_zoom_param.zoom_multiplier =
      fminf(game_state->offset_zoom_param.zoom_multiplier, ADL_MAX_ZOOM);
00238                 }
00239                 if (event.key.keysym.sym == SDLK_q) {
00240                     game_state->offset_zoom_param.zoom_multiplier -=
      0.1*game_state->offset_zoom_param.zoom_multiplier;
00241                     game_state->offset_zoom_param.zoom_multiplier =
      fminf(game_state->offset_zoom_param.zoom_multiplier, ADL_MAX_ZOOM);
00242                 }
00243                 if (event.key.keysym.sym == SDLK_r) {
00244                     game_state->offset_zoom_param.zoom_multiplier = 1;
00245                     game_state->offset_zoom_param.offset_x = 0;
00246                     game_state->offset_zoom_param.offset_y = 0;
00247                 }
00248                 break;
00249             case SDL_MOUSEBUTTONDOWN:
00250                 if (event.button.button == SDL_BUTTON_LEFT) {
00251                     game_state->left_button_pressed = 1;
00252                 }
00253                 break;
00254             case SDL_MOUSEBUTTONUP:
00255                 if (event.button.button == SDL_BUTTON_LEFT) {
00256                     game_state->left_button_pressed = 0;
00257                 }
00258                 break;
00259         }
00260     }
00261 }
00262
00263 void update_window(game_state_t *game_state)
00264 {
00265     SDL_GetWindowSize(game_state->window, &(game_state->window_w), &(game_state->window_h));
00266
00267     fix_framerate(game_state);
00268     game_state->elapsed_time += game_state->delta_time;
00269     game_state->fps = 1.0f / game_state->delta_time;
00270     game_state->frame_target_time = 1000/game_state->const_fps;
00271
00272     char fps_count[100];
00273     if (!game_state->to_limit_fps) {
00274         sprintf(fps_count, "dt = %5.02f [ms]", game_state->delta_time*1000);
00275     } else {
00276         sprintf(fps_count, "FPS = %5.2f", game_state->fps);
00277     }
00278
00279     if (game_state->elapsed_time*10-(int)(game_state->elapsed_time*10) < 0.1) {
00280         SDL_SetWindowTitle(game_state->window, fps_count);
00281     }
00282
00283     check_window_mat_size(game_state);
00284
00285     /*------------------------------------------------------------------------------*/
00286
00287     update(game_state);
00288
00289 }
00290
00291 void render_window(game_state_t *game_state)
00292 {
00293     if (game_state->to_clear_renderer) {
00294         // SDL_SetRenderDrawColor(game_state->renderer, HexARGB_RGBA(0xFF181818));
00295         // SDL_RenderClear(game_state->renderer);
00296         // mat2D_fill(game_state->window_pixels_mat, 0x181818);
```

```
00297         memset(game_state->window_pixels_mat.elements, 0x20, sizeof(uint32_t) *
      game_state->window_pixels_mat.rows * game_state->window_pixels_mat.cols);
00298         /* not using mat2D_fill but using memset because it is way faster, so the buffer needs to be
      of 1/z */
00299         memset(game_state->inv_z_buffer_mat.elements, 0x0, sizeof(double) *
      game_state->inv_z_buffer_mat.rows * game_state->inv_z_buffer_mat.cols);
00300     }
00301     /*------------------------------------------------------------------------*/
00302
00303     render(game_state);
00304
00305     /*------------------------------------------------------------------------*/
00306
00307     copy_mat_to_surface_RGB(game_state);
00308     SDL_UpdateWindowSurface(game_state->window);
00309
00310 }
00311
00312 void destroy_window(game_state_t *game_state)
00313 {
00314     mat2D_free_uint32(game_state->window_pixels_mat);
00315
00316     if (!game_state->window_surface) SDL_FreeSurface(game_state->window_surface);
00317     if (!game_state->window_texture) SDL_DestroyTexture(game_state->window_texture);
00318
00319     SDL_DestroyRenderer(game_state->renderer);
00320     SDL_DestroyWindow(game_state->window);
00321
00322     SDL_Quit();
00323
00324     (void)game_state;
00325 }
00326
00327 void fix_framerate(game_state_t *game_state)
00328 {
00329     int time_ellapsed = SDL_GetTicks() - game_state->previous_frame_time;
00330     int time_to_wait = game_state->frame_target_time - time_ellapsed;
00331     if (time_to_wait > 0 && time_to_wait < game_state->frame_target_time) {
00332         if (game_state->to_limit_fps) {
00333             SDL_Delay(time_to_wait);
00334         }
00335     }
00336     game_state->delta_time = (SDL_GetTicks() - game_state->previous_frame_time) / 1000.0f;
00337     game_state->previous_frame_time = SDL_GetTicks();
00338 }
00339
00340 #ifndef SETUP
00341 #define SETUP
00342 void setup(game_state_t *game_state) { (void)game_state; }
00343 #endif
00344
00345 #ifndef UPDATE
00346 #define UPDATE
00347 void update(game_state_t *game_state) { (void)game_state; }
00348 #endif
00349
00350 #ifndef RENDER
00351 #define RENDER
00352 void render(game_state_t *game_state) { (void)game_state; }
00353 #endif
00354
00355 void check_window_mat_size(game_state_t *game_state)
00356 {
00357     if (game_state->window_h != (int)game_state->window_pixels_mat.rows || game_state->window_w !=
      (int)game_state->window_pixels_mat.cols) {
00358         mat2D_free_uint32(game_state->window_pixels_mat);
00359         mat2D_free(game_state->inv_z_buffer_mat);
00360         SDL_FreeSurface(game_state->window_surface);
00361
00362         game_state->window_pixels_mat = mat2D_alloc_uint32(game_state->window_h,
      game_state->window_w);
00363         game_state->inv_z_buffer_mat = mat2D_alloc(game_state->window_h, game_state->window_w);
00364
00365         game_state->window_surface = SDL_GetWindowSurface(game_state->window);
00366     }
00367 }
00368
00369 void copy_mat_to_surface_RGB(game_state_t *game_state)
00370 {
00371     SDL_LockSurface(game_state->window_surface);
00372
00373     memcpy(game_state->window_surface->pixels, game_state->window_pixels_mat.elements,
      sizeof(uint32_t) * game_state->window_pixels_mat.rows * game_state->window_pixels_mat.cols);
00374
00375     SDL_UnlockSurface(game_state->window_surface);
00376 }
```

4.7 example1.c File Reference

```
#include "./Almog_Draw_Library.h"
#include "./display.c"
#include "./Matrix2D.h"
```

Include dependency graph for example1.c:



Macros

- #define SETUP
- #define UPDATE
- #define RENDER
- #define ALMOG_DRAW_LIBRARY_IMPLEMENTATION
- #define MATRIX2D_IMPLEMENTATION

Functions

- void setup (game_state_t *game_state)
- void update (game_state_t *game_state)
- void render (game_state_t *game_state)

Variables

- Figure figure1
- Figure figure2
- Curve points
- Curve points1

4.7.1 Macro Definition Documentation

4.7.1.1 ALMOG_DRAW_LIBRARY_IMPLEMENTATION

```
#define ALMOG_DRAW_LIBRARY_IMPLEMENTATION
```

Definition at line 4 of file example1.c.

4.7.1.2 MATRIX2D_IMPLEMENTATION

```
#define MATRIX2D_IMPLEMENTATION
```

Definition at line 7 of file example1.c.

4.7.1.3 RENDER

```
#define RENDER
```

Definition at line 3 of file example1.c.

4.7.1.4 SETUP

```
#define SETUP
```

Definition at line 1 of file example1.c.

4.7.1.5 UPDATE

```
#define UPDATE
```

Definition at line 2 of file example1.c.

4.7.2 Function Documentation

4.7.2.1 render()

```
void render (
            game_state_t * game_state )
```

Definition at line 64 of file example1.c.

References adl_character_draw(), adl_curves_plot_on_figure(), ADL_DEFAULT_OFFSET_ZOOM, adl_figure_copy_to_screen(), figure1, figure2, and game_state_t::window_pixels_mat.

4.7.2.2 setup()

```
void setup (
            game_state_t * game_state )
```

Definition at line 15 of file example1.c.

References ada_append, ada_init_array, adl_curve_add_to_figure(), adl_figure_alloc(), Figure::background_color, game_state_t::const_fps, Curve::elements, figure1, figure2, Curve::length, points, points1, Figure::to_draw_axis, and Figure::to_draw_max_min_values.

4.7.2.3 update()

```
void update (
            game_state_t * game_state )
```

Definition at line 60 of file example1.c.

4.7.3 Variable Documentation

4.7.3.1 figure1

```
Figure figure1
```

Definition at line 11 of file example1.c.

Referenced by render(), and setup().

4.7.3.2 figure2

```
Figure figure2
```

Definition at line 12 of file example1.c.

Referenced by render(), and setup().

4.7.3.3 points

```
Curve points
```

Definition at line 13 of file example1.c.

Referenced by adl_lines_draw(), adl_lines_loop_draw(), and setup().

4.7.3.4 points1

```
Curve points1
```

Definition at line 14 of file example1.c.

Referenced by setup().

4.8 example1.c

```
00001 #define SETUP
00002 #define UPDATE
00003 #define RENDER
00004 #define ALMOG_DRAW_LIBRARY_IMPLEMENTATION
00005 #include "./Almog_Draw_Library.h"
00006 #include "./display.c"
00007 #define MATRIX2D_IMPLEMENTATION
00008 #include "./Matrix2D.h"
00009
00010
00011 Figure figure1;
00012 Figure figure2;
00013 Curve points;
00014 Curve points1;
00015 void setup(game_state_t *game_state)
00016 {
00017     game_state->const_fps = 30;
00018     // game_state->to_limit_fps = 0;
00019
00020     figure1 = adl_figure_alloc(100, 70, (Point){100, 100, 0, 0});
00021     figure2 = adl_figure_alloc(600, 500, (Point){190, 100, 0, 0});
00022
00023     ada_init_array(Point, points);
00024     ada_init_array(Point, points1);
00025     Point temp_point = (Point){1,1,0,0};
00026     ada_append(Point, points, temp_point);
00027     ada_append(Point, points1, temp_point);
00028     temp_point = (Point){2,2,0,0};
00029     ada_append(Point, points, temp_point);
00030     ada_append(Point, points1, temp_point);
00031     temp_point = (Point){3,1,0,0};
00032     ada_append(Point, points, temp_point);
00033     ada_append(Point, points1, temp_point);
00034     temp_point = (Point){4,10,0,0};
00035     ada_append(Point, points, temp_point);
```

```
00036     temp_point = (Point){5,-10,0,0};
00037     ada_append(Point, points, temp_point);
00038     temp_point = (Point){3,-20,0,0};
00039     ada_append(Point, points, temp_point);
00040 
00041     temp_point = (Point){3.5,-10,0,0};
00042     ada_append(Point, points1, temp_point);
00043 
00044     figure1.background_color = 0xFFFFFFFF;
00045     figure1.to_draw_axis = true;
00046     figure1.to_draw_max_min_values = true;
00047 
00048     figure2.background_color = 0xFFFFFFFF;
00049     figure2.to_draw_axis = true;
00050     figure2.to_draw_max_min_values = true;
00051 
00052     adl_curve_add_to_figure(&figure1, points.elements, points.length, 0xFFFF0000);
00053     adl_curve_add_to_figure(&figure2, points.elements, points.length, 0xFFFF0000);
00054 
00055     adl_curve_add_to_figure(&figure1, points1.elements, points1.length, 0xFF0000FF);
00056     adl_curve_add_to_figure(&figure2, points1.elements, points1.length, 0xFF0000FF);
00057 
00058 }
00059 
00060 void update(game_state_t *game_state)
00061 {
00062 }
00063 
00064 void render(game_state_t *game_state)
00065 {
00066     adl_curves_plot_on_figure(figure1);
00067     adl_curves_plot_on_figure(figure2);
00068 
00069     adl_figure_copy_to_screen(game_state->window_pixels_mat, figure1);
00070     adl_figure_copy_to_screen(game_state->window_pixels_mat, figure2);
00071 
00072 
00073     adl_character_draw(game_state->window_pixels_mat, 'A', 50, 100, 700 , 200, 0xFFFFFFFF,
       ADL_DEFAULT_OFFSET_ZOOM);
00074     adl_character_draw(game_state->window_pixels_mat, 'B', 50, 100, 755 , 200, 0xFFFFFFFF,
       ADL_DEFAULT_OFFSET_ZOOM);
00075     adl_character_draw(game_state->window_pixels_mat, 'C', 50, 100, 810 , 200, 0xFFFFFFFF,
       ADL_DEFAULT_OFFSET_ZOOM);
00076     adl_character_draw(game_state->window_pixels_mat, 'D', 50, 100, 865 , 200, 0xFFFFFFFF,
       ADL_DEFAULT_OFFSET_ZOOM);
00077     adl_character_draw(game_state->window_pixels_mat, 'E', 50, 100, 920 , 200, 0xFFFFFFFF,
       ADL_DEFAULT_OFFSET_ZOOM);
00078     adl_character_draw(game_state->window_pixels_mat, 'F', 50, 100, 975 , 200, 0xFFFFFFFF,
       ADL_DEFAULT_OFFSET_ZOOM);
00079     adl_character_draw(game_state->window_pixels_mat, 'G', 50, 100, 1030, 200, 0xFFFFFFFF,
       ADL_DEFAULT_OFFSET_ZOOM);
00080     adl_character_draw(game_state->window_pixels_mat, 'H', 50, 100, 1085, 200, 0xFFFFFFFF,
       ADL_DEFAULT_OFFSET_ZOOM);
00081     adl_character_draw(game_state->window_pixels_mat, 'I', 50, 100, 1140, 200, 0xFFFFFFFF,
       ADL_DEFAULT_OFFSET_ZOOM);
00082     adl_character_draw(game_state->window_pixels_mat, 'J', 50, 100, 1195, 200, 0xFFFFFFFF,
       ADL_DEFAULT_OFFSET_ZOOM);
00083     adl_character_draw(game_state->window_pixels_mat, 'K', 50, 100, 700 , 305, 0xFFFFFFFF,
       ADL_DEFAULT_OFFSET_ZOOM);
00084     adl_character_draw(game_state->window_pixels_mat, 'L', 50, 100, 755 , 305, 0xFFFFFFFF,
       ADL_DEFAULT_OFFSET_ZOOM);
00085     adl_character_draw(game_state->window_pixels_mat, 'M', 50, 100, 810 , 305, 0xFFFFFFFF,
       ADL_DEFAULT_OFFSET_ZOOM);
00086     adl_character_draw(game_state->window_pixels_mat, 'N', 50, 100, 865 , 305, 0xFFFFFFFF,
       ADL_DEFAULT_OFFSET_ZOOM);
00087     adl_character_draw(game_state->window_pixels_mat, 'O', 50, 100, 920 , 305, 0xFFFFFFFF,
       ADL_DEFAULT_OFFSET_ZOOM);
00088     adl_character_draw(game_state->window_pixels_mat, 'P', 50, 100, 975 , 305, 0xFFFFFFFF,
       ADL_DEFAULT_OFFSET_ZOOM);
00089     adl_character_draw(game_state->window_pixels_mat, 'Q', 50, 100, 1030, 305, 0xFFFFFFFF,
       ADL_DEFAULT_OFFSET_ZOOM);
00090     adl_character_draw(game_state->window_pixels_mat, 'R', 50, 100, 1085, 305, 0xFFFFFFFF,
       ADL_DEFAULT_OFFSET_ZOOM);
00091     adl_character_draw(game_state->window_pixels_mat, 'S', 50, 100, 1140, 305, 0xFFFFFFFF,
       ADL_DEFAULT_OFFSET_ZOOM);
00092     adl_character_draw(game_state->window_pixels_mat, 'T', 50, 100, 1195, 305, 0xFFFFFFFF,
       ADL_DEFAULT_OFFSET_ZOOM);
00093     adl_character_draw(game_state->window_pixels_mat, 'U', 50, 100, 700 , 410, 0xFFFFFFFF,
       ADL_DEFAULT_OFFSET_ZOOM);
00094     adl_character_draw(game_state->window_pixels_mat, 'V', 50, 100, 755 , 410, 0xFFFFFFFF,
       ADL_DEFAULT_OFFSET_ZOOM);
00095     adl_character_draw(game_state->window_pixels_mat, 'W', 50, 100, 810 , 410, 0xFFFFFFFF,
       ADL_DEFAULT_OFFSET_ZOOM);
00096     adl_character_draw(game_state->window_pixels_mat, 'X', 50, 100, 865 , 410, 0xFFFFFFFF,
       ADL_DEFAULT_OFFSET_ZOOM);
00097     adl_character_draw(game_state->window_pixels_mat, 'Y', 50, 100, 920 , 410, 0xFFFFFFFF,
       ADL_DEFAULT_OFFSET_ZOOM);
```

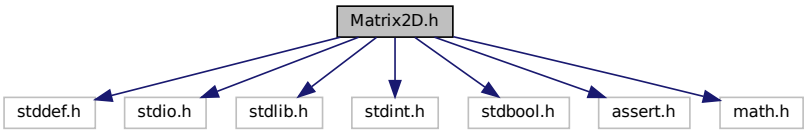
```
00098     adl_character_draw(game_state->window_pixels_mat, 'Z', 50, 100, 975 , 410, 0xFFFFFFFF,
      ADL_DEFAULT_OFFSET_ZOOM);
00099     adl_character_draw(game_state->window_pixels_mat, '.', 50, 100, 1030, 410, 0xFFFFFFFF,
      ADL_DEFAULT_OFFSET_ZOOM);
00100     adl_character_draw(game_state->window_pixels_mat, ':', 50, 100, 1085, 410, 0xFFFFFFFF,
      ADL_DEFAULT_OFFSET_ZOOM);
00101     adl_character_draw(game_state->window_pixels_mat, '0', 50, 100, 700 , 515, 0xFFFFFFFF,
      ADL_DEFAULT_OFFSET_ZOOM);
00102     adl_character_draw(game_state->window_pixels_mat, '1', 50, 100, 755 , 515, 0xFFFFFFFF,
      ADL_DEFAULT_OFFSET_ZOOM);
00103     adl_character_draw(game_state->window_pixels_mat, '2', 50, 100, 810 , 515, 0xFFFFFFFF,
      ADL_DEFAULT_OFFSET_ZOOM);
00104     adl_character_draw(game_state->window_pixels_mat, '3', 50, 100, 865 , 515, 0xFFFFFFFF,
      ADL_DEFAULT_OFFSET_ZOOM);
00105     adl_character_draw(game_state->window_pixels_mat, '4', 50, 100, 920 , 515, 0xFFFFFFFF,
      ADL_DEFAULT_OFFSET_ZOOM);
00106     adl_character_draw(game_state->window_pixels_mat, '5', 50, 100, 975 , 515, 0xFFFFFFFF,
      ADL_DEFAULT_OFFSET_ZOOM);
00107     adl_character_draw(game_state->window_pixels_mat, '6', 50, 100, 1030, 515, 0xFFFFFFFF,
      ADL_DEFAULT_OFFSET_ZOOM);
00108     adl_character_draw(game_state->window_pixels_mat, '7', 50, 100, 1085, 515, 0xFFFFFFFF,
      ADL_DEFAULT_OFFSET_ZOOM);
00109     adl_character_draw(game_state->window_pixels_mat, '8', 50, 100, 1140, 515, 0xFFFFFFFF,
      ADL_DEFAULT_OFFSET_ZOOM);
00110     adl_character_draw(game_state->window_pixels_mat, '9', 50, 100, 1195, 515, 0xFFFFFFFF,
      ADL_DEFAULT_OFFSET_ZOOM);
00111
00112 }
00113
```

4.9 Matrix2D.h File Reference

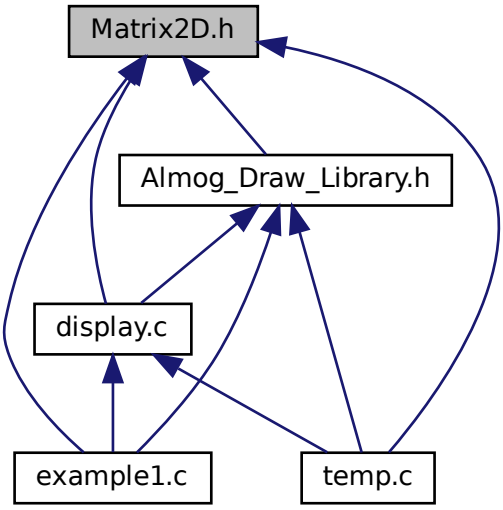
A single-header C library for simple 2D matrix operations on doubles and uint32_t, including allocation, basic arithmetic, linear algebra, and helpers (LUP, inverse, determinant, DCM, etc.).

```
#include <stddef.h>
#include <stdio.h>
#include <stdlib.h>
#include <stdint.h>
#include <stdbool.h>
#include <assert.h>
#include <math.h>
```

Include dependency graph for Matrix2D.h:



This graph shows which files directly or indirectly include this file:



Classes

- struct Mat2D

  Dense row-major matrix of doubles.
- struct Mat2D_uint32

  Dense row-major matrix of uint32_t.
- struct Mat2D_Minor

  A minor "view" into a reference matrix.

Macros

- #define MATRIX2D_MALLOC malloc

  Allocation function used by the library.
- #define MATRIX2D_ASSERT assert

  Assertion macro used by the library for parameter validation.
- #define MAT2D_AT(m, i, j) (m).elements[i ∗ m.stride_r + j]

  Access element (i, j) of a Mat2D (0-based).
- #define MAT2D_AT_UINT32(m, i, j) (m).elements[i ∗ m.stride_r + j]

  Access element (i, j) of a Mat2D_uint32 (0-based).
- #define __USE_MISC
- #define PI M_PI
- #define MAT2D_MINOR_AT(mm, i, j) MAT2D_AT(mm.ref_mat, mm.rows_list[i], mm.cols_list[j])

  Access element (i, j) of a Mat2D_Minor (0-based), dereferencing into the underlying reference matrix.
- #define MAT2D_PRINT(m) mat2D_print(m, #m, 0)

  Convenience macro to print a matrix with its variable name.
- #define MAT2D_PRINT_AS_COL(m) mat2D_print_as_col(m, #m, 0)

Convenience macro to print a matrix as a single column with its name.

- #define MAT2D_MINOR_PRINT(mm) mat2D_minor_print(mm, #mm, 0)

  Convenience macro to print a minor with its variable name.
- #define mat2D_normalize(m) mat2D_mult((m), 1.0 / mat2D_calc_norma((m)))

  In-place normalization of all elements so that the Frobenius norm becomes 1.

Functions

- double mat2D_rand_double (void)

  Return a pseudo-random double in the range [0, 1].
- Mat2D mat2D_alloc (size_t rows, size_t cols)

  Allocate a rows x cols matrix of doubles.
- Mat2D_uint32 mat2D_alloc_uint32 (size_t rows, size_t cols)

  Allocate a rows x cols matrix of uint32_t.
- void mat2D_free (Mat2D m)

  Free the memory owned by a Mat2D (elements pointer).
- void mat2D_free_uint32 (Mat2D_uint32 m)

  Free the memory owned by a Mat2D_uint32 (elements pointer).
- size_t mat2D_offset2d (Mat2D m, size_t i, size_t j)

  Compute the linear offset of element (i, j) in a Mat2D.
- size_t mat2D_offset2d_uint32 (Mat2D_uint32 m, size_t i, size_t j)

  Compute the linear offset of element (i, j) in a Mat2D_uint32.
- void mat2D_fill (Mat2D m, double x)

  Fill all elements of a matrix of doubles with a scalar value.
- void mat2D_fill_sequence (Mat2D m, double start, double step)

  Fill a matrix with an arithmetic sequence laid out in row-major order.
- void mat2D_fill_uint32 (Mat2D_uint32 m, uint32_t x)

  Fill all elements of a matrix of uint32_t with a scalar value.
- void mat2D_rand (Mat2D m, double low, double high)

  Fill a matrix with random doubles in [low, high).
- void mat2D_dot (Mat2D dst, Mat2D a, Mat2D b)

  *Matrix product: dst = a * b.*
- double mat2D_dot_product (Mat2D a, Mat2D b)

  Dot product between two vectors.
- void mat2D_cross (Mat2D dst, Mat2D a, Mat2D b)

  3D cross product: dst = a x b for 3x1 vectors.
- void mat2D_add (Mat2D dst, Mat2D a)

  In-place addition: dst += a.
- void mat2D_add_row_time_factor_to_row (Mat2D m, size_t des_r, size_t src_r, double factor)

  *Row operation: row(des_r) += factor * row(src_r).*
- void mat2D_sub (Mat2D dst, Mat2D a)

  In-place subtraction: dst -= a.
- void mat2D_sub_row_time_factor_to_row (Mat2D m, size_t des_r, size_t src_r, double factor)

  *Row operation: row(des_r) -= factor * row(src_r).*
- void mat2D_mult (Mat2D m, double factor)

  *In-place scalar multiplication: m *= factor.*
- void mat2D_mult_row (Mat2D m, size_t r, double factor)

  *In-place row scaling: row(r) *= factor.*
- void mat2D_print (Mat2D m, const char *name, size_t padding)

  Print a matrix to stdout with a name and indentation padding.

- void mat2D_print_as_col (Mat2D m, const char *name, size_t padding)

  Print a matrix as a flattened column vector to stdout.
- void mat2D_set_identity (Mat2D m)

  Set a square matrix to the identity matrix.
- double mat2D_make_identity (Mat2D m)

  Reduce a matrix to identity via Gauss-Jordan elimination and return the cumulative scaling factor.
- void mat2D_set_rot_mat_x (Mat2D m, float angle_deg)

  Set a 3x3 rotation matrix for rotation about the X-axis.
- void mat2D_set_rot_mat_y (Mat2D m, float angle_deg)

  Set a 3x3 rotation matrix for rotation about the Y-axis.
- void mat2D_set_rot_mat_z (Mat2D m, float angle_deg)

  Set a 3x3 rotation matrix for rotation about the Z-axis.
- void mat2D_set_DCM_zyx (Mat2D DCM, float yaw_deg, float pitch_deg, float roll_deg)

  Build a 3x3 direction cosine matrix (DCM) from Z-Y-X Euler angles.
- void mat2D_copy (Mat2D des, Mat2D src)

  Copy all elements from src to des.
- void mat2D_copy_mat_to_mat_at_window (Mat2D des, Mat2D src, size_t is, size_t js, size_t ie, size_t je)

  Copy a rectangular window from src into des.
- void mat2D_get_col (Mat2D des, size_t des_col, Mat2D src, size_t src_col)

  Copy a column from src into a column of des.
- void mat2D_add_col_to_col (Mat2D des, size_t des_col, Mat2D src, size_t src_col)

  Add a source column into a destination column: des[:, des_col] += src[:, src_col].
- void mat2D_sub_col_to_col (Mat2D des, size_t des_col, Mat2D src, size_t src_col)

  Subtract a source column from a destination column: des[:, des_col] -= src[:, src_col].
- void mat2D_swap_rows (Mat2D m, size_t r1, size_t r2)

  Swap two rows of a matrix in-place.
- void mat2D_get_row (Mat2D des, size_t des_row, Mat2D src, size_t src_row)

  Copy a row from src into a row of des.
- void mat2D_add_row_to_row (Mat2D des, size_t des_row, Mat2D src, size_t src_row)

  Add a source row into a destination row: des[des_row, :] += src[src_row, :].
- void mat2D_sub_row_to_row (Mat2D des, size_t des_row, Mat2D src, size_t src_row)

  Subtract a source row from a destination row: des[des_row, :] -= src[src_row, :].
- double mat2D_calc_norma (Mat2D m)

  Compute the Frobenius norm of a matrix, sqrt(sum(m_ij^2)).
- bool mat2D_mat_is_all_digit (Mat2D m, double digit)

  Check if all elements of a matrix equal a given digit.
- bool mat2D_row_is_all_digit (Mat2D m, double digit, size_t r)

  Check if all elements of a row equal a given digit.
- bool mat2D_col_is_all_digit (Mat2D m, double digit, size_t c)

  Check if all elements of a column equal a given digit.
- double mat2D_det_2x2_mat (Mat2D m)

  Determinant of a 2x2 matrix.
- double mat2D_triangulate (Mat2D m)

  Forward elimination to transform a matrix to upper triangular form.
- double mat2D_det (Mat2D m)

  Determinant of an NxN matrix via Gaussian elimination.
- void mat2D_LUP_decomposition_with_swap (Mat2D src, Mat2D l, Mat2D p, Mat2D u)

  *Compute LUP decomposition: P*A = L*U with L unit diagonal.*
- void mat2D_transpose (Mat2D des, Mat2D src)

  Transpose a matrix: des = src^T.
- void mat2D_invert (Mat2D des, Mat2D src)

Invert a square matrix using Gauss-Jordan elimination.

- void mat2D_solve_linear_sys_LUP_decomposition (Mat2D A, Mat2D x, Mat2D B)

  Solve the linear system A x = B using LUP decomposition.
- Mat2D_Minor mat2D_minor_alloc_fill_from_mat (Mat2D ref_mat, size_t i, size_t j)

  Allocate a minor view by excluding row i and column j of ref_mat.
- Mat2D_Minor mat2D_minor_alloc_fill_from_mat_minor (Mat2D_Minor ref_mm, size_t i, size_t j)

  Allocate a nested minor view from an existing minor by excluding row i and column j of the minor.
- void mat2D_minor_free (Mat2D_Minor mm)

  Free the index arrays owned by a minor.
- void mat2D_minor_print (Mat2D_Minor mm, const char *name, size_t padding)

  Print a minor matrix to stdout with a name and indentation padding.
- double mat2D_det_2x2_mat_minor (Mat2D_Minor mm)

  Determinant of a 2x2 minor.
- double mat2D_minor_det (Mat2D_Minor mm)

  Determinant of a minor via recursive expansion by minors.

4.9.1 Detailed Description

A single-header C library for simple 2D matrix operations on doubles and uint32_t, including allocation, basic arithmetic, linear algebra, and helpers (LUP, inverse, determinant, DCM, etc.).

- Storage is contiguous row-major (C-style). The element at row i, column j (0-based) is located at `elements[i * stride_r + j]`.
- Dense matrices of `double` are represented by Mat2D, and dense matrices of `uint32_t` are represented by Mat2D_uint32.
- Some routines assert shape compatibility using MATRIX2D_ASSERT.
- Random number generation uses the C library `rand()`; it is not cryptographically secure.
- Inversion is done via Gauss-Jordan elimination with partial pivoting only when a pivot is zero; this can be numerically unstable for ill-conditioned matrices. See notes below.
- To compile the implementation, define MATRIX2D_IMPLEMENTATION in exactly one translation unit before including this header.

Example: #define MATRIX2D_IMPLEMENTATION #include "matrix2d.h"

Note

This one-file library is heavily inspired by Tsoding's nn.h implementation of matrix creation and operations: `https://github.com/tsoding/nn.h` and the video: `https://youtu.be/L1TbWe8b↩VOc?list=PLpM-Dvs8t0VZPZKggcql-MmjaBdZKeDMw`

Warning

Numerical stability:

- There is a set of functions for minors that can be used to compute the determinant, but that approach is factorial in complexity and too slow for larger matrices. This library uses Gaussian elimination instead.
- The inversion function can fail or be unstable if pivot values become very small. Consider preconditioning or using a more robust decomposition (e.g., full pivoting, SVD) for ill-conditioned problems.

Definition in file Matrix2D.h.

4.9.2 Macro Definition Documentation

4.9.2.1 __USE_MISC

```
#define __USE_MISC
```

Definition at line 151 of file Matrix2D.h.

4.9.2.2 MAT2D_AT

```
#define MAT2D_AT(
              m,
              i,
              j ) (m).elements[i * m.stride_r + j]
```

Access element (i, j) of a Mat2D (0-based).

Warning

This macro does not perform bounds checking in the fast configuration. Use carefully.

Definition at line 145 of file Matrix2D.h.

4.9.2.3 MAT2D_AT_UINT32

```
#define MAT2D_AT_UINT32(
              m,
              i,
              j ) (m).elements[i * m.stride_r + j]
```

Access element (i, j) of a Mat2D_uint32 (0-based).

Warning

This macro does not perform bounds checking in the fast configuration. Use carefully.

Definition at line 146 of file Matrix2D.h.

4.9.2.4 MAT2D_MINOR_AT

```
#define MAT2D_MINOR_AT(
              mm,
              i,
              j ) MAT2D_AT(mm.ref_mat, mm.rows_list[i], mm.cols_list[j])
```

Access element (i, j) of a Mat2D_Minor (0-based), dereferencing into the underlying reference matrix.

Definition at line 162 of file Matrix2D.h.

4.9.2.5 MAT2D_MINOR_PRINT

```
#define MAT2D_MINOR_PRINT(
              mm ) mat2D_minor_print(mm, #mm, 0)
```

Convenience macro to print a minor with its variable name.

Definition at line 177 of file Matrix2D.h.

4.9.2.6 mat2D_normalize

```
#define mat2D_normalize(
              m ) mat2D_mult((m), 1.0 / mat2D_calc_norma((m)))
```

In-place normalization of all elements so that the Frobenius norm becomes 1.

Equivalent to: m *= 1.0 / mat2D_calc_norma(m).

Definition at line 184 of file Matrix2D.h.

4.9.2.7 MAT2D_PRINT

```
#define MAT2D_PRINT(
              m ) mat2D_print(m, #m, 0)
```

Convenience macro to print a matrix with its variable name.

Definition at line 167 of file Matrix2D.h.

4.9.2.8 MAT2D_PRINT_AS_COL

```
#define MAT2D_PRINT_AS_COL(
             m ) mat2D_print_as_col(m, #m, 0)
```

Convenience macro to print a matrix as a single column with its name.

Definition at line 172 of file Matrix2D.h.

4.9.2.9 MATRIX2D_ASSERT

```
#define MATRIX2D_ASSERT assert
```

Assertion macro used by the library for parameter validation.

Defaults to C `assert`. Override by defining MATRIX2D_ASSERT before including this header if you want custom behavior.

Definition at line 68 of file Matrix2D.h.

4.9.2.10 MATRIX2D_MALLOC

```
#define MATRIX2D_MALLOC malloc
```

Allocation function used by the library.

Defaults to `malloc`. Override by defining MATRIX2D_MALLOC before including this header if you want to use a custom allocator.

Definition at line 56 of file Matrix2D.h.

4.9.2.11 PI

```
#define PI M_PI
```

Definition at line 154 of file Matrix2D.h.

4.9.3 Function Documentation

4.9.3.1 mat2D_add()

```
void mat2D_add (
            Mat2D dst,
            Mat2D a )
```

In-place addition: dst += a.

Parameters

dst	Destination matrix to be incremented.
a	Summand of same shape as dst.

Precondition

Shapes match.

Definition at line 496 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, MATRIX2D_ASSERT, and Mat2D::rows.

Referenced by adl_arrow_draw().

4.9.3.2 mat2D_add_col_to_col()

```
void mat2D_add_col_to_col (
            Mat2D des,
            size_t des_col,
            Mat2D src,
            size_t src_col )
```

Add a source column into a destination column: des[:, des_col] += src[:, src_col].

Parameters

des	Destination matrix (same row count as src).
des_col	Column index in destination.
src	Source matrix.
src_col	Column index in source.

Definition at line 828 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, MATRIX2D_ASSERT, and Mat2D::rows.

4.9.3.3 mat2D_add_row_time_factor_to_row()

```
void mat2D_add_row_time_factor_to_row (
            Mat2D m,
            size_t des_r,
            size_t src_r,
            double factor )
```

Row operation: row(des_r) += factor $*$ row(src_r).

Parameters

m	Matrix.
des_r	Destination row index.
src_r	Source row index.
factor	Scalar multiplier.

Definition at line 514 of file Matrix2D.h.

References Mat2D::cols, and MAT2D_AT.

4.9.3.4 mat2D_add_row_to_row()

```
void mat2D_add_row_to_row (
            Mat2D des,
            size_t des_row,
            Mat2D src,
            size_t src_row )
```

Add a source row into a destination row: des[des_row, :] += src[src_row, :].

Parameters

des	Destination matrix (same number of columns as src).
des_row	Row index in destination.
src	Source matrix.
src_row	Row index in source.

Definition at line 897 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, MATRIX2D_ASSERT, and Mat2D::rows.

4.9.3.5 mat2D_alloc()

```
Mat2D mat2D_alloc (
            size_t rows,
            size_t cols )
```

Allocate a rows x cols matrix of doubles.

Parameters

rows	Number of rows (>= 1).
cols	Number of columns (>= 1).

Returns

A Mat2D with contiguous storage; must be freed with mat2D_free.

Postcondition

m.stride_r == cols.

Definition at line 278 of file Matrix2D.h.

References Mat2D::cols, Mat2D::elements, MATRIX2D_ASSERT, MATRIX2D_MALLOC, Mat2D::rows, and Mat2D::stride_r.

Referenced by adl_arrow_draw(), adl_figure_alloc(), check_window_mat_size(), mat2D_det(), mat2D_invert(), mat2D_set_DCM_zyx(), mat2D_solve_linear_sys_LUP_decomposition(), and setup_window().

4.9.3.6 mat2D_alloc_uint32()

```
Mat2D_uint32 mat2D_alloc_uint32 (
            size_t rows,
            size_t cols )
```

Allocate a rows x cols matrix of uint32_t.

Parameters

rows	Number of rows (>= 1).
cols	Number of columns (>= 1).

Returns

A Mat2D_uint32 with contiguous storage; free with mat2D_free_uint32.

Postcondition

m.stride_r == cols.

Definition at line 297 of file Matrix2D.h.

References Mat2D_uint32::cols, Mat2D_uint32::elements, MATRIX2D_ASSERT, MATRIX2D_MALLOC, Mat2D_uint32::rows, and Mat2D_uint32::stride_r.

Referenced by adl_figure_alloc(), check_window_mat_size(), and setup_window().

4.9.3.7 mat2D_calc_norma()

```
double mat2D_calc_norma (
            Mat2D m )
```

Compute the Frobenius norm of a matrix, sqrt(sum(m_ij^2)).

Parameters

m	Matrix.

Returns

Frobenius norm.

Definition at line 931 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, and Mat2D::rows.

4.9.3.8 mat2D_col_is_all_digit()

```
bool mat2D_col_is_all_digit (
            Mat2D m,
            double digit,
            size_t c )
```

Check if all elements of a column equal a given digit.

Parameters

m	Matrix.
digit	Value to compare.
c	Column index.

Returns

true if every element equals digit, false otherwise.

Definition at line 985 of file Matrix2D.h.

References Mat2D::cols, and MAT2D_AT.

Referenced by mat2D_det().

4.9.3.9 mat2D_copy()

```
void mat2D_copy (
            Mat2D des,
            Mat2D src )
```

Copy all elements from src to des.

Parameters

des	Destination matrix.
src	Source matrix.

Precondition

Shapes match.

Definition at line 768 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, MATRIX2D_ASSERT, and Mat2D::rows.

Referenced by adl_arrow_draw(), mat2D_det(), mat2D_invert(), and mat2D_LUP_decomposition_with_swap().

4.9.3.10 mat2D_copy_mat_to_mat_at_window()

```
void mat2D_copy_mat_to_mat_at_window (
            Mat2D des,
            Mat2D src,
            size_t is,
            size_t js,
            size_t ie,
            size_t je )
```

Copy a rectangular window from src into des.

Parameters

des	Destination matrix. Must have size (ie - is + 1) x (je - js + 1).
src	Source matrix.
is	Start row index in src (inclusive).
js	Start column index in src (inclusive).
ie	End row index in src (inclusive).
je	End column index in src (inclusive).

Precondition

0 <= is <= ie < src.rows, 0 <= js <= je < src.cols.

Definition at line 790 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, MATRIX2D_ASSERT, and Mat2D::rows.

4.9.3.11 mat2D_cross()

```
void mat2D_cross (
            Mat2D dst,
            Mat2D a,
            Mat2D b )
```

3D cross product: dst = a x b for 3x1 vectors.

Parameters

dst	3x1 destination vector.
a	3x1 input vector.
b	3x1 input vector.

Precondition

All matrices have shape 3x1.

Definition at line 479 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, MATRIX2D_ASSERT, and Mat2D::rows.

4.9.3.12 mat2D_det()

```
double mat2D_det (
            Mat2D m )
```

Determinant of an NxN matrix via Gaussian elimination.

Parameters

m	Square matrix.

Returns

det(m).

Copies m internally, triangulates it, and returns the product of diagonal elements (adjusted by any scaling factor as implemented).

Definition at line 1052 of file Matrix2D.h.

References Mat2D::cols, mat2D_alloc(), MAT2D_AT, mat2D_col_is_all_digit(), mat2D_copy(), mat2D_free(), mat2D_row_is_all_digit(), mat2D_triangulate(), MATRIX2D_ASSERT, and Mat2D::rows.

Referenced by mat2D_invert().

4.9.3.13 mat2D_det_2x2_mat()

```
double mat2D_det_2x2_mat (
            Mat2D m )
```

Determinant of a 2x2 matrix.

Parameters

m	Matrix (must be 2x2).

Returns

det(m) = a11 a22 - a12 a21.

Definition at line 1000 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, MATRIX2D_ASSERT, and Mat2D::rows.

4.9.3.14 mat2D_det_2x2_mat_minor()

```
double mat2D_det_2x2_mat_minor (
            Mat2D_Minor mm )
```

Determinant of a 2x2 minor.

Parameters

mm	Minor (must be 2x2).

Returns

det(mm).

Definition at line 1383 of file Matrix2D.h.

References Mat2D_Minor::cols, MAT2D_MINOR_AT, MATRIX2D_ASSERT, and Mat2D_Minor::rows.

Referenced by mat2D_minor_det().

4.9.3.15 mat2D_dot()

```
void mat2D_dot (
            Mat2D dst,
            Mat2D a,
            Mat2D b )
```

Matrix product: dst = a $*$ b.

Parameters

dst	Destination matrix (size a.rows x b.cols).
a	Left matrix (size a.rows x a.cols).
b	Right matrix (size a.cols x b.cols).

Precondition

a.cols == b.rows, dst.rows == a.rows, dst.cols == b.cols.

Postcondition

dst is overwritten.

Definition at line 424 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, MATRIX2D_ASSERT, and Mat2D::rows.

Referenced by adl_arrow_draw(), mat2D_set_DCM_zyx(), and mat2D_solve_linear_sys_LUP_decomposition().

4.9.3.16 mat2D_dot_product()

```
double mat2D_dot_product (
            Mat2D a,
            Mat2D b )
```

Dot product between two vectors.

Parameters

a	Vector (shape n x 1 or 1 x n).
b	Vector (same shape as a).

Returns

The scalar dot product sum.

Precondition

a.rows == b.rows, a.cols == b.cols, and one dimension equals 1.

Definition at line 450 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, MATRIX2D_ASSERT, and Mat2D::rows.

4.9.3.17 mat2D_fill()

```
void mat2D_fill (
            Mat2D m,
            double x )
```

Fill all elements of a matrix of doubles with a scalar value.

Parameters

m	Matrix to fill.
x	Value to assign to every element.

Definition at line 362 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, and Mat2D::rows.

Referenced by adl_arrow_draw(), mat2D_invert(), mat2D_LUP_decomposition_with_swap(), and mat2D_solve_linear_sys_LUP_deco

4.9.3.18 mat2D_fill_sequence()

```
void mat2D_fill_sequence (
            Mat2D m,
            double start,
            double step )
```

Fill a matrix with an arithmetic sequence laid out in row-major order.

Parameters

m	Matrix to fill.
start	First value in the sequence.
step	Increment between consecutive elements.

Element at linear index k gets value start + step ∗ k.

Definition at line 378 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, mat2D_offset2d(), and Mat2D::rows.

4.9.3.19 mat2D_fill_uint32()

```
void mat2D_fill_uint32 (
            Mat2D_uint32 m,
            uint32_t x )
```

Fill all elements of a matrix of uint32_t with a scalar value.

Parameters

m	Matrix to fill.
x	Value to assign to every element.

Definition at line 391 of file Matrix2D.h.

References Mat2D_uint32::cols, MAT2D_AT_UINT32, and Mat2D_uint32::rows.

Referenced by adl_2Dscalar_interp_on_figure(), and adl_curves_plot_on_figure().

4.9.3.20 mat2D_free()

```
void mat2D_free (
            Mat2D m )
```

Free the memory owned by a Mat2D (elements pointer).

Parameters

m	Matrix whose elements were allocated via MATRIX2D_MALLOC.

Note

Safe to call with m.elements == NULL.

Definition at line 314 of file Matrix2D.h.

References Mat2D::elements.

Referenced by adl_arrow_draw(), check_window_mat_size(), mat2D_det(), mat2D_invert(), mat2D_set_DCM_zyx(), and mat2D_solve_linear_sys_LUP_decomposition().

4.9.3.21 mat2D_free_uint32()

```
void mat2D_free_uint32 (
            Mat2D_uint32 m )
```

Free the memory owned by a Mat2D_uint32 (elements pointer).

Parameters

m	Matrix whose elements were allocated via MATRIX2D_MALLOC.

Note

Safe to call with m.elements == NULL.

Definition at line 324 of file Matrix2D.h.

References Mat2D_uint32::elements.

Referenced by check_window_mat_size(), and destroy_window().

4.9.3.22 mat2D_get_col()

```
void mat2D_get_col (
            Mat2D des,
            size_t des_col,
            Mat2D src,
            size_t src_col )
```

Copy a column from src into a column of des.

Parameters

des	Destination matrix (same row count as src).
des_col	Column index in destination.
src	Source matrix.
src_col	Column index in source.

Definition at line 810 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, MATRIX2D_ASSERT, and Mat2D::rows.

4.9.3.23 mat2D_get_row()

```
void mat2D_get_row (
            Mat2D des,
            size_t des_row,
            Mat2D src,
            size_t src_row )
```

Copy a row from src into a row of des.

Parameters

des	Destination matrix (same number of columns as src).
des_row	Row index in destination.
src	Source matrix.
src_row	Row index in source.

Definition at line 879 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, MATRIX2D_ASSERT, and Mat2D::rows.

4.9.3.24 mat2D_invert()

```
void mat2D_invert (
            Mat2D des,
            Mat2D src )
```

Invert a square matrix using Gauss-Jordan elimination.

Parameters

des	Destination matrix (same shape as src).
src	Source square matrix.

Precondition

src is square and nonsingular.

If det(src) == 0, prints an error and sets des to all zeros.

Warning

May be numerically unstable for ill-conditioned matrices.

Definition at line 1169 of file Matrix2D.h.

References Mat2D::cols, mat2D_alloc(), MAT2D_AT, mat2D_copy(), mat2D_det(), mat2D_fill(), mat2D_free(), mat2D_mult_row(), mat2D_set_identity(), mat2D_sub_row_time_factor_to_row(), mat2D_swap_rows(), MATRIX2D_ASSERT, and Mat2D::rows.

Referenced by mat2D_solve_linear_sys_LUP_decomposition().

4.9.3.25 mat2D_LUP_decomposition_with_swap()

```
void mat2D_LUP_decomposition_with_swap (
            Mat2D src,
            Mat2D l,
            Mat2D p,
            Mat2D u )
```

Compute LUP decomposition: P∗A = L∗U with L unit diagonal.

Parameters

src	Input matrix A (not modified).
l	Lower triangular matrix with unit diagonal (output).
p	Permutation matrix (output).
u	Upper triangular matrix (output).

Precondition

l, p, u are allocated to match src shape; src is square.

Definition at line 1107 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, mat2D_copy(), mat2D_fill(), mat2D_set_identity(), mat2D_sub_row_time_factor_to_row(), mat2D_swap_rows(), and Mat2D::rows.

Referenced by mat2D_solve_linear_sys_LUP_decomposition().

4.9.3.26 mat2D_make_identity()

```
double mat2D_make_identity (
            Mat2D m )
```

Reduce a matrix to identity via Gauss-Jordan elimination and return the cumulative scaling factor.

Parameters

m	Matrix reduced in-place to identity (if nonsingular).

Returns

The product of row scaling factors applied during elimination.

Note

Intended as a helper for determinant-related operations.

Warning

Not robust to singular or ill-conditioned matrices.

Definition at line 643 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, mat2D_mult_row(), mat2D_sub_row_time_factor_to_row(), mat2D_swap_rows(), and Mat2D::rows.

4.9.3.27 mat2D_mat_is_all_digit()

```
bool mat2D_mat_is_all_digit (
            Mat2D m,
            double digit )
```

Check if all elements of a matrix equal a given digit.

Parameters

m	Matrix.
digit	Value to compare.

Returns

true if every element equals digit, false otherwise.

Definition at line 949 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, and Mat2D::rows.

4.9.3.28 mat2D_minor_alloc_fill_from_mat()

```
Mat2D_Minor mat2D_minor_alloc_fill_from_mat (
            Mat2D ref_mat,
            size_t i,
            size_t j )
```

Allocate a minor view by excluding row i and column j of ref_mat.

Parameters

ref_mat	Reference square matrix.
i	Excluded row index in ref_mat.
j	Excluded column index in ref_mat.

Returns

A Mat2D_Minor that references ref_mat.

Note

Free rows_list and cols_list with mat2D_minor_free when done.

Definition at line 1279 of file Matrix2D.h.

References Mat2D::cols, Mat2D_Minor::cols, Mat2D_Minor::cols_list, MATRIX2D_ASSERT, MATRIX2D_MALLOC, Mat2D_Minor::ref_mat, Mat2D::rows, Mat2D_Minor::rows, Mat2D_Minor::rows_list, and Mat2D_Minor::stride_r.

4.9.3.29 mat2D_minor_alloc_fill_from_mat_minor()

```
Mat2D_Minor mat2D_minor_alloc_fill_from_mat_minor (
            Mat2D_Minor ref_mm,
            size_t i,
            size_t j )
```

Allocate a nested minor view from an existing minor by excluding row i and column j of the minor.

Parameters

ref_mm	Reference minor.
i	Excluded row index in the minor.
j	Excluded column index in the minor.

Returns

A new Mat2D_Minor that references the same underlying matrix.

Note

Free rows_list and cols_list with mat2D_minor_free when done.

Definition at line 1318 of file Matrix2D.h.

References Mat2D_Minor::cols, Mat2D_Minor::cols_list, MATRIX2D_ASSERT, MATRIX2D_MALLOC, Mat2D_Minor::ref_mat, Mat2D_Minor::rows, Mat2D_Minor::rows_list, and Mat2D_Minor::stride_r.

Referenced by mat2D_minor_det().

4.9.3.30 mat2D_minor_det()

```
double mat2D_minor_det (
            Mat2D_Minor mm )
```

Determinant of a minor via recursive expansion by minors.

Parameters

mm	Square minor.

Returns

det(mm).

Warning

Exponential complexity (factorial). Intended for educational or very small matrices only.

Definition at line 1396 of file Matrix2D.h.

References Mat2D_Minor::cols, mat2D_det_2x2_mat_minor(), mat2D_minor_alloc_fill_from_mat_minor(), MAT2D_MINOR_AT, mat2D_minor_free(), MATRIX2D_ASSERT, and Mat2D_Minor::rows.

4.9.3.31 mat2D_minor_free()

```
void mat2D_minor_free (
            Mat2D_Minor mm )
```

Free the index arrays owned by a minor.

Parameters

mm	Minor to free.

Note

After this call, mm.rows_list and mm.cols_list are invalid.

Definition at line 1353 of file Matrix2D.h.

References Mat2D_Minor::cols_list, and Mat2D_Minor::rows_list.

Referenced by mat2D_minor_det().

4.9.3.32 mat2D_minor_print()

```
void mat2D_minor_print (
            Mat2D_Minor mm,
            const char * name,
            size_t padding )
```

Print a minor matrix to stdout with a name and indentation padding.

Parameters

mm	Minor to print.
name	Label to print.
padding	Left padding in spaces.

Definition at line 1365 of file Matrix2D.h.

References Mat2D_Minor::cols, MAT2D_MINOR_AT, and Mat2D_Minor::rows.

4.9.3.33 mat2D_mult()

```
void mat2D_mult (
            Mat2D m,
            double factor )
```

In-place scalar multiplication: m *= factor.

Parameters

m	Matrix.
factor	Scalar multiplier.

Definition at line 557 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, and Mat2D::rows.

4.9.3.34 mat2D_mult_row()

```
void mat2D_mult_row (
            Mat2D m,
            size_t r,
            double factor )
```

In-place row scaling: row(r) *= factor.

Parameters

m	Matrix.
r	Row index.
factor	Scalar multiplier.

Definition at line 572 of file Matrix2D.h.

References Mat2D::cols, and MAT2D_AT.

Referenced by mat2D_invert(), and mat2D_make_identity().

4.9.3.35 mat2D_offset2d()

```
size_t mat2D_offset2d (
            Mat2D m,
```

```
        size_t i,
        size_t j )
```

Compute the linear offset of element (i, j) in a Mat2D.

Parameters

m	Matrix.
i	Row index (0-based).
j	Column index (0-based).

Returns

The linear offset i ∗ stride_r + j.

Precondition

0 <= i < rows, 0 <= j < cols (asserted).

Definition at line 337 of file Matrix2D.h.

References Mat2D::cols, MATRIX2D_ASSERT, Mat2D::rows, and Mat2D::stride_r.

Referenced by mat2D_fill_sequence().

4.9.3.36 mat2D_offset2d_uint32()

```
size_t mat2D_offset2d_uint32 (
            Mat2D_uint32 m,
            size_t i,
            size_t j )
```

Compute the linear offset of element (i, j) in a Mat2D_uint32.

Parameters

m	Matrix.
i	Row index (0-based).
j	Column index (0-based).

Returns

The linear offset i ∗ stride_r + j.

Precondition

0 <= i < rows, 0 <= j < cols (asserted).

Definition at line 351 of file Matrix2D.h.

References Mat2D_uint32::cols, MATRIX2D_ASSERT, Mat2D_uint32::rows, and Mat2D_uint32::stride_r.

4.9.3.37 mat2D_print()

```
void mat2D_print (
            Mat2D m,
            const char * name,
            size_t padding )
```

Print a matrix to stdout with a name and indentation padding.

Parameters

m	Matrix to print.
name	Label to print.
padding	Left padding in spaces.

Definition at line 585 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, and Mat2D::rows.

4.9.3.38 mat2D_print_as_col()

```
void mat2D_print_as_col (
            Mat2D m,
            const char * name,
            size_t padding )
```

Print a matrix as a flattened column vector to stdout.

Parameters

m	Matrix to print (flattened in row-major).
name	Label to print.
padding	Left padding in spaces.

Definition at line 604 of file Matrix2D.h.

References Mat2D::cols, Mat2D::elements, and Mat2D::rows.

4.9.3.39 mat2D_rand()

```
void mat2D_rand (
            Mat2D m,
            double low,
            double high )
```

Fill a matrix with random doubles in [low, high).

Parameters

m	Matrix to fill.
low	Lower bound (inclusive).
high	Upper bound (exclusive).

Precondition

high $>$ low.

Definition at line 407 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, mat2D_rand_double(), and Mat2D::rows.

4.9.3.40 mat2D_rand_double()

```
double mat2D_rand_double (
            void  )
```

Return a pseudo-random double in the range [0, 1].

Note

Uses C library rand() and RAND_MAX. Not cryptographically secure.

Definition at line 266 of file Matrix2D.h.

Referenced by mat2D_rand().

4.9.3.41 mat2D_row_is_all_digit()

```
bool mat2D_row_is_all_digit (
            Mat2D m,
            double digit,
            size_t r )
```

Check if all elements of a row equal a given digit.

Parameters

m	Matrix.
digit	Value to compare.
r	Row index.

Returns

true if every element equals digit, false otherwise.

Definition at line 968 of file Matrix2D.h.

References Mat2D::cols, and MAT2D_AT.

Referenced by mat2D_det().

4.9.3.42 mat2D_set_DCM_zyx()

```
void mat2D_set_DCM_zyx (
            Mat2D DCM,
            float yaw_deg,
            float pitch_deg,
            float roll_deg )
```

Build a 3x3 direction cosine matrix (DCM) from Z-Y-X Euler angles.

Parameters

DCM	3x3 destination matrix.
yaw_deg	Rotation about Z in degrees.
pitch_deg	Rotation about Y in degrees.
roll_deg	Rotation about X in degrees.

Computes DCM = R_x(roll) ∗ R_y(pitch) ∗ R_z(yaw).

Definition at line 743 of file Matrix2D.h.

References mat2D_alloc(), mat2D_dot(), mat2D_free(), mat2D_set_rot_mat_x(), mat2D_set_rot_mat_y(), and mat2D_set_rot_mat_z().

4.9.3.43 mat2D_set_identity()

```
void mat2D_set_identity (
            Mat2D m )
```

Set a square matrix to the identity matrix.

Parameters

m	Matrix (must be square).

Precondition

m.rows == m.cols.

Definition at line 619 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, MATRIX2D_ASSERT, and Mat2D::rows.

Referenced by mat2D_invert(), mat2D_LUP_decomposition_with_swap(), mat2D_set_rot_mat_x(), mat2D_set_rot_mat_y(), and mat2D_set_rot_mat_z().

4.9.3.44 mat2D_set_rot_mat_x()

```
void mat2D_set_rot_mat_x (
            Mat2D m,
            float angle_deg )
```

Set a 3x3 rotation matrix for rotation about the X-axis.

Parameters

m	3x3 destination matrix.
angle_deg	Angle in degrees.

Definition at line 689 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, mat2D_set_identity(), MATRIX2D_ASSERT, PI, and Mat2D::rows.

Referenced by mat2D_set_DCM_zyx().

4.9.3.45 mat2D_set_rot_mat_y()

```
void mat2D_set_rot_mat_y (
            Mat2D m,
            float angle_deg )
```

Set a 3x3 rotation matrix for rotation about the Y-axis.

Parameters

m	3x3 destination matrix.
angle_deg	Angle in degrees.

Definition at line 706 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, mat2D_set_identity(), MATRIX2D_ASSERT, PI, and Mat2D::rows.

Referenced by mat2D_set_DCM_zyx().

4.9.3.46 mat2D_set_rot_mat_z()

```
void mat2D_set_rot_mat_z (
            Mat2D m,
            float angle_deg )
```

Set a 3x3 rotation matrix for rotation about the Z-axis.

Parameters

m	3x3 destination matrix.
angle_deg	Angle in degrees.

Definition at line 723 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, mat2D_set_identity(), MATRIX2D_ASSERT, PI, and Mat2D::rows.

Referenced by adl_arrow_draw(), and mat2D_set_DCM_zyx().

4.9.3.47 mat2D_solve_linear_sys_LUP_decomposition()

```
void mat2D_solve_linear_sys_LUP_decomposition (
            Mat2D A,
            Mat2D x,
            Mat2D B )
```

Solve the linear system A x = B using LUP decomposition.

Parameters

A	Coefficient matrix (NxN).
x	Solution vector (N x 1) (output).
B	Right-hand side vector (N x 1).

Internally computes LUP and uses explicit inverses of L and U.

Warning

Forming inverses explicitly can be less stable; a forward/backward substitution would be preferable for production-quality code.

Definition at line 1236 of file Matrix2D.h.

References Mat2D::cols, mat2D_alloc(), mat2D_dot(), mat2D_fill(), mat2D_free(), mat2D_invert(), mat2D_LUP_decomposition_with_s
MATRIX2D_ASSERT, and Mat2D::rows.

4.9.3.48 mat2D_sub()

```
void mat2D_sub (
            Mat2D dst,
            Mat2D a )
```

In-place subtraction: dst -= a.

Parameters

dst	Destination matrix to be decremented.
a	Subtrahend of same shape as dst.

Precondition

Shapes match.

Definition at line 527 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, MATRIX2D_ASSERT, and Mat2D::rows.

Referenced by adl_arrow_draw().

4.9.3.49 mat2D_sub_col_to_col()

```
void mat2D_sub_col_to_col (
            Mat2D des,
            size_t des_col,
            Mat2D src,
            size_t src_col )
```

Subtract a source column from a destination column: des[:, des_col] -= src[:, src_col].

Parameters

des	Destination matrix (same row count as src).
des_col	Column index in destination.
src	Source matrix.
src_col	Column index in source.

Definition at line 846 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, MATRIX2D_ASSERT, and Mat2D::rows.

4.9.3.50 mat2D_sub_row_time_factor_to_row()

```
void mat2D_sub_row_time_factor_to_row (
            Mat2D m,
```

```
            size_t des_r,
            size_t src_r,
            double factor )
```

Row operation: row(des_r) -= factor * row(src_r).

Parameters

m	Matrix.
des_r	Destination row index.
src_r	Source row index.
factor	Scalar multiplier.

Definition at line 545 of file Matrix2D.h.

References Mat2D::cols, and MAT2D_AT.

Referenced by mat2D_invert(), mat2D_LUP_decomposition_with_swap(), mat2D_make_identity(), and mat2D_triangulate().

4.9.3.51 mat2D_sub_row_to_row()

```
void mat2D_sub_row_to_row (
            Mat2D des,
            size_t des_row,
            Mat2D src,
            size_t src_row )
```

Subtract a source row from a destination row: des[des_row, :] -= src[src_row, :].

Parameters

des	Destination matrix (same number of columns as src).
des_row	Row index in destination.
src	Source matrix.
src_row	Row index in source.

Definition at line 915 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, MATRIX2D_ASSERT, and Mat2D::rows.

4.9.3.52 mat2D_swap_rows()

```
void mat2D_swap_rows (
            Mat2D m,
            size_t r1,
            size_t r2 )
```

Swap two rows of a matrix in-place.

Parameters

m	Matrix.
r1	First row index.
r2	Second row index.

Definition at line 863 of file Matrix2D.h.

References Mat2D::cols, and MAT2D_AT.

Referenced by mat2D_invert(), mat2D_LUP_decomposition_with_swap(), mat2D_make_identity(), and mat2D_triangulate().

4.9.3.53 mat2D_transpose()

```
void mat2D_transpose (
            Mat2D des,
            Mat2D src )
```

Transpose a matrix: des = src^T.

Parameters

des	Destination matrix (shape src.cols x src.rows).
src	Source matrix.

Definition at line 1149 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, MATRIX2D_ASSERT, and Mat2D::rows.

4.9.3.54 mat2D_triangulate()

```
double mat2D_triangulate (
            Mat2D m )
```

Forward elimination to transform a matrix to upper triangular form.

Parameters

m	Matrix transformed in-place.

Returns

Product of row scaling factors (currently 1 in this implementation).

Note

Used as part of determinant computation via triangularization.

Warning

Not robust for linearly dependent rows or tiny pivots.

Definition at line 1013 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, mat2D_sub_row_time_factor_to_row(), mat2D_swap_rows(), and Mat2D::rows.

Referenced by mat2D_det().

4.10 Matrix2D.h

```
00001
00039 #ifndef MATRIX2D_H_
00040 #define MATRIX2D_H_
00041
00042 #include <stddef.h>
00043 #include <stdio.h>
00044 #include <stdlib.h>
00045 #include <stdint.h>
00046 #include <stdbool.h>
00047
00055 #ifndef MATRIX2D_MALLOC
00056 #define MATRIX2D_MALLOC malloc
00057 #endif //MATRIX2D_MALLOC
00058
00066 #ifndef MATRIX2D_ASSERT
00067 #include <assert.h>
00068 #define MATRIX2D_ASSERT assert
00069 #endif //MATRIX2D_ASSERT
00070
00081 typedef struct {
00082     size_t rows;
00083     size_t cols;
00084     size_t stride_r; /* how many element you need to traves to get to the element underneath */
00085     double *elements;
00086 } Mat2D;
00087
00098 typedef struct {
00099     size_t rows;
00100     size_t cols;
00101     size_t stride_r; /* how many element you need to traves to get to the element underneath */
00102     uint32_t *elements;
00103 } Mat2D_uint32;
00104
00119 typedef struct {
00120     size_t rows;
00121     size_t cols;
00122     size_t stride_r; /* how many element you need to traves to get to the element underneath */
00123     size_t *rows_list;
00124     size_t *cols_list;
00125     Mat2D ref_mat;
00126 } Mat2D_Minor;
00127
00141 #if 0
00142 #define MAT2D_AT(m, i, j) (m).elements[mat2D_offset2d((m), (i), (j))]
00143 #define MAT2D_AT_UINT32(m, i, j) (m).elements[mat2D_offset2d_uint32((m), (i), (j))]
00144 #else /* use this macro for batter performance but no assertion */
00145 #define MAT2D_AT(m, i, j) (m).elements[i * m.stride_r + j]
00146 #define MAT2D_AT_UINT32(m, i, j) (m).elements[i * m.stride_r + j]
00147 #endif
00148
00149 #ifndef PI
00150     #ifndef __USE_MISC
00151     #define __USE_MISC
00152     #endif
00153     #include <math.h>
00154     #define PI M_PI
00155 #endif
00156
```

```
00162 #define MAT2D_MINOR_AT(mm, i, j) MAT2D_AT(mm.ref_mat, mm.rows_list[i], mm.cols_list[j])
00167 #define MAT2D_PRINT(m) mat2D_print(m, #m, 0)
00172 #define MAT2D_PRINT_AS_COL(m) mat2D_print_as_col(m, #m, 0)
00177 #define MAT2D_MINOR_PRINT(mm) mat2D_minor_print(mm, #mm, 0)
00184 #define mat2D_normalize(m) mat2D_mult((m), 1.0 / mat2D_calc_norma((m)))
00185
00186 double mat2D_rand_double(void);
00187
00188 Mat2D mat2D_alloc(size_t rows, size_t cols);
00189 Mat2D_uint32 mat2D_alloc_uint32(size_t rows, size_t cols);
00190 void mat2D_free(Mat2D m);
00191 void mat2D_free_uint32(Mat2D_uint32 m);
00192 size_t mat2D_offset2d(Mat2D m, size_t i, size_t j);
00193 size_t mat2D_offset2d_uint32(Mat2D_uint32 m, size_t i, size_t j);
00194
00195 void mat2D_fill(Mat2D m, double x);
00196 void mat2D_fill_sequence(Mat2D m, double start, double step);
00197 void mat2D_fill_uint32(Mat2D_uint32 m, uint32_t x);
00198 void mat2D_rand(Mat2D m, double low, double high);
00199
00200 void mat2D_dot(Mat2D dst, Mat2D a, Mat2D b);
00201 double mat2D_dot_product(Mat2D a, Mat2D b);
00202 void mat2D_cross(Mat2D dst, Mat2D a, Mat2D b);
00203
00204 void mat2D_add(Mat2D dst, Mat2D a);
00205 void mat2D_add_row_time_factor_to_row(Mat2D m, size_t des_r, size_t src_r, double factor);
00206
00207 void mat2D_sub(Mat2D dst, Mat2D a);
00208 void mat2D_sub_row_time_factor_to_row(Mat2D m, size_t des_r, size_t src_r, double factor);
00209
00210 void mat2D_mult(Mat2D m, double factor);
00211 void mat2D_mult_row(Mat2D m, size_t r, double factor);
00212
00213 void mat2D_print(Mat2D m, const char *name, size_t padding);
00214 void mat2D_print_as_col(Mat2D m, const char *name, size_t padding);
00215
00216 void mat2D_set_identity(Mat2D m);
00217 double mat2D_make_identity(Mat2D m);
00218 void mat2D_set_rot_mat_x(Mat2D m, float angle_deg);
00219 void mat2D_set_rot_mat_y(Mat2D m, float angle_deg);
00220 void mat2D_set_rot_mat_z(Mat2D m, float angle_deg);
00221 void mat2D_set_DCM_zyx(Mat2D DCM, float yaw_deg, float pitch_deg, float roll_deg);
00222
00223 void mat2D_copy(Mat2D des, Mat2D src);
00224 void mat2D_copy_mat_to_mat_at_window(Mat2D des, Mat2D src, size_t is, size_t js, size_t ie, size_t
      je);
00225
00226 void mat2D_get_col(Mat2D des, size_t des_col, Mat2D src, size_t src_col);
00227 void mat2D_add_col_to_col(Mat2D des, size_t des_col, Mat2D src, size_t src_col);
00228 void mat2D_sub_col_to_col(Mat2D des, size_t des_col, Mat2D src, size_t src_col);
00229
00230 void mat2D_swap_rows(Mat2D m, size_t r1, size_t r2);
00231 void mat2D_get_row(Mat2D des, size_t des_row, Mat2D src, size_t src_row);
00232 void mat2D_add_row_to_row(Mat2D des, size_t des_row, Mat2D src, size_t src_row);
00233 void mat2D_sub_row_to_row(Mat2D des, size_t des_row, Mat2D src, size_t src_row);
00234
00235 double mat2D_calc_norma(Mat2D m);
00236
00237 bool mat2D_mat_is_all_digit(Mat2D m, double digit);
00238 bool mat2D_row_is_all_digit(Mat2D m, double digit, size_t r);
00239 bool mat2D_col_is_all_digit(Mat2D m, double digit, size_t c);
00240
00241 double mat2D_det_2x2_mat(Mat2D m);
00242 double mat2D_triangulate(Mat2D m);
00243 double mat2D_det(Mat2D m);
00244 void mat2D_LUP_decomposition_with_swap(Mat2D src, Mat2D l, Mat2D p, Mat2D u);
00245 void mat2D_transpose(Mat2D des, Mat2D src);
00246 void mat2D_invert(Mat2D des, Mat2D src);
00247 void mat2D_solve_linear_sys_LUP_decomposition(Mat2D A, Mat2D x, Mat2D B);
00248
00249 Mat2D_Minor mat2D_minor_alloc_fill_from_mat(Mat2D ref_mat, size_t i, size_t j);
00250 Mat2D_Minor mat2D_minor_alloc_fill_from_mat_minor(Mat2D_Minor ref_mm, size_t i, size_t j);
00251 void mat2D_minor_free(Mat2D_Minor mm);
00252 void mat2D_minor_print(Mat2D_Minor mm, const char *name, size_t padding);
00253 double mat2D_det_2x2_mat_minor(Mat2D_Minor mm);
00254 double mat2D_minor_det(Mat2D_Minor mm);
00255
00256 #endif // MATRIX2D_H_
00257
00258 #ifdef MATRIX2D_IMPLEMENTATION
00259 #undef MATRIX2D_IMPLEMENTATION
00260
00261
00266 double mat2D_rand_double(void)
00267 {
00268     return (double) rand() / (double) RAND_MAX;
00269 }
```

```
00270
00278 Mat2D mat2D_alloc(size_t rows, size_t cols)
00279 {
00280     Mat2D m;
00281     m.rows = rows;
00282     m.cols = cols;
00283     m.stride_r = cols;
00284     m.elements = (double*)MATRIX2D_MALLOC(sizeof(double)*rows*cols);
00285     MATRIX2D_ASSERT(m.elements != NULL);
00286
00287     return m;
00288 }
00289
00297 Mat2D_uint32 mat2D_alloc_uint32(size_t rows, size_t cols)
00298 {
00299     Mat2D_uint32 m;
00300     m.rows = rows;
00301     m.cols = cols;
00302     m.stride_r = cols;
00303     m.elements = (uint32_t*)MATRIX2D_MALLOC(sizeof(uint32_t)*rows*cols);
00304     MATRIX2D_ASSERT(m.elements != NULL);
00305
00306     return m;
00307 }
00308
00314 void mat2D_free(Mat2D m)
00315 {
00316     free(m.elements);
00317 }
00318
00324 void mat2D_free_uint32(Mat2D_uint32 m)
00325 {
00326     free(m.elements);
00327 }
00328
00337 size_t mat2D_offset2d(Mat2D m, size_t i, size_t j)
00338 {
00339     MATRIX2D_ASSERT(i < m.rows && j < m.cols);
00340     return i * m.stride_r + j;
00341 }
00342
00351 size_t mat2D_offset2d_uint32(Mat2D_uint32 m, size_t i, size_t j)
00352 {
00353     MATRIX2D_ASSERT(i < m.rows && j < m.cols);
00354     return i * m.stride_r + j;
00355 }
00356
00362 void mat2D_fill(Mat2D m, double x)
00363 {
00364     for (size_t i = 0; i < m.rows; ++i) {
00365         for (size_t j = 0; j < m.cols; ++j) {
00366             MAT2D_AT(m, i, j) = x;
00367         }
00368     }
00369 }
00370
00378 void mat2D_fill_sequence(Mat2D m, double start, double step) {
00379     for (size_t i = 0; i < m.rows; i++) {
00380         for (size_t j = 0; j < m.cols; j++) {
00381             MAT2D_AT(m, i, j) = start + step * mat2D_offset2d(m, i, j);
00382         }
00383     }
00384 }
00385
00391 void mat2D_fill_uint32(Mat2D_uint32 m, uint32_t x)
00392 {
00393     for (size_t i = 0; i < m.rows; ++i) {
00394         for (size_t j = 0; j < m.cols; ++j) {
00395             MAT2D_AT_UINT32(m, i, j) = x;
00396         }
00397     }
00398 }
00399
00407 void mat2D_rand(Mat2D m, double low, double high)
00408 {
00409     for (size_t i = 0; i < m.rows; ++i) {
00410         for (size_t j = 0; j < m.cols; ++j) {
00411             MAT2D_AT(m, i, j) = mat2D_rand_double()*(high - low) + low;
00412         }
00413     }
00414 }
00415
00424 void mat2D_dot(Mat2D dst, Mat2D a, Mat2D b)
00425 {
00426     MATRIX2D_ASSERT(a.cols == b.rows);
00427     MATRIX2D_ASSERT(a.rows == dst.rows);
00428     MATRIX2D_ASSERT(b.cols == dst.cols);
```

```
00429
00430     size_t i, j, k;
00431
00432     for (i = 0; i < dst.rows; i++) {
00433         for (j = 0; j < dst.cols; j++) {
00434             MAT2D_AT(dst, i, j) = 0;
00435             for (k = 0; k < a.cols; k++) {
00436                 MAT2D_AT(dst, i, j) += MAT2D_AT(a, i, k)*MAT2D_AT(b, k, j);
00437             }
00438         }
00439     }
00440
00441 }
00442
00450 double mat2D_dot_product(Mat2D a, Mat2D b)
00451 {
00452     MATRIX2D_ASSERT(a.rows == b.rows);
00453     MATRIX2D_ASSERT(a.cols == b.cols);
00454     MATRIX2D_ASSERT((1 == a.cols && 1 == b.cols) || (1 == a.rows && 1 == b.rows));
00455
00456     double dot_product = 0;
00457
00458     if (1 == a.cols) {
00459         for (size_t i = 0; i < a.rows; i++) {
00460             dot_product += MAT2D_AT(a, i, 0) * MAT2D_AT(b, i, 0);
00461         }
00462     } else {
00463         for (size_t j = 0; j < a.cols; j++) {
00464             dot_product += MAT2D_AT(a, 0, j) * MAT2D_AT(b, 0, j);
00465         }
00466     }
00467
00468     return dot_product;
00469
00470 }
00471
00479 void mat2D_cross(Mat2D dst, Mat2D a, Mat2D b)
00480 {
00481     MATRIX2D_ASSERT(3 == dst.rows && 1 == dst.cols);
00482     MATRIX2D_ASSERT(3 == a.rows && 1 == a.cols);
00483     MATRIX2D_ASSERT(3 == b.rows && 1 == b.cols);
00484
00485     MAT2D_AT(dst, 0, 0) = MAT2D_AT(a, 1, 0) * MAT2D_AT(b, 2, 0) - MAT2D_AT(a, 2, 0) * MAT2D_AT(b, 1,
      0);
00486     MAT2D_AT(dst, 1, 0) = MAT2D_AT(a, 2, 0) * MAT2D_AT(b, 0, 0) - MAT2D_AT(a, 0, 0) * MAT2D_AT(b, 2,
      0);
00487     MAT2D_AT(dst, 2, 0) = MAT2D_AT(a, 0, 0) * MAT2D_AT(b, 1, 0) - MAT2D_AT(a, 1, 0) * MAT2D_AT(b, 0,
      0);
00488 }
00489
00496 void mat2D_add(Mat2D dst, Mat2D a)
00497 {
00498     MATRIX2D_ASSERT(dst.rows == a.rows);
00499     MATRIX2D_ASSERT(dst.cols == a.cols);
00500     for (size_t i = 0; i < dst.rows; ++i) {
00501         for (size_t j = 0; j < dst.cols; ++j) {
00502             MAT2D_AT(dst, i, j) += MAT2D_AT(a, i, j);
00503         }
00504     }
00505 }
00506
00514 void mat2D_add_row_time_factor_to_row(Mat2D m, size_t des_r, size_t src_r, double factor)
00515 {
00516     for (size_t j = 0; j < m.cols; ++j) {
00517         MAT2D_AT(m, des_r, j) += factor * MAT2D_AT(m, src_r, j);
00518     }
00519 }
00520
00527 void mat2D_sub(Mat2D dst, Mat2D a)
00528 {
00529     MATRIX2D_ASSERT(dst.rows == a.rows);
00530     MATRIX2D_ASSERT(dst.cols == a.cols);
00531     for (size_t i = 0; i < dst.rows; ++i) {
00532         for (size_t j = 0; j < dst.cols; ++j) {
00533             MAT2D_AT(dst, i, j) -= MAT2D_AT(a, i, j);
00534         }
00535     }
00536 }
00537
00545 void mat2D_sub_row_time_factor_to_row(Mat2D m, size_t des_r, size_t src_r, double factor)
00546 {
00547     for (size_t j = 0; j < m.cols; ++j) {
00548         MAT2D_AT(m, des_r, j) -= factor * MAT2D_AT(m, src_r, j);
00549     }
00550 }
00551
00557 void mat2D_mult(Mat2D m, double factor)
```

```
00558 {
00559     for (size_t i = 0; i < m.rows; ++i) {
00560         for (size_t j = 0; j < m.cols; ++j) {
00561             MAT2D_AT(m, i, j) *= factor;
00562         }
00563     }
00564 }
00565
00572 void mat2D_mult_row(Mat2D m, size_t r, double factor)
00573 {
00574     for (size_t j = 0; j < m.cols; ++j) {
00575         MAT2D_AT(m, r, j) *= factor;
00576     }
00577 }
00578
00585 void mat2D_print(Mat2D m, const char *name, size_t padding)
00586 {
00587     printf("%*s%s = [\n", (int) padding, "", name);
00588     for (size_t i = 0; i < m.rows; ++i) {
00589         printf("%*s    ", (int) padding, "");
00590         for (size_t j = 0; j < m.cols; ++j) {
00591             printf("%9.6f ", MAT2D_AT(m, i, j));
00592         }
00593         printf("\n");
00594     }
00595     printf("%*s]\n", (int) padding, "");
00596 }
00597
00604 void mat2D_print_as_col(Mat2D m, const char *name, size_t padding)
00605 {
00606     printf("%*s%s = [\n", (int) padding, "", name);
00607     for (size_t i = 0; i < m.rows*m.cols; ++i) {
00608             printf("%*s    ", (int) padding, "");
00609             printf("%f\n", m.elements[i]);
00610     }
00611     printf("%*s]\n", (int) padding, "");
00612 }
00613
00619 void mat2D_set_identity(Mat2D m)
00620 {
00621     MATRIX2D_ASSERT(m.cols == m.rows);
00622     for (size_t i = 0; i < m.rows; ++i) {
00623         for (size_t j = 0; j < m.cols; ++j) {
00624             MAT2D_AT(m, i, j) = i == j ? 1 : 0;
00625             // if (i == j) {
00626             //     MAT2D_AT(m, i, j) = 1;
00627             // }
00628             // else {
00629             //     MAT2D_AT(m, i, j) = 0;
00630             // }
00631         }
00632     }
00633 }
00634
00643 double mat2D_make_identity(Mat2D m)
00644 {
00645     /* make identity matrix using Gauss elimination */
00646     /* preforming Gauss elimination: https://en.wikipedia.org/wiki/Gaussian_elimination */
00647     /* returns the factor multiplying the determinant */
00648
00649     double factor_to_return = 1;
00650
00651     for (size_t i = 0; i < (size_t)fmin(m.rows-1, m.cols); i++) {
00652         /* check if it is the biggest first number (absolute value) */
00653         size_t biggest_r = i;
00654         for (size_t index = i; index < m.rows; index++) {
00655             if (fabs(MAT2D_AT(m, index, index)) > fabs(MAT2D_AT(m, biggest_r, 0))) {
00656                 biggest_r = index;
00657             }
00658         }
00659         if (i != biggest_r) {
00660             mat2D_swap_rows(m, i, biggest_r);
00661             factor_to_return *= -1;
00662         }
00663         for (size_t j = i+1; j < m.cols; j++) {
00664             double factor = 1 / MAT2D_AT(m, i, i);
00665             mat2D_sub_row_time_factor_to_row(m, j, i, MAT2D_AT(m, j, i) * factor);
00666             mat2D_mult_row(m, i, factor);
00667             factor_to_return *= factor;
00668         }
00669     }
00670     double factor = 1 / MAT2D_AT(m, m.rows-1, m.cols-1);
00671     mat2D_mult_row(m, m.rows-1, factor);
00672     factor_to_return *= factor;
00673     for (size_t c = m.cols-1; c > 0; c--) {
00674         for (int r = c-1; r >= 0; r--) {
00675             double factor = 1 / MAT2D_AT(m, c, c);
```

```
00676             mat2D_sub_row_time_factor_to_row(m, r, c, MAT2D_AT(m, r, c) * factor);
00677         }
00678     }
00679
00680
00681     return factor_to_return;
00682 }
00683
00689 void mat2D_set_rot_mat_x(Mat2D m, float angle_deg)
00690 {
00691     MATRIX2D_ASSERT(3 == m.cols && 3 == m.rows);
00692
00693     float angle_rad = angle_deg * PI / 180;
00694     mat2D_set_identity(m);
00695     MAT2D_AT(m, 1, 1) =  cos(angle_rad);
00696     MAT2D_AT(m, 1, 2) =  sin(angle_rad);
00697     MAT2D_AT(m, 2, 1) = -sin(angle_rad);
00698     MAT2D_AT(m, 2, 2) =  cos(angle_rad);
00699 }
00700
00706 void mat2D_set_rot_mat_y(Mat2D m, float angle_deg)
00707 {
00708     MATRIX2D_ASSERT(3 == m.cols && 3 == m.rows);
00709
00710     float angle_rad = angle_deg * PI / 180;
00711     mat2D_set_identity(m);
00712     MAT2D_AT(m, 0, 0) =  cos(angle_rad);
00713     MAT2D_AT(m, 0, 2) = -sin(angle_rad);
00714     MAT2D_AT(m, 2, 0) =  sin(angle_rad);
00715     MAT2D_AT(m, 2, 2) =  cos(angle_rad);
00716 }
00717
00723 void mat2D_set_rot_mat_z(Mat2D m, float angle_deg)
00724 {
00725     MATRIX2D_ASSERT(3 == m.cols && 3 == m.rows);
00726
00727     float angle_rad = angle_deg * PI / 180;
00728     mat2D_set_identity(m);
00729     MAT2D_AT(m, 0, 0) =  cos(angle_rad);
00730     MAT2D_AT(m, 0, 1) =  sin(angle_rad);
00731     MAT2D_AT(m, 1, 0) = -sin(angle_rad);
00732     MAT2D_AT(m, 1, 1) =  cos(angle_rad);
00733 }
00734
00743 void mat2D_set_DCM_zyx(Mat2D DCM, float yaw_deg, float pitch_deg, float roll_deg)
00744 {
00745     Mat2D RotZ = mat2D_alloc(3,3);
00746     mat2D_set_rot_mat_z(RotZ, yaw_deg);
00747     Mat2D RotY = mat2D_alloc(3,3);
00748     mat2D_set_rot_mat_y(RotY, pitch_deg);
00749     Mat2D RotX = mat2D_alloc(3,3);
00750     mat2D_set_rot_mat_x(RotX, roll_deg);
00751     Mat2D temp = mat2D_alloc(3,3);
00752
00753     mat2D_dot(temp, RotY, RotZ);
00754     mat2D_dot(DCM, RotX, temp); /* I have a DCM */
00755
00756     mat2D_free(RotZ);
00757     mat2D_free(RotY);
00758     mat2D_free(RotX);
00759     mat2D_free(temp);
00760 }
00761
00768 void mat2D_copy(Mat2D des, Mat2D src)
00769 {
00770     MATRIX2D_ASSERT(des.cols == src.cols);
00771     MATRIX2D_ASSERT(des.rows == src.rows);
00772
00773     for (size_t i = 0; i < des.rows; ++i) {
00774         for (size_t j = 0; j < des.cols; ++j) {
00775             MAT2D_AT(des, i, j) = MAT2D_AT(src, i, j);
00776         }
00777     }
00778 }
00779
00790 void mat2D_copy_mat_to_mat_at_window(Mat2D des, Mat2D src, size_t is, size_t js, size_t ie, size_t je)
00791 {
00792     MATRIX2D_ASSERT(je > js && ie > is);
00793     MATRIX2D_ASSERT(je-js+1 == des.cols);
00794     MATRIX2D_ASSERT(ie-is+1 == des.rows);
00795
00796     for (size_t index = 0; index < des.rows; ++index) {
00797         for (size_t jndex = 0; jndex < des.cols; ++jndex) {
00798             MAT2D_AT(des, index, jndex) = MAT2D_AT(src, is+index, js+jndex);
00799         }
00800     }
00801 }
```

```
00802
00810 void mat2D_get_col(Mat2D des, size_t des_col, Mat2D src, size_t src_col)
00811 {
00812     MATRIX2D_ASSERT(src_col < src.cols);
00813     MATRIX2D_ASSERT(des.rows == src.rows);
00814     MATRIX2D_ASSERT(des_col < des.cols);
00815
00816     for (size_t i = 0; i < des.rows; i++) {
00817         MAT2D_AT(des, i, des_col) = MAT2D_AT(src, i, src_col);
00818     }
00819 }
00820
00828 void mat2D_add_col_to_col(Mat2D des, size_t des_col, Mat2D src, size_t src_col)
00829 {
00830     MATRIX2D_ASSERT(src_col < src.cols);
00831     MATRIX2D_ASSERT(des.rows == src.rows);
00832     MATRIX2D_ASSERT(des_col < des.cols);
00833
00834     for (size_t i = 0; i < des.rows; i++) {
00835         MAT2D_AT(des, i, des_col) += MAT2D_AT(src, i, src_col);
00836     }
00837 }
00838
00846 void mat2D_sub_col_to_col(Mat2D des, size_t des_col, Mat2D src, size_t src_col)
00847 {
00848     MATRIX2D_ASSERT(src_col < src.cols);
00849     MATRIX2D_ASSERT(des.rows == src.rows);
00850     MATRIX2D_ASSERT(des_col < des.cols);
00851
00852     for (size_t i = 0; i < des.rows; i++) {
00853         MAT2D_AT(des, i, des_col) -= MAT2D_AT(src, i, src_col);
00854     }
00855 }
00856
00863 void mat2D_swap_rows(Mat2D m, size_t r1, size_t r2)
00864 {
00865     for (size_t j = 0; j < m.cols; j++) {
00866         double temp = MAT2D_AT(m, r1, j);
00867         MAT2D_AT(m, r1, j) = MAT2D_AT(m, r2, j);
00868         MAT2D_AT(m, r2, j) = temp;
00869     }
00870 }
00871
00879 void mat2D_get_row(Mat2D des, size_t des_row, Mat2D src, size_t src_row)
00880 {
00881     MATRIX2D_ASSERT(src_row < src.rows);
00882     MATRIX2D_ASSERT(des.cols == src.cols);
00883     MATRIX2D_ASSERT(des_row < des.rows);
00884
00885     for (size_t j = 0; j < des.cols; j++) {
00886         MAT2D_AT(des, des_row, j) = MAT2D_AT(src, src_row, j);
00887     }
00888 }
00889
00897 void mat2D_add_row_to_row(Mat2D des, size_t des_row, Mat2D src, size_t src_row)
00898 {
00899     MATRIX2D_ASSERT(src_row < src.rows);
00900     MATRIX2D_ASSERT(des.cols == src.cols);
00901     MATRIX2D_ASSERT(des_row < des.rows);
00902
00903     for (size_t j = 0; j < des.cols; j++) {
00904         MAT2D_AT(des, des_row, j) += MAT2D_AT(src, src_row, j);
00905     }
00906 }
00907
00915 void mat2D_sub_row_to_row(Mat2D des, size_t des_row, Mat2D src, size_t src_row)
00916 {
00917     MATRIX2D_ASSERT(src_row < src.rows);
00918     MATRIX2D_ASSERT(des.cols == src.cols);
00919     MATRIX2D_ASSERT(des_row < des.rows);
00920
00921     for (size_t j = 0; j < des.cols; j++) {
00922         MAT2D_AT(des, des_row, j) -= MAT2D_AT(src, src_row, j);
00923     }
00924 }
00925
00931 double mat2D_calc_norma(Mat2D m)
00932 {
00933     double sum = 0;
00934
00935     for (size_t i = 0; i < m.rows; ++i) {
00936         for (size_t j = 0; j < m.cols; ++j) {
00937             sum += MAT2D_AT(m, i, j) * MAT2D_AT(m, i, j);
00938         }
00939     }
00940     return sqrt(sum);
00941 }
```

```
00942
00949 bool mat2D_mat_is_all_digit(Mat2D m, double digit)
00950 {
00951     for (size_t i = 0; i < m.rows; ++i) {
00952         for (size_t j = 0; j < m.cols; ++j) {
00953             if (MAT2D_AT(m, i, j) != digit) {
00954                 return false;
00955             }
00956         }
00957     }
00958     return true;
00959 }
00960
00968 bool mat2D_row_is_all_digit(Mat2D m, double digit, size_t r)
00969 {
00970     for (size_t j = 0; j < m.cols; ++j) {
00971         if (MAT2D_AT(m, r, j) != digit) {
00972             return false;
00973         }
00974     }
00975     return true;
00976 }
00977
00985 bool mat2D_col_is_all_digit(Mat2D m, double digit, size_t c)
00986 {
00987     for (size_t i = 0; i < m.cols; ++i) {
00988         if (MAT2D_AT(m, i, c) != digit) {
00989             return false;
00990         }
00991     }
00992     return true;
00993 }
00994
01000 double mat2D_det_2x2_mat(Mat2D m)
01001 {
01002     MATRIX2D_ASSERT(2 == m.cols && 2 == m.rows && "Not a 2x2 matrix");
01003     return MAT2D_AT(m, 0, 0) * MAT2D_AT(m, 1, 1) - MAT2D_AT(m, 0, 1) * MAT2D_AT(m, 1, 0);
01004 }
01005
01013 double mat2D_triangulate(Mat2D m)
01014 {
01015     /* preforming Gauss elimination: https://en.wikipedia.org/wiki/Gaussian_elimination */
01016     /* returns the factor multiplying the determinant */
01017
01018     double factor_to_return = 1;
01019
01020     for (size_t i = 0; i < (size_t)fmin(m.rows-1, m.cols); i++) {
01021         if (!MAT2D_AT(m, i, i)) {   /* swapping only if it is zero */
01022             /* finding biggest first number (absolute value) */
01023             size_t biggest_r = i;
01024             for (size_t index = i; index < m.rows; index++) {
01025                 if (fabs(MAT2D_AT(m, index, i)) > fabs(MAT2D_AT(m, biggest_r, i))) {
01026                     biggest_r = index;
01027                 }
01028             }
01029             if (i != biggest_r) {
01030                 mat2D_swap_rows(m, i, biggest_r);
01031             }
01032         }
01033         for (size_t j = i+1; j < m.cols; j++) {
01034             double factor = 1 / MAT2D_AT(m, i, i);
01035             if (!isfinite(factor)) {
01036                 printf("%s:%d: [Error] unable to transfrom into uperr triangular matrix. Probably some
      of the rows are not independent.\n", __FILE__, __LINE__);
01037             }
01038             double mat_value = MAT2D_AT(m, j, i);
01039             mat2D_sub_row_time_factor_to_row(m, j, i, mat_value * factor);
01040         }
01041     }
01042     return factor_to_return;
01043 }
01044
01052 double mat2D_det(Mat2D m)
01053 {
01054     MATRIX2D_ASSERT(m.cols == m.rows && "should be a square matrix");
01055
01056     /* checking if there is a row or column with all zeros */
01057     /* checking rows */
01058     for (size_t i = 0; i < m.rows; i++) {
01059         if (mat2D_row_is_all_digit(m, 0, i)) {
01060             return 0;
01061         }
01062     }
01063     /* checking cols */
01064     for (size_t j = 0; j < m.rows; j++) {
01065         if (mat2D_col_is_all_digit(m, 0, j)) {
01066             return 0;
```

```
01067         }
01068     }
01069
01070     /* This is an implementation of naive determinant calculation using minors. This is too slow */
01071
01072     // double det = 0;
01073     // /* TODO: finding beast row or col? */
01074     // for (size_t i = 0, j = 0; i < m.rows; i++) { /* first column */
01075     //     if (MAT2D_AT(m, i, j) < 1e-10) continue;
01076     //     Mat2D_Minor sub_mm = mat2D_minor_alloc_fill_from_mat(m, i, j);
01077     //     int factor = (i+j)%2 ? -1 : 1;
01078     //     if (sub_mm.cols != 2) {
01079     //         MATRIX2D_ASSERT(sub_mm.cols == sub_mm.rows && "should be a square matrix");
01080     //         det += MAT2D_AT(m, i, j) * (factor) * mat2D_minor_det(sub_mm);
01081     //     } else if (sub_mm.cols == 2 && sub_mm.rows == 2) {
01082     //         det += MAT2D_AT(m, i, j) * (factor) * mat2D_det_2x2_mat_minor(sub_mm);;
01083     //     }
01084     //     mat2D_minor_free(sub_mm);
01085     // }
01086
01087     Mat2D temp_m = mat2D_alloc(m.rows, m.cols);
01088     mat2D_copy(temp_m, m);
01089     double factor = mat2D_triangulate(temp_m);
01090     double diag_mul = 1;
01091     for (size_t i = 0; i < temp_m.rows; i++) {
01092         diag_mul *= MAT2D_AT(temp_m, i, i);
01093     }
01094     mat2D_free(temp_m);
01095
01096     return diag_mul / factor;
01097 }
01098
01107 void mat2D_LUP_decomposition_with_swap(Mat2D src, Mat2D l, Mat2D p, Mat2D u)
01108 {
01109     /* performing LU decomposition Following the Wikipedia page:
      https://en.wikipedia.org/wiki/LU_decomposition */
01110
01111     mat2D_copy(u, src);
01112     mat2D_set_identity(p);
01113     mat2D_fill(l, 0);
01114
01115     for (size_t i = 0; i < (size_t)fmin(u.rows-1, u.cols); i++) {
01116         if (!MAT2D_AT(u, i, i)) {   /* swapping only if it is zero */
01117             /* finding biggest first number (absolute value) */
01118             size_t biggest_r = i;
01119             for (size_t index = i; index < u.rows; index++) {
01120                 if (fabs(MAT2D_AT(u, index, i)) > fabs(MAT2D_AT(u, biggest_r, i))) {
01121                     biggest_r = index;
01122                 }
01123             }
01124             if (i != biggest_r) {
01125                 mat2D_swap_rows(u, i, biggest_r);
01126                 mat2D_swap_rows(p, i, biggest_r);
01127                 mat2D_swap_rows(l, i, biggest_r);
01128             }
01129         }
01130         for (size_t j = i+1; j < u.cols; j++) {
01131             double factor = 1 / MAT2D_AT(u, i, i);
01132             if (!isfinite(factor)) {
01133                 printf("%s:%d: [Error] unable to transfrom into uper triangular matrix. Probably some
      of the rows are not independent.\n", __FILE__, __LINE__);
01134             }
01135             double mat_value = MAT2D_AT(u, j, i);
01136             mat2D_sub_row_time_factor_to_row(u, j, i, mat_value * factor);
01137             MAT2D_AT(l, j, i) = mat_value * factor;
01138         }
01139         MAT2D_AT(l, i, i) = 1;
01140     }
01141     MAT2D_AT(l, l.rows-1, l.cols-1) = 1;
01142 }
01143
01149 void mat2D_transpose(Mat2D des, Mat2D src)
01150 {
01151     MATRIX2D_ASSERT(des.cols == src.rows);
01152     MATRIX2D_ASSERT(des.rows == src.cols);
01153
01154     for (size_t index = 0; index < des.rows; ++index) {
01155         for (size_t jndex = 0; jndex < des.cols; ++jndex) {
01156             MAT2D_AT(des, index, jndex) = MAT2D_AT(src, jndex, index);
01157         }
01158     }
01159 }
01160
01169 void mat2D_invert(Mat2D des, Mat2D src)
01170 {
01171     MATRIX2D_ASSERT(src.cols == src.rows && "should be an NxN matrix");
01172     MATRIX2D_ASSERT(des.cols == src.cols && des.rows == des.cols);
```

```
01173
01174     Mat2D m = mat2D_alloc(src.rows, src.cols);
01175     mat2D_copy(m, src);
01176
01177     mat2D_set_identity(des);
01178
01179     if (!mat2D_det(m)) {
01180         mat2D_fill(des, 0);
01181         printf("%s:%d: [Error] Can't invert the matrix. Determinant is zero! Set the inverse matrix to
      all zeros\n", __FILE__, __LINE__);
01182         return;
01183     }
01184
01185     for (size_t i = 0; i < (size_t)fmin(m.rows-1, m.cols); i++) {
01186         if (!MAT2D_AT(m, i, i)) {   /* swapping only if it is zero */
01187             /* finding biggest first number (absolute value) */
01188             size_t biggest_r = i;
01189             for (size_t index = i; index < m.rows; index++) {
01190                 if (fabs(MAT2D_AT(m, index, i)) > fabs(MAT2D_AT(m, biggest_r, i))) {
01191                     biggest_r = index;
01192                 }
01193             }
01194             if (i != biggest_r) {
01195                 mat2D_swap_rows(m, i, biggest_r);
01196                 mat2D_swap_rows(des, i, biggest_r);
01197                 printf("%s:%d: [INFO] swapping row %zu with row %zu.\n", __FILE__, __LINE__, i,
      biggest_r);
01198             } else {
01199                 MATRIX2D_ASSERT(0 && "can't inverse");
01200             }
01201         }
01202         for (size_t j = i+1; j < m.cols; j++) {
01203             double factor = 1 / MAT2D_AT(m, i, i);
01204             double mat_value = MAT2D_AT(m, j, i);
01205             mat2D_sub_row_time_factor_to_row(m, j, i, mat_value * factor);
01206             mat2D_mult_row(m, i, factor);
01207
01208             mat2D_sub_row_time_factor_to_row(des, j, i, mat_value * factor);
01209             mat2D_mult_row(des, i, factor);
01210         }
01211     }
01212     double factor = 1 / MAT2D_AT(m, m.rows-1, m.cols-1);
01213     mat2D_mult_row(m, m.rows-1, factor);
01214     mat2D_mult_row(des, des.rows-1, factor);
01215     for (size_t c = m.cols-1; c > 0; c--) {
01216         for (int r = c-1; r >= 0; r--) {
01217             double factor = 1 / MAT2D_AT(m, c, c);
01218             double mat_value = MAT2D_AT(m, r, c);
01219             mat2D_sub_row_time_factor_to_row(m, r, c, mat_value * factor);
01220             mat2D_sub_row_time_factor_to_row(des, r, c, mat_value * factor);
01221         }
01222     }
01223
01224     mat2D_free(m);
01225 }
01226
01236 void mat2D_solve_linear_sys_LUP_decomposition(Mat2D A, Mat2D x, Mat2D B)
01237 {
01238     MATRIX2D_ASSERT(A.cols == x.rows);
01239     MATRIX2D_ASSERT(1 == x.cols);
01240     MATRIX2D_ASSERT(A.rows == B.rows);
01241     MATRIX2D_ASSERT(1 == B.cols);
01242
01243     Mat2D y     = mat2D_alloc(x.rows, x.cols);
01244     Mat2D l     = mat2D_alloc(A.rows, A.cols);
01245     Mat2D p     = mat2D_alloc(A.rows, A.cols);
01246     Mat2D u     = mat2D_alloc(A.rows, A.cols);
01247     Mat2D inv_l = mat2D_alloc(l.rows, l.cols);
01248     Mat2D inv_u = mat2D_alloc(u.rows, u.cols);
01249
01250     mat2D_LUP_decomposition_with_swap(A, l, p, u);
01251
01252     mat2D_invert(inv_l, l);
01253     mat2D_invert(inv_u, u);
01254
01255     mat2D_fill(x, 0);   /* x here is only a temp mat*/
01256     mat2D_fill(y, 0);
01257     mat2D_dot(x, p, B);
01258     mat2D_dot(y, inv_l, x);
01259
01260     mat2D_fill(x, 0);
01261     mat2D_dot(x, inv_u, y);
01262
01263     mat2D_free(y);
01264     mat2D_free(l);
01265     mat2D_free(p);
01266     mat2D_free(u);
```

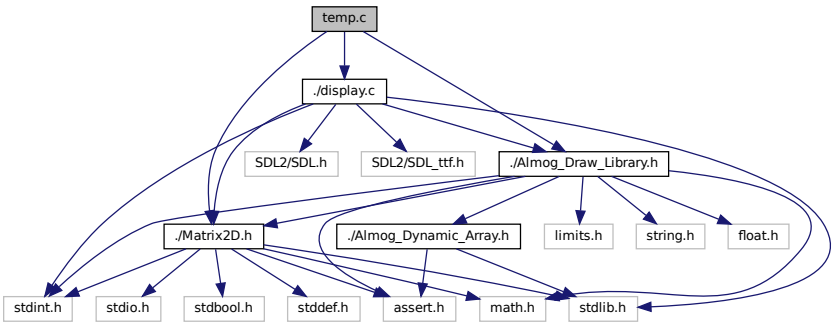
```
01267     mat2D_free(inv_l);
01268     mat2D_free(inv_u);
01269 }
01270
01279 Mat2D_Minor mat2D_minor_alloc_fill_from_mat(Mat2D ref_mat, size_t i, size_t j)
01280 {
01281     MATRIX2D_ASSERT(ref_mat.cols == ref_mat.rows && "minor is defined only for square matrix");
01282
01283     Mat2D_Minor mm;
01284     mm.cols = ref_mat.cols-1;
01285     mm.rows = ref_mat.rows-1;
01286     mm.stride_r = ref_mat.cols-1;
01287     mm.cols_list = (size_t*)MATRIX2D_MALLOC(sizeof(double)*(ref_mat.cols-1));
01288     mm.rows_list = (size_t*)MATRIX2D_MALLOC(sizeof(double)*(ref_mat.rows-1));
01289     mm.ref_mat = ref_mat;
01290
01291     MATRIX2D_ASSERT(mm.cols_list != NULL && mm.rows_list != NULL);
01292
01293     for (size_t index = 0, temp_index = 0; index < ref_mat.rows; index++) {
01294         if (index != i) {
01295             mm.rows_list[temp_index] = index;
01296             temp_index++;
01297         }
01298     }
01299     for (size_t jndex = 0, temp_jndex = 0; jndex < ref_mat.rows; jndex++) {
01300         if (jndex != j) {
01301             mm.cols_list[temp_jndex] = jndex;
01302             temp_jndex++;
01303         }
01304     }
01305
01306     return mm;
01307 }
01308
01318 Mat2D_Minor mat2D_minor_alloc_fill_from_mat_minor(Mat2D_Minor ref_mm, size_t i, size_t j)
01319 {
01320     MATRIX2D_ASSERT(ref_mm.cols == ref_mm.rows && "minor is defined only for square matrix");
01321
01322     Mat2D_Minor mm;
01323     mm.cols = ref_mm.cols-1;
01324     mm.rows = ref_mm.rows-1;
01325     mm.stride_r = ref_mm.cols-1;
01326     mm.cols_list = (size_t*)MATRIX2D_MALLOC(sizeof(double)*(ref_mm.cols-1));
01327     mm.rows_list = (size_t*)MATRIX2D_MALLOC(sizeof(double)*(ref_mm.rows-1));
01328     mm.ref_mat = ref_mm.ref_mat;
01329
01330     MATRIX2D_ASSERT(mm.cols_list != NULL && mm.rows_list != NULL);
01331
01332     for (size_t index = 0, temp_index = 0; index < ref_mm.rows; index++) {
01333         if (index != i) {
01334             mm.rows_list[temp_index] = ref_mm.rows_list[index];
01335             temp_index++;
01336         }
01337     }
01338     for (size_t jndex = 0, temp_jndex = 0; jndex < ref_mm.rows; jndex++) {
01339         if (jndex != j) {
01340             mm.cols_list[temp_jndex] = ref_mm.cols_list[jndex];
01341             temp_jndex++;
01342         }
01343     }
01344
01345     return mm;
01346 }
01347
01353 void mat2D_minor_free(Mat2D_Minor mm)
01354 {
01355     free(mm.cols_list);
01356     free(mm.rows_list);
01357 }
01358
01365 void mat2D_minor_print(Mat2D_Minor mm, const char *name, size_t padding)
01366 {
01367     printf("%*s%s = [\n", (int) padding, "", name);
01368     for (size_t i = 0; i < mm.rows; ++i) {
01369         printf("%*s    ", (int) padding, "");
01370         for (size_t j = 0; j < mm.cols; ++j) {
01371             printf("%f ", MAT2D_MINOR_AT(mm, i, j));
01372         }
01373         printf("\n");
01374     }
01375     printf("%*s]\n", (int) padding, "");
01376 }
01377
01383 double mat2D_det_2x2_mat_minor(Mat2D_Minor mm)
01384 {
01385     MATRIX2D_ASSERT(2 == mm.cols && 2 == mm.rows && "Not a 2x2 matrix");
01386     return MAT2D_MINOR_AT(mm, 0, 0) * MAT2D_MINOR_AT(mm, 1, 1) - MAT2D_MINOR_AT(mm, 0, 1) *
```

```
      MAT2D_MINOR_AT(mm, 1, 0);
01387 }
01388
01396 double mat2D_minor_det(Mat2D_Minor mm)
01397 {
01398     MATRIX2D_ASSERT(mm.cols == mm.rows && "should be a square matrix");
01399
01400     double det = 0;
01401     /* TODO: finding beast row or col? */
01402     for (size_t i = 0, j = 0; i < mm.rows; i++) { /* first column */
01403         if (MAT2D_MINOR_AT(mm, i, j) < 1e-10) continue;
01404         Mat2D_Minor sub_mm = mat2D_minor_alloc_fill_from_mat_minor(mm, i, j);
01405         int factor = (i+j)%2 ? -1 : 1;
01406         if (sub_mm.cols != 2) {
01407             MATRIX2D_ASSERT(sub_mm.cols == sub_mm.rows && "should be a square matrix");
01408             det += MAT2D_MINOR_AT(mm, i, j) * (factor) * mat2D_minor_det(sub_mm);
01409         } else if (sub_mm.cols == 2 && sub_mm.rows == 2) {
01410             det += MAT2D_MINOR_AT(mm, i, j) * (factor) * mat2D_det_2x2_mat_minor(sub_mm);;
01411         }
01412         mat2D_minor_free(sub_mm);
01413     }
01414     return det;
01415 }
01416
01417
01418 #endif // MATRIX2D_IMPLEMENTATION
```

4.11 temp.c File Reference

```
#include "./Almog_Draw_Library.h"
#include "./display.c"
#include "./Matrix2D.h"
```

Include dependency graph for temp.c:



Macros

- #define SETUP
- #define UPDATE
- #define RENDER
- #define ALMOG_DRAW_LIBRARY_IMPLEMENTATION
- #define MATRIX2D_IMPLEMENTATION

Functions

- void setup (game_state_t *game_state)
- void update (game_state_t *game_state)
- void render (game_state_t *game_state)

Variables

- Quad quad1
- Tri tri

4.11.1 Macro Definition Documentation

4.11.1.1 ALMOG_DRAW_LIBRARY_IMPLEMENTATION

```
#define ALMOG_DRAW_LIBRARY_IMPLEMENTATION
```

Definition at line 4 of file temp.c.

4.11.1.2 MATRIX2D_IMPLEMENTATION

```
#define MATRIX2D_IMPLEMENTATION
```

Definition at line 7 of file temp.c.

4.11.1.3 RENDER

```
#define RENDER
```

Definition at line 3 of file temp.c.

4.11.1.4 SETUP

```
#define SETUP
```

Definition at line 1 of file temp.c.

4.11.1.5 UPDATE

```
#define UPDATE
```

Definition at line 2 of file temp.c.

4.11.2 Function Documentation

4.11.2.1 render()

```
void render (
            game_state_t * game_state )
```

Definition at line 50 of file temp.c.

References adl_linear_map(), adl_quad_draw(), adl_quad_fill_interpolate_color_mean_value(), adl_tri_draw(), adl_tri_fill_Pinedas_rasterizer_interpolate_color(), Mat2D::cols, game_state_t::inv_z_buffer_mat, MAT2D_AT, MAT2D_AT_UINT32, game_state_t::offset_zoom_param, quad1, RGB_hexRGB, Mat2D::rows, tri, and game_state_t::window_pixels_mat.

4.11.2.2 setup()

```
void setup (
            game_state_t * game_state )
```

Definition at line 13 of file temp.c.

References Tri::colors, Quad::colors, Tri::light_intensity, Quad::light_intensity, Tri::points, Quad::points, quad1, Tri::to_draw, Quad::to_draw, game_state_t::to_limit_fps, and tri.

4.11.2.3 update()

```
void update (
            game_state_t * game_state )
```

Definition at line 45 of file temp.c.

4.11.3 Variable Documentation

4.11.3.1 quad1

```
Quad quad1
```

Definition at line 10 of file temp.c.

Referenced by render(), and setup().

4.11.3.2 tri

```
Tri tri
```

Definition at line 11 of file temp.c.

Referenced by adl_tri_draw(), adl_tri_fill_Pinedas_rasterizer(), adl_tri_fill_Pinedas_rasterizer_interpolate_color(), adl_tri_fill_Pinedas_rasterizer_interpolate_normal(), adl_tri_mesh_draw(), adl_tri_mesh_fill_Pinedas_rasterizer(), adl_tri_mesh_fill_Pinedas_rasterizer_interpolate_color(), adl_tri_mesh_fill_Pinedas_rasterizer_interpolate_normal(), render(), and setup().

4.12 temp.c

```
00001 #define SETUP
00002 #define UPDATE
00003 #define RENDER
00004 #define ALMOG_DRAW_LIBRARY_IMPLEMENTATION
00005 #include "./Almog_Draw_Library.h"
00006 #include "./display.c"
00007 #define MATRIX2D_IMPLEMENTATION
00008 #include "./Matrix2D.h"
00009
00010 Quad quad1;
00011 Tri tri;
00012
00013 void setup(game_state_t *game_state)
00014 {
00015     // game_state->const_fps = 30;
00016     game_state->to_limit_fps = 0;
00017
00018     quad1.points[3] = (Point){200, 100, 1, 1};
00019     quad1.points[2] = (Point){600, 50 , 1, 1};
00020     quad1.points[1] = (Point){200, 700, 1, 1};
00021     quad1.points[0] = (Point){100, 300, 1, 1};
00022     quad1.to_draw = true;
00023     quad1.light_intensity[0] = 1;
00024     quad1.light_intensity[1] = 1;
00025     quad1.light_intensity[2] = 1;
00026     quad1.light_intensity[3] = 1;
00027     quad1.colors[0] = 0xFFFFFFFF;
00028     quad1.colors[1] = 0xFF0000FF;
00029     quad1.colors[2] = 0xFF00FF00;
00030     quad1.colors[3] = 0xFFFF0000;
00031
00032     tri.points[2] = (Point){750 , 100, 1, 1};
00033     tri.points[1] = (Point){1250, 700, 1, 1};
00034     tri.points[0] = (Point){650 , 500, 1, 1};
00035     tri.to_draw = true;
00036     tri.light_intensity[0] = 1;
00037     tri.light_intensity[1] = 1;
00038     tri.light_intensity[2] = 1;
00039     tri.colors[0] = 0xFFFFFFFF;
00040     tri.colors[1] = 0xFF0000FF;
00041     tri.colors[2] = 0xFF00FF00;
00042
00043 }
00044
00045 void update(game_state_t *game_state)
00046 {
00047     SDL_Delay(1);
00048 }
00049
00050 void render(game_state_t *game_state)
00051 {
00052     adl_quad_fill_interpolate_color_mean_value(game_state->window_pixels_mat,
      game_state->inv_z_buffer_mat, quad1, game_state->offset_zoom_param);
00053     adl_quad_draw(game_state->window_pixels_mat, game_state->inv_z_buffer_mat, quad1, 0xFF000000,
      game_state->offset_zoom_param);
00054
00055     adl_tri_fill_Pinedas_rasterizer_interpolate_color(game_state->window_pixels_mat,
      game_state->inv_z_buffer_mat, tri, game_state->offset_zoom_param);
00056     adl_tri_draw(game_state->window_pixels_mat, tri, 0xff000000, game_state->offset_zoom_param);
00057
00058     #if 0
00059     Mat2D inv_z_buffer = game_state->inv_z_buffer_mat;
00060     double max_inv_z = 0;
00061     double min_inv_z = DBL_MAX;
00062     for (size_t i = 0; i < inv_z_buffer.rows; i++) {
```

```
00063         for (size_t j = 0; j < inv_z_buffer.cols; j++) {
00064             if (MAT2D_AT(inv_z_buffer, i, j) > max_inv_z) {
00065                 max_inv_z = MAT2D_AT(inv_z_buffer, i, j);
00066             }
00067             if (MAT2D_AT(inv_z_buffer, i, j) < min_inv_z && MAT2D_AT(inv_z_buffer, i, j) > 0) {
00068                 min_inv_z = MAT2D_AT(inv_z_buffer, i, j);
00069             }
00070         }
00071     }
00072     for (size_t i = 0; i < inv_z_buffer.rows; i++) {
00073         for (size_t j = 0; j < inv_z_buffer.cols; j++) {
00074             double z_fraq = MAT2D_AT(inv_z_buffer, i, j);
00075             z_fraq = fmax(z_fraq, min_inv_z);
00076             z_fraq = adl_linear_map(z_fraq, min_inv_z, max_inv_z, 0.1, 1);
00077             uint32_t color = RGB_hexRGB(0xFF*z_fraq, 0xFF*z_fraq, 0xFF*z_fraq);
00078             MAT2D_AT_UINT32(game_state->window_pixels_mat, i, j) = color;
00079         }
00080     }
00081     #endif
00082 }
00083
```

Index