Almog Draw Library

Generated by Doxygen 1.9.1

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:

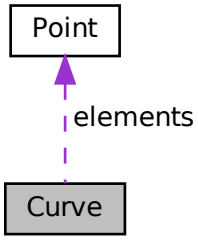
Chapter 3

Class Documentation

3.1 Curve Struct Reference

`#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

Definition at line 60 of file Almog_Draw_Library.h.

3.1.2 Member Data Documentation

3.1.2.1 capacity

```
size_t Curve::capacity
```

Definition at line 63 of file Almog_Draw_Library.h.

3.1.2.2 color

```
uint32_t Curve::color
```

Definition at line 61 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
```

Definition at line 64 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
```

Definition at line 62 of file Almog_Draw_Library.h.

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

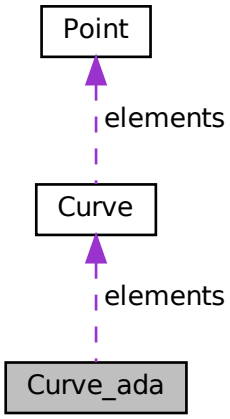
The documentation for this struct was generated from the following file:

- Almog_Draw_Library.h

3.2 Curve_ada Struct Reference

`#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

Definition at line 70 of file Almog_Draw_Library.h.

3.2.2 Member Data Documentation

3.2.2.1 capacity

`size_t Curve_ada::capacity`

Definition at line 72 of file Almog_Draw_Library.h.

3.2.2.2 elements

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

Definition at line 73 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
```

Definition at line 71 of file Almog_Draw_Library.h.

Referenced by adl_curves_plot_on_figure(), and adl_grid_draw().

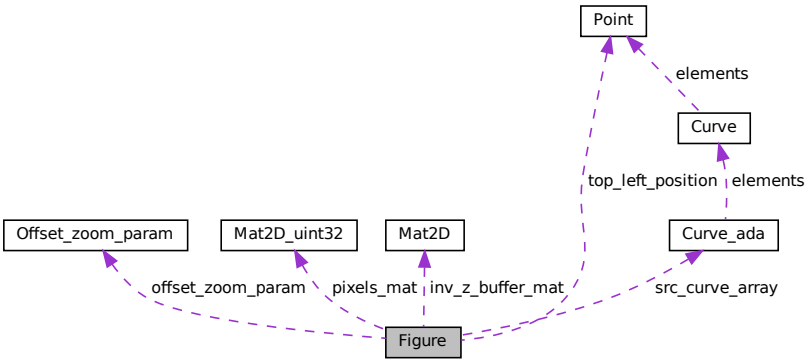
The documentation for this struct was generated from the following file:

- Almog_Draw_Library.h

3.3 Figure Struct Reference

```
#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

Definition at line 118 of file Almog_Draw_Library.h.

3.3.2 Member Data Documentation

3.3.2.1 background_color

```
uint32_t Figure::background_color
```

Definition at line 134 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
```

Definition at line 133 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
```

Definition at line 124 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
```

Definition at line 120 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
```

Definition at line 126 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
```

Definition at line 122 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
```

Definition at line 123 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
```

Definition at line 119 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
```

Definition at line 125 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
```

Definition at line 121 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
```

Definition at line 129 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
```

Definition at line 132 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
```

Definition at line 130 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
```

Definition at line 135 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
```

Definition at line 136 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
```

Definition at line 131 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
```

Definition at line 127 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
```

Definition at line 128 of file Almog_Draw_Library.h.

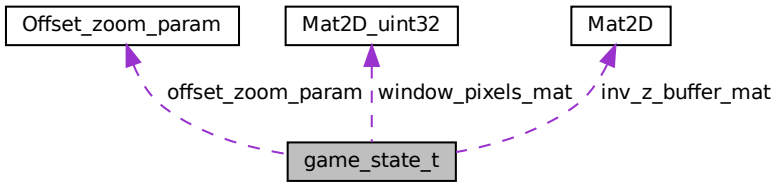
Referenced by adl_axis_draw_on_figure(), and adl_max_min_values_draw_on_figure().

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().

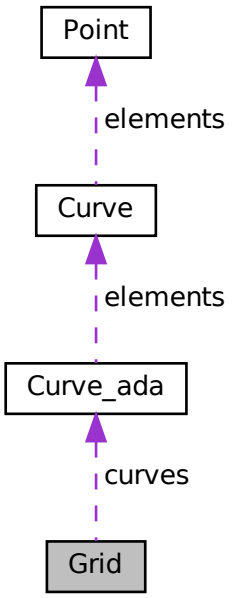
The documentation for this struct was generated from the following file:

- display.c

3.5 Grid Struct Reference

```
#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

Definition at line 139 of file Almog_Draw_Library.h.

3.5.2 Member Data Documentation

3.5.2.1 curves

```
Curve_ada Grid::curves
```

Definition at line 140 of file Almog_Draw_Library.h.

Referenced by adl_cartesian_grid_create(), and adl_grid_draw().

3.5.2.2 de1

```
float Grid::de1
```

Definition at line 147 of file Almog_Draw_Library.h.

Referenced by adl_cartesian_grid_create().

3.5.2.3 de2

```
float Grid::de2
```

Definition at line 148 of file Almog_Draw_Library.h.

Referenced by adl_cartesian_grid_create().

3.5.2.4 max_e1

```
float Grid::max_e1
```

Definition at line 142 of file Almog_Draw_Library.h.

Referenced by adl_cartesian_grid_create().

3.5.2.5 max_e2

```
float Grid::max_e2
```

Definition at line 144 of file Almog_Draw_Library.h.

Referenced by adl_cartesian_grid_create().

3.5.2.6 min_e1

```
float Grid::min_e1
```

Definition at line 141 of file Almog_Draw_Library.h.

Referenced by adl_cartesian_grid_create().

3.5.2.7 min_e2

```
float Grid::min_e2
```

Definition at line 143 of file Almog_Draw_Library.h.

Referenced by adl_cartesian_grid_create().

3.5.2.8 num_samples_e1

```
int Grid::num_samples_e1
```

Definition at line 145 of file Almog_Draw_Library.h.

Referenced by adl_cartesian_grid_create().

3.5.2.9 num_samples_e2

```
int Grid::num_samples_e2
```

Definition at line 146 of file Almog_Draw_Library.h.

Referenced by adl_cartesian_grid_create().

3.5.2.10 plane

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

Definition at line 149 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:

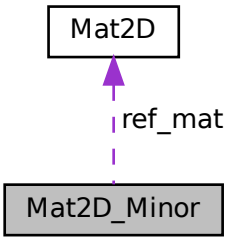
- Matrix2D.h

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

`#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

Definition at line 40 of file Almog_Draw_Library.h.

3.9.2 Member Data Documentation

3.9.2.1 mouse_x

`int Offset_zoom_param::mouse_x`

Definition at line 44 of file Almog_Draw_Library.h.

3.9.2.2 mouse_y

`int Offset_zoom_param::mouse_y`

Definition at line 45 of file Almog_Draw_Library.h.

3.9.2.3 offset_x

`float Offset_zoom_param::offset_x`

Definition at line 42 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
```

Definition at line 43 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
```

Definition at line 41 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

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

Public Attributes

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

3.10.1 Detailed Description

Definition at line 50 of file Almog_Draw_Library.h.

3.10.2 Member Data Documentation

3.10.2.1 w

```
float Point::w
```

Definition at line 54 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
```

Definition at line 51 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
```

Definition at line 52 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
```

Definition at line 53 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().

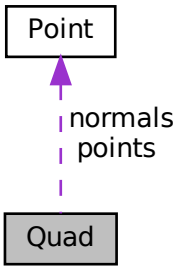
The documentation for this struct was generated from the following file:

- Almog_Draw_Library.h

3.11 Quad Struct Reference

`#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

Definition at line 91 of file Almog_Draw_Library.h.

3.11.2 Member Data Documentation

3.11.2.1 colors

`uint32_t Quad::colors[4]`

Definition at line 94 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]
```

Definition at line 96 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]
```

Definition at line 93 of file Almog_Draw_Library.h.

3.11.2.4 points

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

Definition at line 92 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_me
adl_quad_fill_interpolate_normal_mean_value(), and setup().

3.11.2.5 to_draw

```
bool Quad::to_draw
```

Definition at line 95 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().

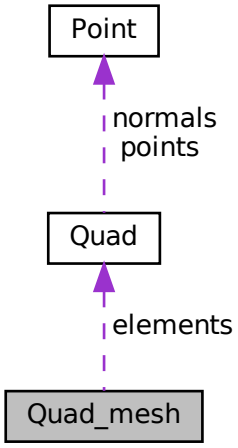
The documentation for this struct was generated from the following file:

- Almog_Draw_Library.h

3.12 Quad_mesh Struct Reference

`#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

Definition at line 111 of file Almog_Draw_Library.h.

3.12.2 Member Data Documentation

3.12.2.1 capacity

`size_t Quad_mesh::capacity`

Definition at line 113 of file Almog_Draw_Library.h.

3.12.2.2 elements

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

Definition at line 114 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
```

Definition at line 112 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().

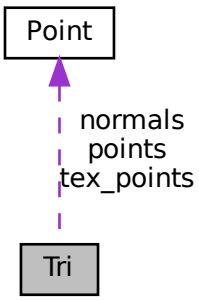
The documentation for this struct was generated from the following file:

- Almog_Draw_Library.h

3.13 Tri Struct Reference

```
#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

Definition at line 79 of file Almog_Draw_Library.h.

3.13.2 Member Data Documentation

3.13.2.1 colors

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

Definition at line 83 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]
```

Definition at line 85 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]
```

Definition at line 82 of file Almog_Draw_Library.h.

3.13.2.4 points

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

Definition at line 80 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]
```

Definition at line 81 of file Almog_Draw_Library.h.

3.13.2.6 to_draw

```
bool Tri::to_draw
```

Definition at line 84 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().

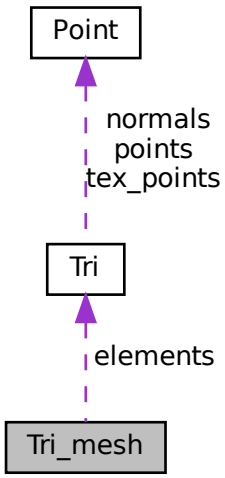
The documentation for this struct was generated from the following file:

- Almog_Draw_Library.h

3.14 Tri_mesh Struct Reference

```
#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

Definition at line 102 of file Almog_Draw_Library.h.

3.14.2 Member Data Documentation

3.14.2.1 capacity

```
size_t Tri_mesh::capacity
```

Definition at line 104 of file Almog_Draw_Library.h.

3.14.2.2 elements

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

Definition at line 105 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
```

Definition at line 103 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

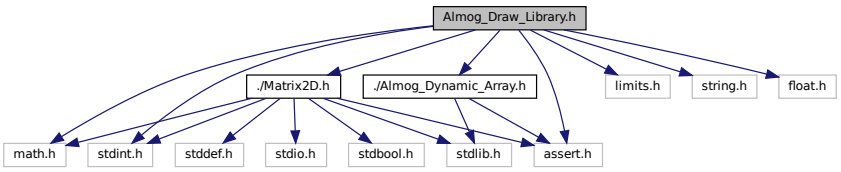
File Documentation

4.1 Almog_Draw_Library.h File Reference

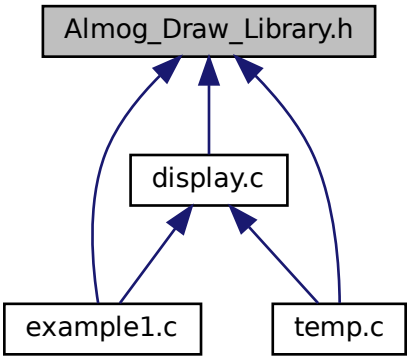
Immediate-mode 2D/3D raster helpers for drawing onto Mat2D_uint32 pixel buffers.

```
#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
- struct Point
- struct Curve
- struct Curve_ada
- struct Tri
- struct Quad
- struct Tri_mesh
- struct Quad_mesh
- struct Figure
- struct Grid

Macros

- #define ADL_ASSERT 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.

Conventions

- Pixel buffer: Mat2D_uint32 with elements encoded as ARGB 0xAARRGGBB.
- Coordinates: x grows to the right, y grows downward; origin is the top-left corner of the destination buffer.
- Depth: Functions that accept inv_z_buffer perform a depth test using inverse-Z (larger values are closer). The buffer stores doubles.
- Transform: Most drawing functions accept an Offset_zoom_param describing a pan/zoom transform that is applied about the screen center. Use ADL_DEFAULT_OFFSET_ZOOM for identity.
- Colors: Unless noted otherwise, colors are ARGB in 0xAARRGGBB format.
- Alpha: adl_point_draw alpha-blends source over destination and writes an opaque result (A = 255) to the pixel buffer.

This header contains function declarations and optional implementations (guarded by ALMOG_DRAW_LIBRARY↩ _IMPLEMENTATION).

Definition in file Almog_Draw_Library.h.

4.1.2 Macro Definition Documentation

4.1.2.1 ADL_ASSERT

```
#define ADL_ASSERT assert
```

Definition at line 37 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 243 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 247 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 244 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 264 of file Almog_Draw_Library.h.

4.1.2.6 ADL_FIGURE_AXIS_COLOR

```
#define ADL_FIGURE_AXIS_COLOR 0xff000000
```

Definition at line 257 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 256 of file Almog_Draw_Library.h.

4.1.2.8 ADL_FIGURE_PADDING_PRECENTAGE

```
#define ADL_FIGURE_PADDING_PRECENTAGE 20
```

Definition at line 252 of file Almog_Draw_Library.h.

4.1.2.9 ADL_MAX_CHARACTER_OFFSET

```
#define ADL_MAX_CHARACTER_OFFSET 10
```

Definition at line 259 of file Almog_Draw_Library.h.

4.1.2.10 ADL_MAX_FIGURE_PADDING

```
#define ADL_MAX_FIGURE_PADDING 70
```

Definition at line 253 of file Almog_Draw_Library.h.

4.1.2.11 ADL_MAX_HEAD_SIZE

```
#define ADL_MAX_HEAD_SIZE 15
```

Definition at line 255 of file Almog_Draw_Library.h.

4.1.2.12 ADL_MAX_POINT_VAL

```
#define ADL_MAX_POINT_VAL 1e5
```

Definition at line 242 of file Almog_Draw_Library.h.

4.1.2.13 ADL_MAX_SENTENCE_LEN

```
#define ADL_MAX_SENTENCE_LEN 256
```

Definition at line 261 of file Almog_Draw_Library.h.

4.1.2.14 ADL_MAX_ZOOM

```
#define ADL_MAX_ZOOM 1e3
```

Definition at line 262 of file Almog_Draw_Library.h.

4.1.2.15 ADL_MIN_CHARACTER_OFFSET

```
#define ADL_MIN_CHARACTER_OFFSET 5
```

Definition at line 260 of file Almog_Draw_Library.h.

4.1.2.16 ADL_MIN_FIGURE_PADDING

```
#define ADL_MIN_FIGURE_PADDING 20
```

Definition at line 254 of file Almog_Draw_Library.h.

4.1.2.17 adl_offset2d

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

Definition at line 2227 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 265 of file Almog_Draw_Library.h.

4.1.2.19 BLUE_hexARGB

```
#define BLUE_hexARGB 0xFF0000FF
```

Definition at line 232 of file Almog_Draw_Library.h.

4.1.2.20 CURVE

```
#define CURVE
```

Definition at line 59 of file Almog_Draw_Library.h.

4.1.2.21 CURVE_ADA

```
#define CURVE_ADA
```

Definition at line 69 of file Almog_Draw_Library.h.

4.1.2.22 CYAN_hexARGB

```
#define CYAN_hexARGB 0xFF00FFFF
```

Definition at line 234 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 237 of file Almog_Draw_Library.h.

4.1.2.24 GREEN_hexARGB

```
#define GREEN_hexARGB 0xFF00FF00
```

Definition at line 231 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 157 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 154 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 160 of file Almog_Draw_Library.h.

4.1.2.28 is_left_edge

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

Definition at line 239 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 238 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 240 of file Almog_Draw_Library.h.

4.1.2.31 POINT

```
#define POINT
```

Definition at line 49 of file Almog_Draw_Library.h.

4.1.2.32 PURPLE_hexARGB

```
#define PURPLE_hexARGB 0xFFFF00FF
```

Definition at line 233 of file Almog_Draw_Library.h.

4.1.2.33 QUAD

```
#define QUAD
```

Definition at line 90 of file Almog_Draw_Library.h.

4.1.2.34 QUAD_MESH

```
#define QUAD_MESH
```

Definition at line 110 of file Almog_Draw_Library.h.

4.1.2.35 RED_hexARGB

```
#define RED_hexARGB 0xFFFF0000
```

Definition at line 230 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 163 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 166 of file Almog_Draw_Library.h.

4.1.2.38 TRI

```
#define TRI
```

Definition at line 78 of file Almog_Draw_Library.h.

4.1.2.39 TRI_MESH

```
#define TRI_MESH
```

Definition at line 101 of file Almog_Draw_Library.h.

4.1.2.40 YELLOW_hexARGB

```
#define YELLOW_hexARGB 0xFFFFFF00
```

Definition at line 235 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 2247 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 451 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 2077 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 2446 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 519 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 1360 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.

Parameters

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 1382 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 2163 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 2198 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 2014 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 2057 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 2724 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 1986 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 316 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 1798 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 1878 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 1945 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 403 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 423 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 2103 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 1913 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 1964 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 283 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 1818 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 943 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 961 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 1149 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 1055 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 1253 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 1277 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 1334 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 1304 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).
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 906 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 925 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 882 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 1778 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 1402 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 1425 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 1506 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 1597 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 1679 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 1701 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 1725 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 1750 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
00023 #ifndef ALMOG_DRAW_LIBRARY_H_
00024 #define ALMOG_DRAW_LIBRARY_H_
00025
00026 #include <math.h>
00027 #include <stdint.h>
00028 #include <limits.h>
00029 #include <string.h>
00030 #include <float.h>
00031
00032 #include "./Matrix2D.h"
00033 #include "./Almog_Dynamic_Array.h"
00034
00035 #ifndef ADL_ASSERT
00036 #include <assert.h>
00037 #define ADL_ASSERT assert
00038 #endif
00039
00040 typedef struct {
00041     float zoom_multiplier;
00042     float offset_x;
00043     float offset_y;
00044     int mouse_x;
00045     int mouse_y;
00046 } Offset_zoom_param;
00047
00048 #ifndef POINT
00049 #define POINT
00050 typedef struct {
00051     float x;
00052     float y;
00053     float z;
00054     float w;
00055 } Point ;
00056 #endif
00057
00058 #ifndef CURVE
00059 #define CURVE
00060 typedef struct {
00061     uint32_t color;
00062     size_t length;
00063     size_t capacity;
00064     Point *elements;
00065 } Curve;
00066 #endif
00067
00068 #ifndef CURVE_ADA
00069 #define CURVE_ADA
00070 typedef struct {
00071     size_t length;
00072     size_t capacity;
00073     Curve *elements;
00074 } Curve_ada;
00075 #endif
00076
00077 #ifndef TRI
00078 #define TRI
00079 typedef struct {
00080     Point points[3];
00081     Point tex_points[3];
00082     Point normals[3];
00083     uint32_t colors[3];
00084     bool to_draw;
00085     float light_intensity[3];
00086 } Tri;
00087 #endif
00088
00089 #ifndef QUAD
00090 #define QUAD
00091 typedef struct {
00092     Point points[4];
00093     Point normals[4];
00094     uint32_t colors[4];
00095     bool to_draw;
00096     float light_intensity[4];
00097 } Quad;
00098 #endif
00099
00100 #ifndef TRI_MESH
00101 #define TRI_MESH
00102 typedef struct {
00103     size_t length;
00104     size_t capacity;
00105     Tri *elements;
00106 } Tri_mesh; /* Tri ada array */
```

```
00107 #endif
00108
00109 #ifndef QUAD_MESH
00110 #define QUAD_MESH
00111 typedef struct {
00112     size_t length;
00113     size_t capacity;
00114     Quad *elements;
00115 } Quad_mesh; /* Quad ada array */
00116 #endif
00117
00118 typedef struct {
00119     int min_x_pixel;
00120     int max_x_pixel;
00121     int min_y_pixel;
00122     int max_y_pixel;
00123     float min_x;
00124     float max_x;
00125     float min_y;
00126     float max_y;
00127     int x_axis_head_size;
00128     int y_axis_head_size;
00129     Offset_zoom_param offset_zoom_param;
00130     Curve_ada src_curve_array;
00131     Point top_left_position;
00132     Mat2D_uint32 pixels_mat;
00133     Mat2D inv_z_buffer_mat;
00134     uint32_t background_color;
00135     bool to_draw_axis;
00136     bool to_draw_max_min_values;
00137 } Figure;
00138
00139 typedef struct {
00140     Curve_ada curves;
00141     float min_e1;
00142     float max_e1;
00143     float min_e2;
00144     float max_e2;
00145     int num_samples_e1;
00146     int num_samples_e2;
00147     float de1;
00148     float de2;
00149     char plane[3];
00150 } Grid; /* direction: e1, e2 */
00151
00152
00153 #ifndef HexARGB_RGBA
00154 #define HexARGB_RGBA(x) ((x)»(8*2)&0xFF), ((x)»(8*1)&0xFF), ((x)»(8*0)&0xFF), ((x)»(8*3)&0xFF)
00155 #endif
00156 #ifndef HexARGB_RGB_VAR
00157 #define HexARGB_RGB_VAR(x, r, g, b) r = ((x)»(8*2)&0xFF); g = ((x)»(8*1)&0xFF); b = ((x)»(8*0)&0xFF);
00158 #endif
00159 #ifndef HexARGB_RGBA_VAR
00160 #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)
00161 #endif
00162 #ifndef RGB_hexRGB
00163 #define RGB_hexRGB(r, g, b) (int)(0x010000*(int)(r) + 0x000100*(int)(g) + 0x000001*(int)(b))
00164 #endif
00165 #ifndef RGBA_hexARGB
00166 #define RGBA_hexARGB(r, g, b, a) (int)(0x010000001*(int)(fminf(a, 255)) + 0x010000*(int)(r) +
      0x000100*(int)(g) + 0x000001*(int)(b))
00167 #endif
00168
00169
00170 void    adl_point_draw(Mat2D_uint32 screen_mat, int x, int y, uint32_t color, Offset_zoom_param
      offset_zoom_param);
00171 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);
00172 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);
00173 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);
00174 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);
00175
00176 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);
00177 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);
00178
00179 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);
00180 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);
00181
```

```
00182 void    adl_quad_draw(Mat2D_uint32 screen_mat, Mat2D inv_z_buffer, Quad quad, uint32_t color,
       Offset_zoom_param offset_zoom_param);
00183 void    adl_quad_fill(Mat2D_uint32 screen_mat, Mat2D inv_z_buffer, Quad quad, uint32_t color,
       Offset_zoom_param offset_zoom_param);
00184 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);
00185 void    adl_quad_fill_interpolate_color_mean_value(Mat2D_uint32 screen_mat, Mat2D inv_z_buffer, Quad
       quad, Offset_zoom_param offset_zoom_param);
00186
00187 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);
00188 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);
00189 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);
00190 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);
00191
00192 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);
00193 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);
00194
00195 void    adl_tri_draw(Mat2D_uint32 screen_mat, Tri tri, uint32_t color, Offset_zoom_param
       offset_zoom_param);
00196 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);
00197 void    adl_tri_fill_Pinedas_rasterizer_interpolate_color(Mat2D_uint32 screen_mat, Mat2D inv_z_buffer,
       Tri tri, Offset_zoom_param offset_zoom_param);
00198 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);
00199
00200 void    adl_tri_mesh_draw(Mat2D_uint32 screen_mat, Tri_mesh mesh, uint32_t color, Offset_zoom_param
       offset_zoom_param);
00201 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);
00202 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);
00203 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);
00204
00205 float   adl_tan_half_angle(Point vi, Point vj, Point p, float li, float lj);
00206 float   adl_linear_map(float s, float min_in, float max_in, float min_out, float max_out);
00207 void    adl_quad2tris(Quad quad, Tri *tri1, Tri *tri2, char split_line[]);
00208 void    adl_linear_sRGB_to_okLab(uint32_t hex_ARGB, float *L, float *a, float *b);
00209 void    adl_okLab_to_linear_sRGB(float L, float a, float b, uint32_t *hex_ARGB);
00210 void    adl_linear_sRGB_to_okLch(uint32_t hex_ARGB, float *L, float *c, float *h_deg);
00211 void    adl_okLch_to_linear_sRGB(float L, float c, float h_deg, uint32_t *hex_ARGB);
00212 void    adl_interpolate_ARGBcolor_on_okLch(uint32_t color1, uint32_t color2, float t, float
       num_of_rotations, uint32_t *color_out);
00213
00214 Figure  adl_figure_alloc(size_t rows, size_t cols, Point top_left_position);
00215 void    adl_figure_copy_to_screen(Mat2D_uint32 screen_mat, Figure figure);
00216 void    adl_axis_draw_on_figure(Figure *figure);
00217 void    adl_max_min_values_draw_on_figure(Figure figure);
00218 void    adl_curve_add_to_figure(Figure *figure, Point *src_points, size_t src_len, uint32_t color);
00219 void    adl_curves_plot_on_figure(Figure figure);
00220 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);
00221
00222 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);
00223 void    adl_grid_draw(Mat2D_uint32 screen_mat, Grid grid, uint32_t color, Offset_zoom_param
       offset_zoom_param);
00224
00225 #endif /*ALMOG_RENDER_SHAPES_H_*/
00226
00227 #ifdef ALMOG_DRAW_LIBRARY_IMPLEMENTATION
00228 #undef ALMOG_DRAW_LIBRARY_IMPLEMENTATION
00229
00230 #define RED_hexARGB    0xFFFF0000
00231 #define GREEN_hexARGB  0xFF00FF00
00232 #define BLUE_hexARGB   0xFF0000FF
00233 #define PURPLE_hexARGB 0xFFFF00FF
00234 #define CYAN_hexARGB   0xFF00FFFF
00235 #define YELLOW_hexARGB 0xFFFFFF00
00236
00237 #define edge_cross_point(a1, b, a2, p) (b.x-a1.x)*(p.y-a2.y)-(b.y-a1.y)*(p.x-a2.x)
00238 #define is_top_edge(x, y) (y == 0 && x > 0)
00239 #define is_left_edge(x, y) (y < 0)
00240 #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))
00241
00242 #define ADL_MAX_POINT_VAL 1e5
00243 #define adl_assert_point_is_valid(p) ADL_ASSERT(isfinite(p.x) && isfinite(p.y) && isfinite(p.z) &&
       isfinite(p.w))
00244 #define adl_assert_tri_is_valid(tri) adl_assert_point_is_valid(tri.points[0]); \
00245         adl_assert_point_is_valid(tri.points[1]);                              \
```

```
00246         adl_assert_point_is_valid(tri.points[2])
00247 #define adl_assert_quad_is_valid(quad) adl_assert_point_is_valid(quad.points[0]);   \
00248         adl_assert_point_is_valid(quad.points[1]);                                  \
00249         adl_assert_point_is_valid(quad.points[2]);                                  \
00250         adl_assert_point_is_valid(quad.points[3])
00251
00252 #define ADL_FIGURE_PADDING_PRECENTAGE 20
00253 #define ADL_MAX_FIGURE_PADDING 70
00254 #define ADL_MIN_FIGURE_PADDING 20
00255 #define ADL_MAX_HEAD_SIZE 15
00256 #define ADL_FIGURE_HEAD_ANGLE_DEG 30
00257 #define ADL_FIGURE_AXIS_COLOR 0xff000000
00258
00259 #define ADL_MAX_CHARACTER_OFFSET 10
00260 #define ADL_MIN_CHARACTER_OFFSET 5
00261 #define ADL_MAX_SENTENCE_LEN 256
00262 #define ADL_MAX_ZOOM 1e3
00263
00264 #define ADL_DEFAULT_OFFSET_ZOOM (Offset_zoom_param){1,0,0,0,0}
00265 #define adl_offset_zoom_point(p, window_w, window_h, offset_zoom_param)
                \
00266     (p).x = ((p).x - (window_w)/2 + offset_zoom_param.offset_x) * offset_zoom_param.zoom_multiplier +
     (window_w)/2; \
00267     (p).y = ((p).y - (window_h)/2 + offset_zoom_param.offset_y) * offset_zoom_param.zoom_multiplier +
     (window_h)/2
00268
00283 void adl_point_draw(Mat2D_uint32 screen_mat, int x, int y, uint32_t color, Offset_zoom_param
     offset_zoom_param)
00284 {
00285     float window_w = (float)screen_mat.cols;
00286     float window_h = (float)screen_mat.rows;
00287
00288     x = (x - window_w/2 + offset_zoom_param.offset_x) * offset_zoom_param.zoom_multiplier +
     window_w/2;
00289     y = (y - window_h/2 + offset_zoom_param.offset_y) * offset_zoom_param.zoom_multiplier +
     window_h/2;
00290
00291     if ((x < (int)screen_mat.cols && y < (int)screen_mat.rows) && (x >= 0 && y >= 0)) { /* point is in
     screen */
00292         uint8_t r_new, g_new, b_new, a_new;
00293         uint8_t r_current, g_current, b_current, a_current;
00294         HexARGB_RGBA_VAR(MAT2D_AT_UINT32(screen_mat, y, x), r_current, g_current, b_current,
     a_current);
00295         HexARGB_RGBA_VAR(color, r_new, g_new, b_new, a_new);
00296         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);
00297         (void)a_current;
00298     }
00299 }
00300
00316 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)
00317 {
00318     /* 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. */
00319
00320     float window_w = (float)screen_mat.cols;
00321     float window_h = (float)screen_mat.rows;
00322
00323     int x1 = (x1_input - window_w/2 + offset_zoom_param.offset_x) * offset_zoom_param.zoom_multiplier
     + window_w/2;
00324     int x2 = (x2_input - window_w/2 + offset_zoom_param.offset_x) * offset_zoom_param.zoom_multiplier
     + window_w/2;
00325     int y1 = (y1_input - window_h/2 + offset_zoom_param.offset_y) * offset_zoom_param.zoom_multiplier
     + window_h/2;
00326     int y2 = (y2_input - window_h/2 + offset_zoom_param.offset_y) * offset_zoom_param.zoom_multiplier
     + window_h/2;
00327
00328     ADL_ASSERT((int)fabsf(fabsf((float)x2) - fabsf((float)x1)) < ADL_MAX_POINT_VAL);
00329     ADL_ASSERT((int)fabsf(fabsf((float)y2) - fabsf((float)y1)) < ADL_MAX_POINT_VAL);
00330
00331     int x = x1;
00332     int y = y1;
00333     int dx, dy;
00334
00335     adl_point_draw(screen_mat, x, y, color, (Offset_zoom_param){1,0,0,0,0});
00336
00337     dx = x2 - x1;
00338     dy = y2 - y1;
00339
00340     ADL_ASSERT(dy > INT_MIN && dy < INT_MAX);
00341     ADL_ASSERT(dx > INT_MIN && dx < INT_MAX);
00342
00343     if (0 == dx && 0 == dy) return;
00344     if (0 == dx) {
```

```
00345         while (x != x2 || y != y2) {
00346             if (dy > 0) {
00347                 y++;
00348             }
00349             if (dy < 0) {
00350                 y--;
00351             }
00352             adl_point_draw(screen_mat, x, y, color, (Offset_zoom_param){1,0,0,0,0});
00353         }
00354         return;
00355     }
00356     if (0 == dy) {
00357         while (x != x2 || y != y2) {
00358             if (dx > 0) {
00359                 x++;
00360             }
00361             if (dx < 0) {
00362                 x--;
00363             }
00364             adl_point_draw(screen_mat, x, y, color, (Offset_zoom_param){1,0,0,0,0});
00365         }
00366         return;
00367     }
00368
00369     /* float m = (float)dy / dx */
00370     int b = y1 - dy * x1 / dx;
00371
00372     if (x1 > x2) {
00373         int temp_x = x1;
00374         x1 = x2;
00375         x2 = temp_x;
00376     }
00377     for (x = x1; x < x2; x++) {
00378         int sy1 = dy * x / dx + b;
00379         int sy2 = dy * (x + 1) / dx + b;
00380         if (sy1 > sy2) {
00381             int temp_y = sy1;
00382             sy1 = sy2;
00383             sy2 = temp_y;
00384         }
00385         for (y = sy1; y <= sy2; y++) {
00386             adl_point_draw(screen_mat, x, y, color, (Offset_zoom_param){1,0,0,0,0});
00387         }
00388     }
00389
00390 }
00391
00403 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)
00404 {
00405     if (len == 0) return;
00406     for (size_t i = 0; i < len-1; i++) {
00407         adl_line_draw(screen_mat, points[i].x, points[i].y, points[i+1].x, points[i+1].y, color,
       offset_zoom_param);
00408     }
00409 }
00410
00423 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)
00424 {
00425     if (len == 0) return;
00426     for (size_t i = 0; i < len-1; i++) {
00427         adl_line_draw(screen_mat, points[i].x, points[i].y, points[i+1].x, points[i+1].y, color,
       offset_zoom_param);
00428     }
00429     adl_line_draw(screen_mat, points[len-1].x, points[len-1].y, points[0].x, points[0].y, color,
       offset_zoom_param);
00430 }
00431
00432
00451 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)
00452 {
00453     Mat2D pe = mat2D_alloc(3, 1);
00454     mat2D_fill(pe, 0);
00455     MAT2D_AT(pe, 0, 0) = xe;
00456     MAT2D_AT(pe, 1, 0) = ye;
00457     Mat2D v1 = mat2D_alloc(3, 1);
00458     mat2D_fill(v1, 0);
00459     Mat2D v2 = mat2D_alloc(3, 1);
00460     mat2D_fill(v2, 0);
00461     Mat2D temp_v = mat2D_alloc(3, 1);
00462     mat2D_fill(temp_v, 0);
00463     Mat2D DCM_p = mat2D_alloc(3, 3);
00464     mat2D_fill(DCM_p, 0);
00465     mat2D_set_rot_mat_z(DCM_p, angle_deg);
00466     Mat2D DCM_m = mat2D_alloc(3, 3);
```

```
00467     mat2D_fill(DCM_m, 0);
00468     mat2D_set_rot_mat_z(DCM_m, -angle_deg);
00469 
00470     int x_center = xs*head_size + xe*(1-head_size);
00471     int y_center = ys*head_size + ye*(1-head_size);
00472 
00473     MAT2D_AT(v1, 0, 0) = x_center;
00474     MAT2D_AT(v1, 1, 0) = y_center;
00475     mat2D_copy(v2, v1);
00476 
00477     /* v1 */
00478     mat2D_copy(temp_v, v1);
00479     mat2D_sub(temp_v, pe);
00480     mat2D_fill(v1, 0);
00481     mat2D_dot(v1, DCM_p, temp_v);
00482     mat2D_add(v1, pe);
00483 
00484     /* v2 */
00485     mat2D_copy(temp_v, v2);
00486     mat2D_sub(temp_v, pe);
00487     mat2D_fill(v2, 0);
00488     mat2D_dot(v2, DCM_m, temp_v);
00489     mat2D_add(v2, pe);
00490 
00491     adl_line_draw(screen_mat, MAT2D_AT(v1, 0, 0), MAT2D_AT(v1, 1, 0), xe, ye, color,
      offset_zoom_param);
00492     adl_line_draw(screen_mat, MAT2D_AT(v2, 0, 0), MAT2D_AT(v2, 1, 0), xe, ye, color,
      offset_zoom_param);
00493     adl_line_draw(screen_mat, xs, ys, xe, ye, color, offset_zoom_param);
00494 
00495     mat2D_free(pe);
00496     mat2D_free(v1);
00497     mat2D_free(v2);
00498     mat2D_free(temp_v);
00499     mat2D_free(DCM_p);
00500     mat2D_free(DCM_m);
00501 }
00502 
00519 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)
00520 {
00521     switch (c)
00522     {
00523     case 'a':
00524     case 'A':
00525         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);
00526         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);
00527         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);
00528         break;
00529     case 'b':
00530     case 'B':
00531         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left, y_top_left+hight_pixel, color,
      offset_zoom_param);
00532         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);
00533         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);
00534         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);
00535         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);
00536 
00537         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);
00538 
00539         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);
00540         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);
00541         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);
00542         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);
00543         break;
00544     case 'c':
00545     case 'C':
00546         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);
00547         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);
00548         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);
00549         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);
```

```
00550         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);
00551         break;
00552     case 'd':
00553     case 'D':
00554         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);
00555         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);
00556         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);
00557         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);
00558         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);
00559         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel, x_top_left, y_top_left, color,
      offset_zoom_param);
00560         break;
00561     case 'e':
00562     case 'E':
00563         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left, x_top_left, y_top_left, color,
      offset_zoom_param);
00564         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left, y_top_left+hight_pixel, color,
      offset_zoom_param);
00565         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);
00566
00567         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);
00568         break;
00569     case 'f':
00570     case 'F':
00571         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left, x_top_left, y_top_left, color,
      offset_zoom_param);
00572         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left, y_top_left+hight_pixel, color,
      offset_zoom_param);
00573
00574         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);
00575         break;
00576     case 'g':
00577     case 'G':
00578         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);
00579         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);
00580         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);
00581         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);
00582         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);
00583         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);
00584         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);
00585         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);
00586         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);
00587         break;
00588     case 'h':
00589     case 'H':
00590         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left, y_top_left+hight_pixel, color,
      offset_zoom_param);
00591         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);
00592         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);
00593         break;
00594     case 'i':
00595     case 'I':
00596         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left+width_pixel, y_top_left, color,
      offset_zoom_param);
00597         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);
00598         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);
00599         break;
00600     case 'j':
00601     case 'J':
00602         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left+width_pixel, y_top_left, color,
      offset_zoom_param);
00603         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);
00604         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);
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00605         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);
00606         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);
00607         break;
00608     case 'k':
00609     case 'K':
00610         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left, y_top_left+hight_pixel, color,
      offset_zoom_param);
00611         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);
00612         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);
00613         break;
00614     case 'l':
00615     case 'L':
00616         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left, y_top_left+hight_pixel, color,
      offset_zoom_param);
00617         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);
00618         break;
00619     case 'm':
00620     case 'M':
00621         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel, x_top_left, y_top_left, color,
      offset_zoom_param);
00622         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);
00623         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);
00624         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);
00625         break;
00626     case 'n':
00627     case 'N':
00628         adl_line_draw(screen_mat, x_top_left, y_top_left+hight_pixel, x_top_left, y_top_left, color,
      offset_zoom_param);
00629         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);
00630         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);
00631         break;
00632     case 'o':
00633     case 'O':
00634         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);
00635         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);
00636         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);
00637         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);
00638         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);
00639         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);
00640         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);
00641         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);
00642         break;
00643     case 'p':
00644     case 'P':
00645         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left, y_top_left+hight_pixel, color,
      offset_zoom_param);
00646         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);
00647         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);
00648         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);
00649         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);
00650
00651         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);
00652         break;
00653     case 'q':
00654     case 'Q':
00655         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);
00656         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);
00657         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);
00658         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);
00659         adl_line_draw(screen_mat, x_top_left+width_pixel/3, y_top_left+hight_pixel,
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      x_top_left+2*width_pixel/3, y_top_left+hight_pixel, color, offset_zoom_param);
00660         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);
00661         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);
00662         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);
00663
00664         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);
00665         break;
00666     case 'r':
00667     case 'R':
00668         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left, y_top_left+hight_pixel, color,
      offset_zoom_param);
00669         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);
00670         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);
00671         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);
00672         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);
00673
00674         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);
00675
00676         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);
00677         break;
00678     case 's':
00679     case 'S':
00680         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);
00681         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);
00682         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);
00683
00684         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);
00685         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);
00686         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);
00687         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);
00688
00689         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);
00690         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);
00691         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);
00692         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);
00693         break;
00694     case 't':
00695     case 'T':
00696         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left+width_pixel, y_top_left, color,
      offset_zoom_param);
00697         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);
00698         break;
00699     case 'u':
00700     case 'U':
00701         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left, y_top_left+hight_pixel/6, color,
      offset_zoom_param);
00702         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);
00703         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);
00704         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);
00705         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);
00706         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);
00707         break;
00708     case 'v':
00709     case 'V':
00710         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);
00711         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);
00712         break;
00713     case 'w':
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00714     case 'W':
00715         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);
00716         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);
00717         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);
00718         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);
00719         break;
00720     case 'x':
00721     case 'X':
00722         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);
00723         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);
00724         break;
00725     case 'y':
00726     case 'Y':
00727         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);
00728         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);
00729         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);
00730         break;
00731     case 'z':
00732     case 'Z':
00733         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left+width_pixel, y_top_left, color,
      offset_zoom_param);
00734         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);
00735         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);
00736         break;
00737     case '.':
00738         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);
00739         break;
00740     case ':':
00741         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);
00742         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);
00743         break;
00744     case '0':
00745         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);
00746         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);
00747         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);
00748         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);
00749         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);
00750         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);
00751         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);
00752         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);
00753
00754         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);
00755         break;
00756     case '1':
00757         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);
00758         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);
00759         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);
00760         break;
00761     case '2':
00762         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);
00763         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);
00764         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);
00765         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);
00766         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);
00767         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);
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00768         break;
00769     case '3':
00770         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);
00771         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);
00772         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);
00773         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);
00774         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);
00775
00776         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);
00777
00778         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);
00779         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);
00780         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);
00781         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);
00782         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);
00783         break;
00784     case '4':
00785         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);
00786         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);
00787         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);
00788         break;
00789     case '5':
00790         adl_line_draw(screen_mat, x_top_left+width_pixel, y_top_left, x_top_left, y_top_left, color,
      offset_zoom_param);
00791         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left, y_top_left+hight_pixel/2, color,
      offset_zoom_param);
00792
00793         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);
00794         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);
00795
00796         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);
00797         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);
00798         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);
00799         break;
00800     case '6':
00801         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);
00802         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);
00803         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);
00804
00805         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);
00806         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);
00807         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);
00808         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);
00809         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);
00810         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);
00811         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);
00812         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);
00813         break;
00814     case '7':
00815         adl_line_draw(screen_mat, x_top_left, y_top_left, x_top_left+width_pixel, y_top_left, color,
      offset_zoom_param);
00816         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);
00817         break;
00818     case '8':
00819         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);
```

```
00820         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);
00821         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);
00822         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);
00823         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);
00824
00825         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);
00826         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);
00827         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);
00828         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);
00829
00830         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);
00831         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);
00832         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);
00833         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);
00834         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);
00835         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);
00836         break;
00837     case '9':
00838         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);
00839         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);
00840         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);
00841         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);
00842         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);
00843         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);
00844         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);
00845         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);
00846         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);
00847         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);
00848         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);
00849         break;
00850     case '-':
00851         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);
00852         break;
00853     case '+':
00854         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);
00855         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);
00856         break;
00857     case ' ':
00858         break;
00859     default:
00860         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);
00861         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);
00862         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);
00863         break;
00864     }
00865 }
00866
00882 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)
00883 {
00884     int character_width_pixel = hight_pixel/2;
00885     int current_x_top_left = x_top_left;
00886     int character_x_offset = (int)fmaxf(fminf(ADL_MAX_CHARACTER_OFFSET, character_width_pixel / 5),
      ADL_MIN_CHARACTER_OFFSET);
00887
```

```
00888     for (size_t char_index = 0; char_index < len; char_index++) {
00889         adl_character_draw(screen_mat, sentence[char_index], character_width_pixel, hight_pixel,
      current_x_top_left, y_top_left, color, offset_zoom_param);
00890         current_x_top_left += character_width_pixel + character_x_offset;
00891     }
00892
00893 }
00894
00906 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)
00907 {
00908     adl_line_draw(screen_mat, min_x, min_y, max_x, min_y, color, offset_zoom_param);
00909     adl_line_draw(screen_mat, min_x, max_y, max_x, max_y, color, offset_zoom_param);
00910     adl_line_draw(screen_mat, min_x, min_y, min_x, max_y, color, offset_zoom_param);
00911     adl_line_draw(screen_mat, max_x, min_y, max_x, max_y, color, offset_zoom_param);
00912 }
00913
00925 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)
00926 {
00927     for (int y = min_y; y <= max_y; y++) {
00928         adl_line_draw(screen_mat, min_x, y, max_x, y, color, offset_zoom_param);
00929     }
00930 }
00931
00943 void adl_quad_draw(Mat2D_uint32 screen_mat, Mat2D inv_z_buffer, Quad quad, uint32_t color,
      Offset_zoom_param offset_zoom_param)
00944 {
00945     (void)inv_z_buffer;
00946     adl_lines_loop_draw(screen_mat, quad.points, 4, color, offset_zoom_param);
00947 }
00948
00961 void adl_quad_fill(Mat2D_uint32 screen_mat, Mat2D inv_z_buffer, Quad quad, uint32_t color,
      Offset_zoom_param offset_zoom_param)
00962 {
00963     Point p0 = quad.points[0];
00964     Point p1 = quad.points[1];
00965     Point p2 = quad.points[2];
00966     Point p3 = quad.points[3];
00967
00968     int x_min = fminf(p0.x, fminf(p1.x, fminf(p2.x, p3.x)));
00969     int x_max = fmaxf(p0.x, fmaxf(p1.x, fmaxf(p2.x, p3.x)));
00970     int y_min = fminf(p0.y, fminf(p1.y, fminf(p2.y, p3.y)));
00971     int y_max = fmaxf(p0.y, fmaxf(p1.y, fmaxf(p2.y, p3.y)));
00972
00973     if (x_min < 0) x_min = 0;
00974     if (y_min < 0) y_min = 0;
00975     if (x_max >= (int)screen_mat.cols) x_max = (int)screen_mat.cols - 1;
00976     if (y_max >= (int)screen_mat.rows) y_max = (int)screen_mat.rows - 1;
00977
00978     float w = edge_cross_point(p0, p1, p1, p2) + edge_cross_point(p2, p3, p3, p0);
00979     if (fabs(w) < 1e-6) {
00980         // adl_quad_draw(screen_mat, inv_z_buffer, quad, quad.colors[0], offset_zoom_param);
00981         return;
00982     }
00983
00984     float size_p3_to_p0 = sqrt((p0.x - p3.x)*(p0.x - p3.x) + (p0.y - p3.y)*(p0.y - p3.y));
00985     float size_p0_to_p1 = sqrt((p1.x - p0.x)*(p1.x - p0.x) + (p1.y - p0.y)*(p1.y - p0.y));
00986     float size_p1_to_p2 = sqrt((p2.x - p1.x)*(p2.x - p1.x) + (p2.y - p1.y)*(p2.y - p1.y));
00987     float size_p2_to_p3 = sqrt((p3.x - p2.x)*(p3.x - p2.x) + (p3.y - p2.y)*(p3.y - p2.y));
00988
00989     int r, g, b, a;
00990     HexARGB_RGBA_VAR(color, r, g, b, a);
00991     float light_intensity = (quad.light_intensity[0] + quad.light_intensity[1] +
      quad.light_intensity[2] + quad.light_intensity[3]) / 4;
00992     uint8_t base_r = (uint8_t)fmaxf(0, fminf(255, r * light_intensity));
00993     uint8_t base_g = (uint8_t)fmaxf(0, fminf(255, g * light_intensity));
00994     uint8_t base_b = (uint8_t)fmaxf(0, fminf(255, b * light_intensity));
00995
00996     for (int y = y_min; y <= y_max; y++) {
00997         for (int x = x_min; x <= x_max; x++) {
00998             Point p = {.x = x, .y = y, .z = 0};
00999             bool in_01, in_12, in_23, in_30;
01000
01001             in_01 = (edge_cross_point(p0, p1, p0, p) >= 0) != (w < 0);
01002             in_12 = (edge_cross_point(p1, p2, p1, p) >= 0) != (w < 0);
01003             in_23 = (edge_cross_point(p2, p3, p2, p) >= 0) != (w < 0);
01004             in_30 = (edge_cross_point(p3, p0, p3, p) >= 0) != (w < 0);
01005
01006             /* https://www.mn.uio.no/math/english/people/aca/michaelf/papers/mv3d.pdf. */
01007             float size_p_to_p0 = sqrt((p0.x - p.x)*(p0.x - p.x) + (p0.y - p.y)*(p0.y - p.y));
01008             float size_p_to_p1 = sqrt((p1.x - p.x)*(p1.x - p.x) + (p1.y - p.y)*(p1.y - p.y));
01009             float size_p_to_p2 = sqrt((p2.x - p.x)*(p2.x - p.x) + (p2.y - p.y)*(p2.y - p.y));
01010             float size_p_to_p3 = sqrt((p3.x - p.x)*(p3.x - p.x) + (p3.y - p.y)*(p3.y - p.y));
01011
01012             /* tangent of half the angle directly using vector math */
01013             float tan_theta_3_over_2 = size_p3_to_p0 / (size_p_to_p3 + size_p_to_p0);
```

```
01014             float tan_theta_0_over_2 = size_p0_to_p1 / (size_p_to_p0 + size_p_to_p1);
01015             float tan_theta_1_over_2 = size_p1_to_p2 / (size_p_to_p1 + size_p_to_p2);
01016             float tan_theta_2_over_2 = size_p2_to_p3 / (size_p_to_p2 + size_p_to_p3);
01017             float w0 = (tan_theta_3_over_2 + tan_theta_0_over_2) / size_p_to_p0;
01018             float w1 = (tan_theta_0_over_2 + tan_theta_1_over_2) / size_p_to_p1;
01019             float w2 = (tan_theta_1_over_2 + tan_theta_2_over_2) / size_p_to_p2;
01020             float w3 = (tan_theta_2_over_2 + tan_theta_3_over_2) / size_p_to_p3;
01021
01022             float inv_w_tot = 1.0f / (w0 + w1 + w2 + w3);
01023             float alpha = w0 * inv_w_tot;
01024             float beta  = w1 * inv_w_tot;
01025             float gamma = w2 * inv_w_tot;
01026             float delta = w3 * inv_w_tot;
01027
01028             if (in_01 && in_12 && in_23 && in_30) {
01029
01030                 double inv_w = alpha * (1.0f / p0.w) + beta  * (1.0f / p1.w) + gamma * (1.0f / p2.w) +
      delta * (1.0f / p3.w);
01031                 double z_over_w = alpha * (p0.z / p0.w) + beta  * (p1.z / p1.w) + gamma * (p2.z /
      p2.w) + delta * (p3.z / p3.w);
01032                 double inv_z = inv_w / z_over_w;
01033
01034                 if (inv_z >= MAT2D_AT(inv_z_buffer, y, x)) {
01035                     adl_point_draw(screen_mat, x, y, RGBA_hexARGB(base_r, base_g, base_b, a),
      offset_zoom_param);
01036                     MAT2D_AT(inv_z_buffer, y, x) = inv_z;
01037                 }
01038             }
01039         }
01040     }
01041 }
01042
01055 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)
01056 {
01057     Point p0 = quad.points[0];
01058     Point p1 = quad.points[1];
01059     Point p2 = quad.points[2];
01060     Point p3 = quad.points[3];
01061
01062     int x_min = fminf(p0.x, fminf(p1.x, fminf(p2.x, p3.x)));
01063     int x_max = fmaxf(p0.x, fmaxf(p1.x, fmaxf(p2.x, p3.x)));
01064     int y_min = fminf(p0.y, fminf(p1.y, fminf(p2.y, p3.y)));
01065     int y_max = fmaxf(p0.y, fmaxf(p1.y, fmaxf(p2.y, p3.y)));
01066
01067     if (x_min < 0) x_min = 0;
01068     if (y_min < 0) y_min = 0;
01069     if (x_max >= (int)screen_mat.cols) x_max = (int)screen_mat.cols - 1;
01070     if (y_max >= (int)screen_mat.rows) y_max = (int)screen_mat.rows - 1;
01071
01072     float w = edge_cross_point(p0, p1, p1, p2) + edge_cross_point(p2, p3, p3, p0);
01073     if (fabs(w) < 1e-6) {
01074         // adl_quad_draw(screen_mat, inv_z_buffer, quad, quad.colors[0], offset_zoom_param);
01075         return;
01076     }
01077
01078     int r, g, b, a;
01079     HexARGB_RGBA_VAR(color, r, g, b, a);
01080
01081     for (int y = y_min; y <= y_max; y++) {
01082         for (int x = x_min; x <= x_max; x++) {
01083             Point p = {.x = x, .y = y, .z = 0};
01084             bool in_01, in_12, in_23, in_30;
01085
01086             in_01 = (edge_cross_point(p0, p1, p0, p) >= 0) != (w < 0);
01087             in_12 = (edge_cross_point(p1, p2, p1, p) >= 0) != (w < 0);
01088             in_23 = (edge_cross_point(p2, p3, p2, p) >= 0) != (w < 0);
01089             in_30 = (edge_cross_point(p3, p0, p3, p) >= 0) != (w < 0);
01090
01091             /* using 'mean value coordinates'
01092              * https://www.mn.uio.no/math/english/people/aca/michaelf/papers/mv3d.pdf. */
01093             float size_p_to_p0 = sqrt((p0.x - p.x)*(p0.x - p.x) + (p0.y - p.y)*(p0.y - p.y));
01094             float size_p_to_p1 = sqrt((p1.x - p.x)*(p1.x - p.x) + (p1.y - p.y)*(p1.y - p.y));
01095             float size_p_to_p2 = sqrt((p2.x - p.x)*(p2.x - p.x) + (p2.y - p.y)*(p2.y - p.y));
01096             float size_p_to_p3 = sqrt((p3.x - p.x)*(p3.x - p.x) + (p3.y - p.y)*(p3.y - p.y));
01097
01098             /* calculating the tangent of half the angle directly using vector math */
01099             float t0 = adl_tan_half_angle(p0, p1, p, size_p_to_p0, size_p_to_p1);
01100             float t1 = adl_tan_half_angle(p1, p2, p, size_p_to_p1, size_p_to_p2);
01101             float t2 = adl_tan_half_angle(p2, p3, p, size_p_to_p2, size_p_to_p3);
01102             float t3 = adl_tan_half_angle(p3, p0, p, size_p_to_p3, size_p_to_p0);
01103
01104             float w0 = (t3 + t0) / size_p_to_p0;
01105             float w1 = (t0 + t1) / size_p_to_p1;
01106             float w2 = (t1 + t2) / size_p_to_p2;
01107             float w3 = (t2 + t3) / size_p_to_p3;
01108
```

```
01109             float inv_w_tot = 1.0f / (w0 + w1 + w2 + w3);
01110             float alpha = w0 * inv_w_tot;
01111             float beta  = w1 * inv_w_tot;
01112             float gamma = w2 * inv_w_tot;
01113             float delta = w3 * inv_w_tot;
01114
01115             if (in_01 && in_12 && in_23 && in_30) {
01116                 float light_intensity = quad.light_intensity[0]*alpha + quad.light_intensity[1]*beta +
      quad.light_intensity[2]*gamma + quad.light_intensity[3]*delta;
01117
01118                 float rf = r * light_intensity;
01119                 float gf = g * light_intensity;
01120                 float bf = b * light_intensity;
01121                 uint8_t r8 = (uint8_t)fmaxf(0, fminf(255, rf));
01122                 uint8_t g8 = (uint8_t)fmaxf(0, fminf(255, gf));
01123                 uint8_t b8 = (uint8_t)fmaxf(0, fminf(255, bf));
01124
01125                 double inv_w = alpha * (1.0f / p0.w) + beta  * (1.0f / p1.w) + gamma * (1.0f / p2.w) +
      delta * (1.0f / p3.w);
01126                 double z_over_w = alpha * (p0.z / p0.w) + beta  * (p1.z / p1.w) + gamma * (p2.z /
      p2.w) + delta * (p3.z / p3.w);
01127                 double inv_z = inv_w / z_over_w;
01128
01129                 if (inv_z >= MAT2D_AT(inv_z_buffer, y, x)) {
01130                     adl_point_draw(screen_mat, x, y, RGBA_hexARGB(r8, g8, b8, a), offset_zoom_param);
01131                     MAT2D_AT(inv_z_buffer, y, x) = inv_z;
01132                 }
01133             }
01134         }
01135     }
01136 }
01137
01149 void adl_quad_fill_interpolate_color_mean_value(Mat2D_uint32 screen_mat, Mat2D inv_z_buffer, Quad
      quad, Offset_zoom_param offset_zoom_param)
01150 {
01151     Point p0 = quad.points[0];
01152     Point p1 = quad.points[1];
01153     Point p2 = quad.points[2];
01154     Point p3 = quad.points[3];
01155
01156     int x_min = fminf(p0.x, fminf(p1.x, fminf(p2.x, p3.x)));
01157     int x_max = fmaxf(p0.x, fmaxf(p1.x, fmaxf(p2.x, p3.x)));
01158     int y_min = fminf(p0.y, fminf(p1.y, fminf(p2.y, p3.y)));
01159     int y_max = fmaxf(p0.y, fmaxf(p1.y, fmaxf(p2.y, p3.y)));
01160
01161     if (x_min < 0) x_min = 0;
01162     if (y_min < 0) y_min = 0;
01163     if (x_max >= (int)screen_mat.cols) x_max = (int)screen_mat.cols - 1;
01164     if (y_max >= (int)screen_mat.rows) y_max = (int)screen_mat.rows - 1;
01165
01166     float w = edge_cross_point(p0, p1, p1, p2) + edge_cross_point(p2, p3, p3, p0);
01167     if (fabs(w) < 1e-6) {
01168         // adl_quad_draw(screen_mat, inv_z_buffer, quad, quad.colors[0], offset_zoom_param);
01169         return;
01170     }
01171
01172     for (int y = y_min; y <= y_max; y++) {
01173         for (int x = x_min; x <= x_max; x++) {
01174             Point p = {.x = x, .y = y, .z = 0};
01175             bool in_01, in_12, in_23, in_30;
01176
01177             in_01 = (edge_cross_point(p0, p1, p0, p) >= 0) != (w < 0);
01178             in_12 = (edge_cross_point(p1, p2, p1, p) >= 0) != (w < 0);
01179             in_23 = (edge_cross_point(p2, p3, p2, p) >= 0) != (w < 0);
01180             in_30 = (edge_cross_point(p3, p0, p3, p) >= 0) != (w < 0);
01181
01182             /* using 'mean value coordinates'
01183              * https://www.mn.uio.no/math/english/people/aca/michaelf/papers/mv3d.pdf. */
01184             float size_p_to_p0 = sqrt((p0.x - p.x)*(p0.x - p.x) + (p0.y - p.y)*(p0.y - p.y));
01185             float size_p_to_p1 = sqrt((p1.x - p.x)*(p1.x - p.x) + (p1.y - p.y)*(p1.y - p.y));
01186             float size_p_to_p2 = sqrt((p2.x - p.x)*(p2.x - p.x) + (p2.y - p.y)*(p2.y - p.y));
01187             float size_p_to_p3 = sqrt((p3.x - p.x)*(p3.x - p.x) + (p3.y - p.y)*(p3.y - p.y));
01188
01189             /* calculating the tangent of half the angle directly using vector math */
01190             float t0 = adl_tan_half_angle(p0, p1, p, size_p_to_p0, size_p_to_p1);
01191             float t1 = adl_tan_half_angle(p1, p2, p, size_p_to_p1, size_p_to_p2);
01192             float t2 = adl_tan_half_angle(p2, p3, p, size_p_to_p2, size_p_to_p3);
01193             float t3 = adl_tan_half_angle(p3, p0, p, size_p_to_p3, size_p_to_p0);
01194
01195             float w0 = (t3 + t0) / size_p_to_p0;
01196             float w1 = (t0 + t1) / size_p_to_p1;
01197             float w2 = (t1 + t2) / size_p_to_p2;
01198             float w3 = (t2 + t3) / size_p_to_p3;
01199
01200             float inv_w_tot = 1.0f / (w0 + w1 + w2 + w3);
01201             float alpha = w0 * inv_w_tot;
01202             float beta  = w1 * inv_w_tot;
```

```
01203             float gamma = w2 * inv_w_tot;
01204             float delta = w3 * inv_w_tot;
01205 
01206             if (in_01 && in_12 && in_23 && in_30) {
01207                 int r0, g0, b0, a0;
01208                 int r1, g1, b1, a1;
01209                 int r2, g2, b2, a2;
01210                 int r3, g3, b3, a3;
01211                 HexARGB_RGBA_VAR(quad.colors[0], r0, g0, b0, a0);
01212                 HexARGB_RGBA_VAR(quad.colors[1], r1, g1, b1, a1);
01213                 HexARGB_RGBA_VAR(quad.colors[2], r2, g2, b2, a2);
01214                 HexARGB_RGBA_VAR(quad.colors[3], r3, g3, b3, a3);
01215 
01216                 uint8_t current_r = r0*alpha + r1*beta + r2*gamma + r3*delta;
01217                 uint8_t current_g = g0*alpha + g1*beta + g2*gamma + g3*delta;
01218                 uint8_t current_b = b0*alpha + b1*beta + b2*gamma + b3*delta;
01219                 uint8_t current_a = a0*alpha + a1*beta + a2*gamma + a3*delta;
01220 
01221                 float light_intensity = (quad.light_intensity[0] + quad.light_intensity[1] +
      quad.light_intensity[2] + quad.light_intensity[3]) / 4;
01222                 float rf = current_r * light_intensity;
01223                 float gf = current_g * light_intensity;
01224                 float bf = current_b * light_intensity;
01225                 uint8_t r8 = (uint8_t)fmaxf(0, fminf(255, rf));
01226                 uint8_t g8 = (uint8_t)fmaxf(0, fminf(255, gf));
01227                 uint8_t b8 = (uint8_t)fmaxf(0, fminf(255, bf));
01228 
01229                 double inv_w = alpha * (1.0f / p0.w) + beta  * (1.0f / p1.w) + gamma * (1.0f / p2.w) +
      delta * (1.0f / p3.w);
01230                 double z_over_w = alpha * (p0.z / p0.w) + beta  * (p1.z / p1.w) + gamma * (p2.z /
      p2.w) + delta * (p3.z / p3.w);
01231                 double inv_z = inv_w / z_over_w;
01232 
01233                 if (inv_z >= MAT2D_AT(inv_z_buffer, y, x)) {
01234                     adl_point_draw(screen_mat, x, y, RGBA_hexARGB(r8, g8, b8, current_a),
      offset_zoom_param);
01235                     MAT2D_AT(inv_z_buffer, y, x) = inv_z;
01236                 }
01237             }
01238         }
01239     }
01240 }
01241 
01253 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)
01254 {
01255     for (size_t i = 0; i < mesh.length; i++) {
01256         Quad quad = mesh.elements[i];
01257         /* Reject invalid quad */
01258         adl_assert_quad_is_valid(quad);
01259 
01260         if (!quad.to_draw) continue;
01261 
01262         adl_quad_draw(screen_mat, inv_z_buffer_mat, quad, color, offset_zoom_param);
01263     }
01264 }
01265 
01277 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)
01278 {
01279     for (size_t i = 0; i < mesh.length; i++) {
01280         Quad quad = mesh.elements[i];
01281         /* Reject invalid quad */
01282         adl_assert_quad_is_valid(quad);
01283 
01284         if (!quad.to_draw) continue;
01285 
01286         // color = rand_double() * 0xFFFFFFFF;
01287 
01288         adl_quad_fill(screen_mat, inv_z_buffer_mat, quad, color, offset_zoom_param);
01289     }
01290 }
01291 
01304 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)
01305 {
01306     for (size_t i = 0; i < mesh.length; i++) {
01307         Quad quad = mesh.elements[i];
01308         /* Reject invalid quad */
01309         adl_assert_quad_is_valid(quad);
01310 
01311         uint8_t a, r, g, b;
01312         HexARGB_RGBA_VAR(color, a, r, g, b);
01313         (void)r;
01314         (void)g;
01315         (void)b;
01316 
```

```
01317         if (!quad.to_draw && a == 255) continue;
01318
01319         adl_quad_fill_interpolate_normal_mean_value(screen_mat, inv_z_buffer_mat, quad, color,
      offset_zoom_param);
01320     }
01321 }
01322
01334 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)
01335 {
01336     for (size_t i = 0; i < mesh.length; i++) {
01337         Quad quad = mesh.elements[i];
01338         /* Reject invalid quad */
01339         adl_assert_quad_is_valid(quad);
01340
01341         if (!quad.to_draw) continue;
01342
01343         adl_quad_fill_interpolate_color_mean_value(screen_mat, inv_z_buffer_mat, quad,
      offset_zoom_param);
01344     }
01345 }
01346
01360 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)
01361 {
01362     for (int dy = -r; dy <= r; dy++) {
01363         for (int dx = -r; dx <= r; dx ++) {
01364             float diff = dx * dx + dy * dy - r * r;
01365             if (diff < 0 && diff > -r*2) {
01366                 adl_point_draw(screen_mat, center_x + dx, center_y + dy, color, offset_zoom_param);
01367             }
01368         }
01369     }
01370 }
01371
01382 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)
01383 {
01384     for (int dy = -r; dy <= r; dy++) {
01385         for (int dx = -r; dx <= r; dx ++) {
01386             float diff = dx * dx + dy * dy - r * r;
01387             if (diff < 0) {
01388                 adl_point_draw(screen_mat, center_x + dx, center_y + dy, color, offset_zoom_param);
01389             }
01390         }
01391     }
01392 }
01393
01402 void adl_tri_draw(Mat2D_uint32 screen_mat, Tri tri, uint32_t color, Offset_zoom_param
      offset_zoom_param)
01403 {
01404     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);
01405     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);
01406     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);
01407
01408     // 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);
01409     // 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);
01410     // 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);
01411 }
01412
01425 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)
01426 {
01427     /* This function follows the rasterizer of 'Pikuma' shown in his YouTube video. You can fine the
      video in this link: https://youtu.be/k5wtuKWmV48. */
01428
01429     Point p0, p1, p2;
01430     p0 = tri.points[0];
01431     p1 = tri.points[1];
01432     p2 = tri.points[2];
01433
01434     /* finding bounding box */
01435     int x_min = fmin(p0.x, fmin(p1.x, p2.x));
01436     int x_max = fmax(p0.x, fmax(p1.x, p2.x));
01437     int y_min = fmin(p0.y, fmin(p1.y, p2.y));
01438     int y_max = fmax(p0.y, fmax(p1.y, p2.y));
01439
01440     /* Clamp to screen bounds */
01441     if (x_min < 0) x_min = 0;
01442     if (y_min < 0) y_min = 0;
01443     if (x_max >= (int)screen_mat.cols) x_max = screen_mat.cols - 1;
```

```
01444     if (y_max >= (int)screen_mat.rows) y_max = screen_mat.rows - 1;
01445
01446     /* draw only outline of the tri if there is no area */
01447     float w = edge_cross_point(p0, p1, p1, p2);
01448     if (fabsf(w) < 1e-6) {
01449         // adl_tri_draw(screen_mat, tri, tri.colors[0], offset_zoom_param);
01450         return;
01451     }
01452     MATRIX2D_ASSERT(fabsf(w) > 1e-6 && "triangle must have area");
01453
01454     /* fill conventions */
01455     int bias0 = is_top_left(p0, p1) ? 0 : -1;
01456     int bias1 = is_top_left(p1, p2) ? 0 : -1;
01457     int bias2 = is_top_left(p2, p0) ? 0 : -1;
01458
01459     for (int y = y_min; y <= y_max; y++) {
01460         for (int x = x_min; x <= x_max; x++) {
01461             Point p = {.x = x, .y = y, .z = 0};
01462
01463             float w0 = edge_cross_point(p0, p1, p0, p) + bias0;
01464             float w1 = edge_cross_point(p1, p2, p1, p) + bias1;
01465             float w2 = edge_cross_point(p2, p0, p2, p) + bias2;
01466
01467             float alpha = fabs(w1 / w);
01468             float beta  = fabs(w2 / w);
01469             float gamma = fabs(w0 / w);
01470
01471             if (w0 * w >= 0 && w1 * w >= 0 &&  w2 * w >= 0) {
01472                 int r, b, g, a;
01473                 HexARGB_RGBA_VAR(color, r, g, b, a);
01474                 float light_intensity = (tri.light_intensity[0] + tri.light_intensity[1] +
    tri.light_intensity[2]) / 3;
01475                 float rf = r * light_intensity;
01476                 float gf = g * light_intensity;
01477                 float bf = b * light_intensity;
01478                 uint8_t r8 = (uint8_t)fmaxf(0, fminf(255, rf));
01479                 uint8_t g8 = (uint8_t)fmaxf(0, fminf(255, gf));
01480                 uint8_t b8 = (uint8_t)fmaxf(0, fminf(255, bf));
01481
01482                 double inv_w = alpha * (1.0 / p0.w) + beta  * (1.0 / p1.w) + gamma * (1.0 / p2.w);
01483                 double z_over_w = alpha * (p0.z / p0.w) + beta  * (p1.z / p1.w) + gamma * (p2.z /
    p2.w);
01484                 double inv_z = inv_w / z_over_w;
01485
01486                 if (inv_z >= MAT2D_AT(inv_z_buffer, y, x)) {
01487                     adl_point_draw(screen_mat, x, y, RGBA_hexARGB(r8, g8, b8, a), offset_zoom_param);
01488                     MAT2D_AT(inv_z_buffer, y, x) = inv_z;
01489                 }
01490             }
01491         }
01492     }
01493 }
01494
01506 void adl_tri_fill_Pinedas_rasterizer_interpolate_color(Mat2D_uint32 screen_mat, Mat2D inv_z_buffer,
    Tri tri, Offset_zoom_param offset_zoom_param)
01507 {
01508     /* This function follows the rasterizer of 'Pikuma' shown in his YouTube video. You can fine the
    video in this link: https://youtu.be/k5wtuKWmV48. */
01509     Point p0, p1, p2;
01510     p0 = tri.points[0];
01511     p1 = tri.points[1];
01512     p2 = tri.points[2];
01513
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(w != 0 && "triangle has 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     /* finding bounding box */
01527     int x_min = fmin(p0.x, fmin(p1.x, p2.x));
01528     int x_max = fmax(p0.x, fmax(p1.x, p2.x));
01529     int y_min = fmin(p0.y, fmin(p1.y, p2.y));
01530     int y_max = fmax(p0.y, fmax(p1.y, p2.y));
01531     // printf("xmin: %d, xmax: %d || ymin: %d, ymax: %d\n", x_min, x_max, y_min, y_max);
01532
01533     /* Clamp to screen bounds */
01534     if (x_min < 0) x_min = 0;
01535     if (y_min < 0) y_min = 0;
01536     if (x_max >= (int)screen_mat.cols) x_max = screen_mat.cols - 1;
01537     if (y_max >= (int)screen_mat.rows) y_max = screen_mat.rows - 1;
```

```
01538
01539     for (int y = y_min; y <= y_max; y++) {
01540         for (int x = x_min; x <= x_max; x++) {
01541             Point p = {.x = x, .y = y, .z = 0};
01542
01543             float w0 = edge_cross_point(p0, p1, p0, p) + bias0;
01544             float w1 = edge_cross_point(p1, p2, p1, p) + bias1;
01545             float w2 = edge_cross_point(p2, p0, p2, p) + bias2;
01546
01547             float alpha = fabs(w1 / w);
01548             float beta  = fabs(w2 / w);
01549             float gamma = fabs(w0 / w);
01550
01551             if (w0 * w >= 0 && w1 * w >= 0 &&  w2 * w >= 0) {
01552                 int r0, b0, g0, a0;
01553                 int r1, b1, g1, a1;
01554                 int r2, b2, g2, a2;
01555                 HexARGB_RGBA_VAR(tri.colors[0], r0, g0, b0, a0);
01556                 HexARGB_RGBA_VAR(tri.colors[1], r1, g1, b1, a1);
01557                 HexARGB_RGBA_VAR(tri.colors[2], r2, g2, b2, a2);
01558
01559                 uint8_t current_r = r0*alpha + r1*beta + r2*gamma;
01560                 uint8_t current_g = g0*alpha + g1*beta + g2*gamma;
01561                 uint8_t current_b = b0*alpha + b1*beta + b2*gamma;
01562                 uint8_t current_a = a0*alpha + a1*beta + a2*gamma;
01563
01564                 float light_intensity = (tri.light_intensity[0] + tri.light_intensity[1] +
    tri.light_intensity[2]) / 3;
01565                 float rf = current_r * light_intensity;
01566                 float gf = current_g * light_intensity;
01567                 float bf = current_b * light_intensity;
01568                 uint8_t r8 = (uint8_t)fmaxf(0, fminf(255, rf));
01569                 uint8_t g8 = (uint8_t)fmaxf(0, fminf(255, gf));
01570                 uint8_t b8 = (uint8_t)fmaxf(0, fminf(255, bf));
01571
01572                 double inv_w = alpha * (1.0 / p0.w) + beta  * (1.0 / p1.w) + gamma * (1.0 / p2.w);
01573                 double z_over_w = alpha * (p0.z / p0.w) + beta  * (p1.z / p1.w) + gamma * (p2.z /
    p2.w);
01574                 double inv_z = inv_w / z_over_w;
01575
01576                 if (inv_z >= MAT2D_AT(inv_z_buffer, y, x)) {
01577                     adl_point_draw(screen_mat, x, y, RGBA_hexARGB(r8, g8, b8, current_a),
    offset_zoom_param);
01578                     MAT2D_AT(inv_z_buffer, y, x) = inv_z;
01579                 }
01580             }
01581         }
01582     }
01583 }
01584
01597 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)
01598 {
01599     /* This function follows the rasterizer of 'Pikuma' shown in his YouTube video. You can fine the
    video in this link: https://youtu.be/k5wtuKWmV48. */
01600     Point p0, p1, p2;
01601     p0 = tri.points[0];
01602     p1 = tri.points[1];
01603     p2 = tri.points[2];
01604
01605     float w = edge_cross_point(p0, p1, p1, p2);
01606     if (fabsf(w) < 1e-6) {
01607         // adl_tri_draw(screen_mat, tri, tri.colors[0], offset_zoom_param);
01608         return;
01609     }
01610     MATRIX2D_ASSERT(w != 0 && "triangle has area");
01611
01612     /* fill conventions */
01613     int bias0 = is_top_left(p0, p1) ? 0 : -1;
01614     int bias1 = is_top_left(p1, p2) ? 0 : -1;
01615     int bias2 = is_top_left(p2, p0) ? 0 : -1;
01616
01617     /* finding bounding box */
01618     int x_min = fmin(p0.x, fmin(p1.x, p2.x));
01619     int x_max = fmax(p0.x, fmax(p1.x, p2.x));
01620     int y_min = fmin(p0.y, fmin(p1.y, p2.y));
01621     int y_max = fmax(p0.y, fmax(p1.y, p2.y));
01622     // printf("xmin: %d, xmax: %d || ymin: %d, ymax: %d\n", x_min, x_max, y_min, y_max);
01623
01624     /* Clamp to screen bounds */
01625     if (x_min < 0) x_min = 0;
01626     if (y_min < 0) y_min = 0;
01627     if (x_max >= (int)screen_mat.cols) x_max = screen_mat.cols - 1;
01628     if (y_max >= (int)screen_mat.rows) y_max = screen_mat.rows - 1;
01629
01630     int r, b, g, a;
01631     HexARGB_RGBA_VAR(color, r, g, b, a);
```

```
01632
01633     for (int y = y_min; y <= y_max; y++) {
01634         for (int x = x_min; x <= x_max; x++) {
01635             Point p = {.x = x, .y = y, .z = 0};
01636
01637             float w0 = edge_cross_point(p0, p1, p0, p) + bias0;
01638             float w1 = edge_cross_point(p1, p2, p1, p) + bias1;
01639             float w2 = edge_cross_point(p2, p0, p2, p) + bias2;
01640
01641             float alpha = fabs(w1 / w);
01642             float beta  = fabs(w2 / w);
01643             float gamma = fabs(w0 / w);
01644
01645             if (w0 * w >= 0 && w1 * w >= 0 &&  w2 * w >= 0) {
01646
01647                 float light_intensity = tri.light_intensity[0]*alpha + tri.light_intensity[1]*beta +
      tri.light_intensity[2]*gamma;
01648
01649                 float rf = r * light_intensity;
01650                 float gf = g * light_intensity;
01651                 float bf = b * light_intensity;
01652                 uint8_t r8 = (uint8_t)fmaxf(0, fminf(255, rf));
01653                 uint8_t g8 = (uint8_t)fmaxf(0, fminf(255, gf));
01654                 uint8_t b8 = (uint8_t)fmaxf(0, fminf(255, bf));
01655
01656                 double inv_w = alpha * (1.0 / p0.w) + beta  * (1.0 / p1.w) + gamma * (1.0 / p2.w);
01657                 double z_over_w = alpha * (p0.z / p0.w) + beta  * (p1.z / p1.w) + gamma * (p2.z /
      p2.w);
01658                 double inv_z = inv_w / z_over_w;
01659
01660                 if (inv_z >= MAT2D_AT(inv_z_buffer, y, x)) {
01661                     adl_point_draw(screen_mat, x, y, RGBA_hexARGB(r8, g8, b8, a), offset_zoom_param);
01662                     MAT2D_AT(inv_z_buffer, y, x) = inv_z;
01663                 }
01664             }
01665         }
01666     }
01667 }
01668
01679 void adl_tri_mesh_draw(Mat2D_uint32 screen_mat, Tri_mesh mesh, uint32_t color, Offset_zoom_param
      offset_zoom_param)
01680 {
01681     for (size_t i = 0; i < mesh.length; i++) {
01682         Tri tri = mesh.elements[i];
01683         if (tri.to_draw) {
01684             // color = rand_double() * 0xFFFFFFFF;
01685             adl_tri_draw(screen_mat, tri, color, offset_zoom_param);
01686         }
01687     }
01688 }
01689
01701 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)
01702 {
01703     for (size_t i = 0; i < mesh.length; i++) {
01704         Tri tri = mesh.elements[i];
01705         /* Reject invalid triangles */
01706         adl_assert_tri_is_valid(tri);
01707
01708         if (!tri.to_draw) continue;
01709
01710         adl_tri_fill_Pinedas_rasterizer(screen_mat, inv_z_buffer_mat, tri, color, offset_zoom_param);
01711     }
01712 }
01713
01725 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)
01726 {
01727     for (size_t i = 0; i < mesh.length; i++) {
01728         Tri tri = mesh.elements[i];
01729         /* Reject invalid triangles */
01730         adl_assert_tri_is_valid(tri);
01731
01732         if (!tri.to_draw) continue;
01733
01734         adl_tri_fill_Pinedas_rasterizer_interpolate_color(screen_mat, inv_z_buffer_mat, tri,
      offset_zoom_param);
01735     }
01736 }
01737
01750 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)
01751 {
01752     for (size_t i = 0; i < mesh.length; i++) {
01753         Tri tri = mesh.elements[i];
01754         /* Reject invalid triangles */
01755         adl_assert_tri_is_valid(tri);
```

```
01756
01757         if (!tri.to_draw) continue;
01758
01759         adl_tri_fill_Pinedas_rasterizer_interpolate_normal(screen_mat, inv_z_buffer_mat, tri, color,
      offset_zoom_param);
01760     }
01761 }
01762
01778 float adl_tan_half_angle(Point vi, Point vj, Point p, float li, float lj)
01779 {
01780     float ax = vi.x - p.x, ay = vi.y - p.y;
01781     float bx = vj.x - p.x, by = vj.y - p.y;
01782     float dot = ax * bx + ay * by;
01783     float cross = ax * by - ay * bx;              // signed 2D cross (scalar)
01784     float denom = dot + li * lj;                   // = |a||b|(1 + cos(alpha))
01785     return fabsf(cross) / fmaxf(1e-20f, denom);    // tan(alpha/2)
01786 }
01787
01798 float adl_linear_map(float s, float min_in, float max_in, float min_out, float max_out)
01799 {
01800     return (min_out + ((s-min_in)*(max_out-min_out))/(max_in-min_in));
01801 }
01802
01818 void adl_quad2tris(Quad quad, Tri *tri1, Tri *tri2, char split_line[])
01819 {
01820     if (!strncmp(split_line, "02", 2)) {
01821         tri1->points[0] = quad.points[0];
01822         tri1->points[1] = quad.points[1];
01823         tri1->points[2] = quad.points[2];
01824         tri1->to_draw = quad.to_draw;
01825         tri1->light_intensity[0] = quad.light_intensity[0];
01826         tri1->light_intensity[1] = quad.light_intensity[1];
01827         tri1->light_intensity[2] = quad.light_intensity[2];
01828         tri1->colors[0] = quad.colors[0];
01829         tri1->colors[1] = quad.colors[1];
01830         tri1->colors[2] = quad.colors[2];
01831
01832         tri2->points[0] = quad.points[2];
01833         tri2->points[1] = quad.points[3];
01834         tri2->points[2] = quad.points[0];
01835         tri2->to_draw = quad.to_draw;
01836         tri1->light_intensity[0] = quad.light_intensity[2];
01837         tri1->light_intensity[1] = quad.light_intensity[3];
01838         tri1->light_intensity[2] = quad.light_intensity[0];
01839         tri2->colors[0] = quad.colors[2];
01840         tri2->colors[1] = quad.colors[3];
01841         tri2->colors[2] = quad.colors[0];
01842     } else if (!strncmp(split_line, "13", 2)) {
01843         tri1->points[0] = quad.points[1];
01844         tri1->points[1] = quad.points[2];
01845         tri1->points[2] = quad.points[3];
01846         tri1->to_draw = quad.to_draw;
01847         tri1->light_intensity[0] = quad.light_intensity[1];
01848         tri1->light_intensity[1] = quad.light_intensity[2];
01849         tri1->light_intensity[2] = quad.light_intensity[3];
01850         tri1->colors[0] = quad.colors[1];
01851         tri1->colors[1] = quad.colors[2];
01852         tri1->colors[2] = quad.colors[3];
01853
01854         tri2->points[0] = quad.points[3];
01855         tri2->points[1] = quad.points[0];
01856         tri2->points[2] = quad.points[1];
01857         tri2->to_draw = quad.to_draw;
01858         tri1->light_intensity[0] = quad.light_intensity[3];
01859         tri1->light_intensity[1] = quad.light_intensity[0];
01860         tri1->light_intensity[2] = quad.light_intensity[1];
01861         tri2->colors[0] = quad.colors[3];
01862         tri2->colors[1] = quad.colors[0];
01863         tri2->colors[2] = quad.colors[1];
01864     }
01865 }
01866
01878 void adl_linear_sRGB_to_okLab(uint32_t hex_ARGB, float *L, float *a, float *b)
01879 {
01880     /* https://bottosson.github.io/posts/oklab/
01881        https://en.wikipedia.org/wiki/Oklab_color_space */
01882     int R_255, G_255, B_255;
01883     HexARGB_RGB_VAR(hex_ARGB, R_255, G_255, B_255);
01884
01885     float R = R_255;
01886     float G = G_255;
01887     float B = B_255;
01888
01889     float l = 0.4122214705f * R + 0.5363325363f * G + 0.0514459929f * B;
01890     float m = 0.2119034982f * R + 0.6806995451f * G + 0.1073969566f * B;
01891     float s = 0.0883024619f * R + 0.2817188376f * G + 0.6299787005f * B;
01892
```

```
01893     float l_ = cbrtf(l);
01894     float m_ = cbrtf(m);
01895     float s_ = cbrtf(s);
01896 
01897     *L = 0.2104542553f * l_ + 0.7936177850f * m_ - 0.0040720468f * s_;
01898     *a = 1.9779984951f * l_ - 2.4285922050f * m_ + 0.4505937099f * s_;
01899     *b = 0.0259040371f * l_ + 0.7827717662f * m_ - 0.8086757660f * s_;
01900 
01901 }
01902 
01913 void adl_okLab_to_linear_sRGB(float L, float a, float b, uint32_t *hex_ARGB)
01914 {
01915     /* https://bottosson.github.io/posts/oklab/
01916        https://en.wikipedia.org/wiki/Oklab_color_space */
01917 
01918     float l_ = L + 0.3963377774f * a + 0.2158037573f * b;
01919     float m_ = L - 0.1055613458f * a - 0.0638541728f * b;
01920     float s_ = L - 0.0894841775f * a - 1.2914855480f * b;
01921 
01922     float l = l_ * l_ * l_;
01923     float m = m_ * m_ * m_;
01924     float s = s_ * s_ * s_;
01925 
01926     float R = + 4.0767416621f * l - 3.3077115913f * m + 0.2309699292f * s;
01927     float G = - 1.2684380046f * l + 2.6097574011f * m - 0.3413193965f * s;
01928     float B = - 0.0041960863f * l - 0.7034186147f * m + 1.7076147010f * s;
01929 
01930     R = fmaxf(fminf(R, 255), 0);
01931     G = fmaxf(fminf(G, 255), 0);
01932     B = fmaxf(fminf(B, 255), 0);
01933 
01934     *hex_ARGB = RGBA_hexARGB(R, G, B, 0xFF);
01935 }
01936 
01945 void adl_linear_sRGB_to_okLch(uint32_t hex_ARGB, float *L, float *c, float *h_deg)
01946 {
01947     float a, b;
01948     adl_linear_sRGB_to_okLab(hex_ARGB, L, &a, &b);
01949 
01950     *c = sqrtf(a * a + b * b);
01951     *h_deg = atan2f(b, a) * 180 / PI;
01952 }
01953 
01964 void adl_okLch_to_linear_sRGB(float L, float c, float h_deg, uint32_t *hex_ARGB)
01965 {
01966     h_deg = fmodf((h_deg + 360), 360);
01967     float a = c * cosf(h_deg * PI / 180);
01968     float b = c * sinf(h_deg * PI / 180);
01969     adl_okLab_to_linear_sRGB(L, a, b, hex_ARGB);
01970 }
01971 
01986 void adl_interpolate_ARGBcolor_on_okLch(uint32_t color1, uint32_t color2, float t, float
       num_of_rotations, uint32_t *color_out)
01987 {
01988     float L_1, c_1, h_1;
01989     float L_2, c_2, h_2;
01990     adl_linear_sRGB_to_okLch(color1, &L_1, &c_1, &h_1);
01991     adl_linear_sRGB_to_okLch(color2, &L_2, &c_2, &h_2);
01992     h_2 = h_2 + 360 * num_of_rotations;
01993 
01994     float L, c, h;
01995     L = L_1 * (1 - t) + L_2 * (t);
01996     c = c_1 * (1 - t) + c_2 * (t);
01997     h = h_1 * (1 - t) + h_2 * (t);
01998     adl_okLch_to_linear_sRGB(L, c, h, color_out);
01999 }
02000 
02014 Figure adl_figure_alloc(size_t rows, size_t cols, Point top_left_position)
02015 {
02016     ADL_ASSERT(rows && cols);
02017     adl_assert_point_is_valid(top_left_position);
02018 
02019     Figure figure = {0};
02020     figure.pixels_mat = mat2D_alloc_uint32(rows, cols);
02021     figure.inv_z_buffer_mat = mat2D_alloc(rows, cols);
02022     memset(figure.inv_z_buffer_mat.elements, 0x0, sizeof(double) * figure.inv_z_buffer_mat.rows *
       figure.inv_z_buffer_mat.cols);
02023     ada_init_array(Curve, figure.src_curve_array);
02024 
02025     figure.top_left_position = top_left_position;
02026 
02027     int max_i    = (int)(figure.pixels_mat.rows);
02028     int max_j    = (int)(figure.pixels_mat.cols);
02029     int offset_i = (int)fminf(figure.pixels_mat.rows * ADL_FIGURE_PADDING_PRECENTAGE / 100.0f,
       ADL_MAX_FIGURE_PADDING);
02030     int offset_j = (int)fminf(figure.pixels_mat.cols * ADL_FIGURE_PADDING_PRECENTAGE / 100.0f,
       ADL_MAX_FIGURE_PADDING);
```

```
02031
02032     figure.min_x_pixel = offset_j;
02033     figure.max_x_pixel = max_j - offset_j;
02034     figure.min_y_pixel = offset_i;
02035     figure.max_y_pixel = max_i - offset_i;
02036
02037     figure.min_x = + FLT_MAX;
02038     figure.max_x = - FLT_MAX;
02039     figure.min_y = + FLT_MAX;
02040     figure.max_y = - FLT_MAX;
02041
02042     figure.offset_zoom_param = ADL_DEFAULT_OFFSET_ZOOM;
02043
02044     return figure;
02045 }
02046
02057 void adl_figure_copy_to_screen(Mat2D_uint32 screen_mat, Figure figure)
02058 {
02059     for (size_t i = 0; i < figure.pixels_mat.rows; i++) {
02060         for (size_t j = 0; j < figure.pixels_mat.cols; j++) {
02061             int offset_i = figure.top_left_position.y;
02062             int offset_j = figure.top_left_position.x;
02063
02064             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});
02065         }
02066     }
02067 }
02068
02077 void adl_axis_draw_on_figure(Figure *figure)
02078 {
02079     int max_i    = (int)(figure->pixels_mat.rows);
02080     int max_j    = (int)(figure->pixels_mat.cols);
02081     int offset_i = (int)fmaxf(fminf(figure->pixels_mat.rows * ADL_FIGURE_PADDING_PRECENTAGE / 100.0f,
      ADL_MAX_FIGURE_PADDING), ADL_MIN_FIGURE_PADDING);
02082     int offset_j = (int)fmaxf(fminf(figure->pixels_mat.cols * ADL_FIGURE_PADDING_PRECENTAGE / 100.0f,
      ADL_MAX_FIGURE_PADDING), ADL_MIN_FIGURE_PADDING);
02083
02084     int arrow_head_size_x = (int)fminf(ADL_MAX_HEAD_SIZE, ADL_FIGURE_PADDING_PRECENTAGE / 100.0f *
      (max_j - 2 * offset_j));
02085     int arrow_head_size_y = (int)fminf(ADL_MAX_HEAD_SIZE, ADL_FIGURE_PADDING_PRECENTAGE / 100.0f *
      (max_i - 2 * offset_i));
02086
02087     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);
02088     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);
02089     // 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);
02090
02091     figure->x_axis_head_size = arrow_head_size_x;
02092     figure->y_axis_head_size = arrow_head_size_y;
02093 }
02094
02103 void adl_max_min_values_draw_on_figure(Figure figure)
02104 {
02105     char x_min_sentence[256];
02106     char x_max_sentence[256];
02107     snprintf(x_min_sentence, 256, "%g", figure.min_x);
02108     snprintf(x_max_sentence, 256, "%g", figure.max_x);
02109
02110     int x_sentence_hight_pixel = (figure.pixels_mat.rows - figure.max_y_pixel -
      ADL_MIN_CHARACTER_OFFSET * 3);
02111     int x_min_char_width_pixel = x_sentence_hight_pixel / 2;
02112     int x_max_char_width_pixel = x_sentence_hight_pixel / 2;
02113
02114     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));
02115     x_min_char_width_pixel = x_min_sentence_width_pixel / strlen(x_min_sentence) -
      ADL_MIN_CHARACTER_OFFSET;
02116
02117     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;
02118     x_max_char_width_pixel = (x_max_sentence_width_pixel + figure.x_axis_head_size) /
      strlen(x_max_sentence) - ADL_MIN_CHARACTER_OFFSET;
02119
02120     int x_min_sentence_hight_pixel = (int)fminf(x_min_char_width_pixel * 2, x_sentence_hight_pixel);
02121     int x_max_sentence_hight_pixel = (int)fminf(x_max_char_width_pixel * 2, x_sentence_hight_pixel);
02122
02123     x_min_sentence_hight_pixel = (int)fminf(x_min_sentence_hight_pixel, x_max_sentence_hight_pixel);
02124     x_max_sentence_hight_pixel = x_min_sentence_hight_pixel;
02125
02126     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;
```

```
02127
02128     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);
02129     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);
02130
02131     char y_min_sentence[256];
02132     char y_max_sentence[256];
02133     snprintf(y_min_sentence, 256, "%g", figure.min_y);
02134     snprintf(y_max_sentence, 256, "%g", figure.max_y);
02135
02136     int y_sentence_width_pixel = figure.min_x_pixel - ADL_MAX_CHARACTER_OFFSET -
      figure.y_axis_head_size;
02137     int y_max_char_width_pixel = y_sentence_width_pixel;
02138     y_max_char_width_pixel /= strlen(y_max_sentence);
02139     int y_max_sentence_hight_pixel = y_max_char_width_pixel * 2;
02140
02141     int y_min_char_width_pixel = y_sentence_width_pixel;
02142     y_min_char_width_pixel /= strlen(y_min_sentence);
02143     int y_min_sentence_hight_pixel = y_min_char_width_pixel * 2;
02144
02145     y_min_sentence_hight_pixel = (int)fmaxf(fminf(y_min_sentence_hight_pixel,
      y_max_sentence_hight_pixel), 1);
02146     y_max_sentence_hight_pixel = y_min_sentence_hight_pixel;
02147
02148     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);
02149     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);
02150 }
02151
02163 void adl_curve_add_to_figure(Figure *figure, Point *src_points, size_t src_len, uint32_t color)
02164 {
02165     Curve src_points_ada;
02166     ada_init_array(Point, src_points_ada);
02167     src_points_ada.color = color;
02168
02169     for (size_t i = 0; i < src_len; i++) {
02170         Point current_point = src_points[i];
02171         if (current_point.x > figure->max_x) {
02172             figure->max_x = current_point.x;
02173         }
02174         if (current_point.y > figure->max_y) {
02175             figure->max_y = current_point.y;
02176         }
02177         if (current_point.x < figure->min_x) {
02178             figure->min_x = current_point.x;
02179         }
02180         if (current_point.y < figure->min_y) {
02181             figure->min_y = current_point.y;
02182         }
02183         ada_append(Point, src_points_ada, current_point);
02184     }
02185
02186     ada_append(Curve, figure->src_curve_array, src_points_ada);
02187 }
02188
02198 void adl_curves_plot_on_figure(Figure figure)
02199 {
02200     mat2D_fill_uint32(figure.pixels_mat, figure.background_color);
02201     memset(figure.inv_z_buffer_mat.elements, 0x0, sizeof(double) * figure.inv_z_buffer_mat.rows *
      figure.inv_z_buffer_mat.cols);
02202     if (figure.to_draw_axis) adl_axis_draw_on_figure(&figure);
02203
02204     for (size_t curve_index = 0; curve_index < figure.src_curve_array.length; curve_index++) {
02205         size_t src_len = figure.src_curve_array.elements[curve_index].length;
02206         Point *src_points = figure.src_curve_array.elements[curve_index].elements;
02207         for (size_t i = 0; i < src_len-1; i++) {
02208             Point src_start = src_points[i];
02209             Point src_end   = src_points[i+1];
02210             Point des_start = {0};
02211             Point des_end = {0};
02212
02213             des_start.x = adl_linear_map(src_start.x, figure.min_x, figure.max_x, figure.min_x_pixel,
      figure.max_x_pixel);
02214             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));
02215
02216             des_end.x = adl_linear_map(src_end.x, figure.min_x, figure.max_x, figure.min_x_pixel,
      figure.max_x_pixel);
02217             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));
02218
```

```
02219             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);
02220         }
02221     }
02222
02223     if (figure.to_draw_max_min_values) adl_max_min_values_draw_on_figure(figure);
02224 }
02225
02226 /* check offset2D. might convert it to a Mat2D */
02227 #define adl_offset2d(i, j, ni) (j) * (ni) + (i)
02247 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)
02248 {
02249     mat2D_fill_uint32(figure.pixels_mat, figure.background_color);
02250     memset(figure.inv_z_buffer_mat.elements, 0x0, sizeof(double) * figure.inv_z_buffer_mat.rows *
      figure.inv_z_buffer_mat.cols);
02251     if (figure.to_draw_axis) adl_axis_draw_on_figure(&figure);
02252
02253     float min_scalar = FLT_MAX;
02254     float max_scalar = FLT_MIN;
02255     for (int i = 0; i < ni; i++) {
02256         for (int j = 0; j < nj; j++) {
02257             float val = scalar_2Dmat[adl_offset2d(i, j, ni)];
02258             if (val > max_scalar) max_scalar = val;
02259             if (val < min_scalar) min_scalar = val;
02260             float current_x = x_2Dmat[adl_offset2d(i, j, ni)];
02261             float current_y = y_2Dmat[adl_offset2d(i, j, ni)];
02262             if (current_x > figure.max_x) {
02263                 figure.max_x = current_x;
02264             }
02265             if (current_y > figure.max_y) {
02266                 figure.max_y = current_y;
02267             }
02268             if (current_x < figure.min_x) {
02269                 figure.min_x = current_x;
02270             }
02271             if (current_y < figure.min_y) {
02272                 figure.min_y = current_y;
02273             }
02274         }
02275     }
02276
02277     float window_w = (float)figure.pixels_mat.cols;
02278     float window_h = (float)figure.pixels_mat.rows;
02279
02280     for (int i = 0; i < ni-1; i++) {
02281         for (int j = 0; j < nj-1; j++) {
02282             Quad quad = {0};
02283             quad.light_intensity[0] = 1;
02284             quad.light_intensity[1] = 1;
02285             quad.light_intensity[2] = 1;
02286             quad.light_intensity[3] = 1;
02287             quad.to_draw = 1;
02288
02289             quad.points[3].x = x_2Dmat[adl_offset2d(i  , j  , ni)];
02290             quad.points[3].y = y_2Dmat[adl_offset2d(i  , j  , ni)];
02291             quad.points[2].x = x_2Dmat[adl_offset2d(i+1, j  , ni)];
02292             quad.points[2].y = y_2Dmat[adl_offset2d(i+1, j  , ni)];
02293             quad.points[1].x = x_2Dmat[adl_offset2d(i+1, j+1, ni)];
02294             quad.points[1].y = y_2Dmat[adl_offset2d(i+1, j+1, ni)];
02295             quad.points[0].x = x_2Dmat[adl_offset2d(i  , j+1, ni)];
02296             quad.points[0].y = y_2Dmat[adl_offset2d(i  , j+1, ni)];
02297
02298             for (int p_index = 0; p_index < 4; p_index++) {
02299                 quad.points[p_index].z = 1;
02300                 quad.points[p_index].w = 1;
02301                 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);
02302                 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));
02303
02304                 adl_offset_zoom_point(quad.points[p_index], window_w, window_h,
      figure.offset_zoom_param);
02305             }
02306
02307             float t3 = adl_linear_map(scalar_2Dmat[adl_offset2d(i  , j  , ni)], min_scalar,
      max_scalar, 0, 1);
02308             float t2 = adl_linear_map(scalar_2Dmat[adl_offset2d(i+1, j  , ni)], min_scalar,
      max_scalar, 0, 1);
02309             float t1 = adl_linear_map(scalar_2Dmat[adl_offset2d(i+1, j+1, ni)], min_scalar,
      max_scalar, 0, 1);
02310             float t0 = adl_linear_map(scalar_2Dmat[adl_offset2d(  i, j+1, ni)], min_scalar,
      max_scalar, 0, 1);
02311
02312             /* https://en.wikipedia.org/wiki/Oklab_color_space */
02313             if (!strcmp(color_scale, "b-c")) {
```

```
02314                uint32_t color = 0, color1 = BLUE_hexARGB, color2 = CYAN_hexARGB;
02315                adl_interpolate_ARGBcolor_on_okLch(color1, color2, t0, num_of_rotations, &color);
02316                quad.colors[0] = color;
02317
02318                adl_interpolate_ARGBcolor_on_okLch(color1, color2, t1, num_of_rotations, &color);
02319                quad.colors[1] = color;
02320
02321                adl_interpolate_ARGBcolor_on_okLch(color1, color2, t2, num_of_rotations, &color);
02322                quad.colors[2] = color;
02323
02324                adl_interpolate_ARGBcolor_on_okLch(color1, color2, t3, num_of_rotations, &color);
02325                quad.colors[3] = color;
02326            } else if (!strcmp(color_scale, "b-g")) {
02327                uint32_t color = 0, color1 = BLUE_hexARGB, color2 = GREEN_hexARGB;
02328                adl_interpolate_ARGBcolor_on_okLch(color1, color2, t0, num_of_rotations, &color);
02329                quad.colors[0] = color;
02330
02331                adl_interpolate_ARGBcolor_on_okLch(color1, color2, t1, num_of_rotations, &color);
02332                quad.colors[1] = color;
02333
02334                adl_interpolate_ARGBcolor_on_okLch(color1, color2, t2, num_of_rotations, &color);
02335                quad.colors[2] = color;
02336
02337                adl_interpolate_ARGBcolor_on_okLch(color1, color2, t3, num_of_rotations, &color);
02338                quad.colors[3] = color;
02339            } else if (!strcmp(color_scale, "b-r")) {
02340                uint32_t color = 0, color1 = BLUE_hexARGB, color2 = RED_hexARGB;
02341                adl_interpolate_ARGBcolor_on_okLch(color1, color2, t0, num_of_rotations, &color);
02342                quad.colors[0] = color;
02343
02344                adl_interpolate_ARGBcolor_on_okLch(color1, color2, t1, num_of_rotations, &color);
02345                quad.colors[1] = color;
02346
02347                adl_interpolate_ARGBcolor_on_okLch(color1, color2, t2, num_of_rotations, &color);
02348                quad.colors[2] = color;
02349
02350                adl_interpolate_ARGBcolor_on_okLch(color1, color2, t3, num_of_rotations, &color);
02351                quad.colors[3] = color;
02352            } else if (!strcmp(color_scale, "b-y")) {
02353                uint32_t color = 0, color1 = BLUE_hexARGB, color2 = YELLOW_hexARGB;
02354                adl_interpolate_ARGBcolor_on_okLch(color1, color2, t0, num_of_rotations, &color);
02355                quad.colors[0] = color;
02356
02357                adl_interpolate_ARGBcolor_on_okLch(color1, color2, t1, num_of_rotations, &color);
02358                quad.colors[1] = color;
02359
02360                adl_interpolate_ARGBcolor_on_okLch(color1, color2, t2, num_of_rotations, &color);
02361                quad.colors[2] = color;
02362
02363                adl_interpolate_ARGBcolor_on_okLch(color1, color2, t3, num_of_rotations, &color);
02364                quad.colors[3] = color;
02365            } else if (!strcmp(color_scale, "g-y")) {
02366                uint32_t color = 0, color1 = GREEN_hexARGB, color2 = YELLOW_hexARGB;
02367                adl_interpolate_ARGBcolor_on_okLch(color1, color2, t0, num_of_rotations, &color);
02368                quad.colors[0] = color;
02369
02370                adl_interpolate_ARGBcolor_on_okLch(color1, color2, t1, num_of_rotations, &color);
02371                quad.colors[1] = color;
02372
02373                adl_interpolate_ARGBcolor_on_okLch(color1, color2, t2, num_of_rotations, &color);
02374                quad.colors[2] = color;
02375
02376                adl_interpolate_ARGBcolor_on_okLch(color1, color2, t3, num_of_rotations, &color);
02377                quad.colors[3] = color;
02378            } else if (!strcmp(color_scale, "g-p")) {
02379                uint32_t color = 0, color1 = GREEN_hexARGB, color2 = PURPLE_hexARGB;
02380                adl_interpolate_ARGBcolor_on_okLch(color1, color2, t0, num_of_rotations, &color);
02381                quad.colors[0] = color;
02382
02383                adl_interpolate_ARGBcolor_on_okLch(color1, color2, t1, num_of_rotations, &color);
02384                quad.colors[1] = color;
02385
02386                adl_interpolate_ARGBcolor_on_okLch(color1, color2, t2, num_of_rotations, &color);
02387                quad.colors[2] = color;
02388
02389                adl_interpolate_ARGBcolor_on_okLch(color1, color2, t3, num_of_rotations, &color);
02390                quad.colors[3] = color;
02391            } else if (!strcmp(color_scale, "g-r")) {
02392                uint32_t color = 0, color1 = GREEN_hexARGB, color2 = RED_hexARGB;
02393                adl_interpolate_ARGBcolor_on_okLch(color1, color2, t0, num_of_rotations, &color);
02394                quad.colors[0] = color;
02395
02396                adl_interpolate_ARGBcolor_on_okLch(color1, color2, t1, num_of_rotations, &color);
02397                quad.colors[1] = color;
02398
02399                adl_interpolate_ARGBcolor_on_okLch(color1, color2, t2, num_of_rotations, &color);
02400                quad.colors[2] = color;
```

```
02401
02402                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t3, num_of_rotations, &color);
02403                 quad.colors[3] = color;
02404             } else if (!strcmp(color_scale, "r-y")) {
02405                 uint32_t color = 0, color1 = RED_hexARGB, color2 = YELLOW_hexARGB;
02406                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t0, num_of_rotations, &color);
02407                 quad.colors[0] = color;
02408
02409                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t1, num_of_rotations, &color);
02410                 quad.colors[1] = color;
02411
02412                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t2, num_of_rotations, &color);
02413                 quad.colors[2] = color;
02414
02415                 adl_interpolate_ARGBcolor_on_okLch(color1, color2, t3, num_of_rotations, &color);
02416                 quad.colors[3] = color;
02417             }
02418
02419             adl_quad_fill_interpolate_color_mean_value(figure.pixels_mat, figure.inv_z_buffer_mat,
      quad, ADL_DEFAULT_OFFSET_ZOOM);
02420         }
02421     }
02422
02423     if (figure.to_draw_max_min_values) {
02424         adl_max_min_values_draw_on_figure(figure);
02425     }
02426
02427 }
02428
02446 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)
02447 {
02448     Grid grid;
02449     ada_init_array(Curve, grid.curves);
02450
02451     grid.min_e1 = min_e1;
02452     grid.max_e1 = max_e1;
02453     grid.min_e2 = min_e2;
02454     grid.max_e2 = max_e2;
02455     grid.num_samples_e1 = num_samples_e1;
02456     grid.num_samples_e2 = num_samples_e2;
02457     strncpy(grid.plane, plane, 2);
02458
02459     float del_e1 = (max_e1 - min_e1) / num_samples_e1;
02460     float del_e2 = (max_e2 - min_e2) / num_samples_e2;
02461
02462     grid.de1 = del_e1;
02463     grid.de2 = del_e2;
02464
02465     if (!strncmp(plane, "XY", 3) || !strncmp(plane, "xy", 3)) {
02466         for (int e1_index = 0; e1_index <= num_samples_e1; e1_index++) {
02467             Curve curve;
02468             ada_init_array(Point, curve);
02469             Point point_max = {0}, point_min = {0};
02470
02471             point_min.x = min_e1 + e1_index * del_e1;
02472             point_min.y = min_e2;
02473             point_min.z = third_direction_position;
02474             point_min.w = 1;
02475
02476             point_max.x = min_e1 + e1_index * del_e1;
02477             point_max.y = max_e2;
02478             point_max.z = third_direction_position;
02479             point_max.w = 1;
02480
02481             ada_append(Point, curve, point_min);
02482             ada_append(Point, curve, point_max);
02483
02484             ada_append(Curve, grid.curves, curve);
02485         }
02486         for (int e2_index = 0; e2_index <= num_samples_e2; e2_index++) {
02487             Curve curve;
02488             ada_init_array(Point, curve);
02489             Point point_max = {0}, point_min = {0};
02490
02491             point_min.x = min_e1;
02492             point_min.y = min_e2 + e2_index * del_e2;
02493             point_min.z = third_direction_position;
02494             point_min.w = 1;
02495
02496             point_max.x = max_e1;
02497             point_max.y = min_e2 + e2_index * del_e2;
02498             point_max.z = third_direction_position;
02499             point_max.w = 1;
02500
02501             ada_append(Point, curve, point_min);
02502             ada_append(Point, curve, point_max);
```

```
02503
02504             ada_append(Curve, grid.curves, curve);
02505         }
02506     } else if (!strncmp(plane, "XZ", 3) || !strncmp(plane, "xz", 3)) {
02507         for (int e1_index = 0; e1_index <= num_samples_e1; e1_index++) {
02508             Curve curve;
02509             ada_init_array(Point, curve);
02510             Point point_max = {0}, point_min = {0};
02511
02512             point_min.x = min_e1 + e1_index * del_e1;
02513             point_min.y = third_direction_position;
02514             point_min.z = min_e2;
02515             point_min.w = 1;
02516
02517             point_max.x = min_e1 + e1_index * del_e1;
02518             point_max.y = third_direction_position;
02519             point_max.z = max_e2;
02520             point_max.w = 1;
02521
02522             ada_append(Point, curve, point_min);
02523             ada_append(Point, curve, point_max);
02524
02525             ada_append(Curve, grid.curves, curve);
02526         }
02527         for (int e2_index = 0; e2_index <= num_samples_e2; e2_index++) {
02528             Curve curve;
02529             ada_init_array(Point, curve);
02530             Point point_max = {0}, point_min = {0};
02531
02532             point_min.x = min_e1;
02533             point_min.y = third_direction_position;
02534             point_min.z = min_e2 + e2_index * del_e2;
02535             point_min.w = 1;
02536
02537             point_max.x = max_e1;
02538             point_max.y = third_direction_position;
02539             point_max.z = min_e2 + e2_index * del_e2;
02540             point_max.w = 1;
02541
02542             ada_append(Point, curve, point_min);
02543             ada_append(Point, curve, point_max);
02544
02545             ada_append(Curve, grid.curves, curve);
02546         }
02547     } else if (!strncmp(plane, "YX", 3) || !strncmp(plane, "yx", 3)) {
02548         for (int e1_index = 0; e1_index <= num_samples_e1; e1_index++) {
02549             Curve curve;
02550             ada_init_array(Point, curve);
02551             Point point_max = {0}, point_min = {0};
02552
02553             point_min.x = min_e2;
02554             point_min.y = min_e1 + e1_index * del_e1;
02555             point_min.z = third_direction_position;
02556             point_min.w = 1;
02557
02558             point_max.x = max_e2;
02559             point_max.y = min_e1 + e1_index * del_e1;
02560             point_max.z = third_direction_position;
02561             point_max.w = 1;
02562
02563             ada_append(Point, curve, point_min);
02564             ada_append(Point, curve, point_max);
02565
02566             ada_append(Curve, grid.curves, curve);
02567         }
02568         for (int e2_index = 0; e2_index <= num_samples_e2; e2_index++) {
02569             Curve curve;
02570             ada_init_array(Point, curve);
02571             Point point_max = {0}, point_min = {0};
02572
02573             point_min.x = min_e2 + e2_index * del_e2;
02574             point_min.y = min_e1;
02575             point_min.z = third_direction_position;
02576             point_min.w = 1;
02577
02578             point_max.x = min_e2 + e2_index * del_e2;
02579             point_max.y = max_e1;
02580             point_max.z = third_direction_position;
02581             point_max.w = 1;
02582
02583             ada_append(Point, curve, point_min);
02584             ada_append(Point, curve, point_max);
02585
02586             ada_append(Curve, grid.curves, curve);
02587         }
02588     } else if (!strncmp(plane, "YZ", 3) || !strncmp(plane, "yz", 3)) {
02589         for (int e1_index = 0; e1_index <= num_samples_e1; e1_index++) {
```

```
02590             Curve curve;
02591             ada_init_array(Point, curve);
02592             Point point_max = {0}, point_min = {0};
02593 
02594             point_min.x = third_direction_position;
02595             point_min.y = min_e1 + e1_index * del_e1;
02596             point_min.z = min_e2;
02597             point_min.w = 1;
02598 
02599             point_max.x = third_direction_position;
02600             point_max.y = min_e1 + e1_index * del_e1;
02601             point_max.z = max_e2;
02602             point_max.w = 1;
02603 
02604             ada_append(Point, curve, point_min);
02605             ada_append(Point, curve, point_max);
02606 
02607             ada_append(Curve, grid.curves, curve);
02608         }
02609         for (int e2_index = 0; e2_index <= num_samples_e2; e2_index++) {
02610             Curve curve;
02611             ada_init_array(Point, curve);
02612             Point point_max = {0}, point_min = {0};
02613 
02614             point_min.x = third_direction_position;
02615             point_min.y = min_e1;
02616             point_min.z = min_e2 + e2_index * del_e2;
02617             point_min.w = 1;
02618 
02619             point_max.x = third_direction_position;
02620             point_max.y = max_e1;
02621             point_max.z = min_e2 + e2_index * del_e2;
02622             point_max.w = 1;
02623 
02624             ada_append(Point, curve, point_min);
02625             ada_append(Point, curve, point_max);
02626 
02627             ada_append(Curve, grid.curves, curve);
02628         }
02629     } else if (!strncmp(plane, "ZX", 3) || !strncmp(plane, "zx", 3)) {
02630         for (int e1_index = 0; e1_index <= num_samples_e1; e1_index++) {
02631             Curve curve;
02632             ada_init_array(Point, curve);
02633             Point point_max = {0}, point_min = {0};
02634 
02635             point_min.x = min_e2;
02636             point_min.y = third_direction_position;
02637             point_min.z = min_e1 + e1_index * del_e1;
02638             point_min.w = 1;
02639 
02640             point_max.x = max_e2;
02641             point_max.y = third_direction_position;
02642             point_max.z = min_e1 + e1_index * del_e1;
02643             point_max.w = 1;
02644 
02645             ada_append(Point, curve, point_min);
02646             ada_append(Point, curve, point_max);
02647 
02648             ada_append(Curve, grid.curves, curve);
02649         }
02650         for (int e2_index = 0; e2_index <= num_samples_e2; e2_index++) {
02651             Curve curve;
02652             ada_init_array(Point, curve);
02653             Point point_max = {0}, point_min = {0};
02654 
02655             point_min.x = min_e2 + e2_index * del_e2;
02656             point_min.y = third_direction_position;
02657             point_min.z = min_e1;
02658             point_min.w = 1;
02659 
02660             point_max.x = min_e2 + e2_index * del_e2;
02661             point_max.y = third_direction_position;
02662             point_max.z = max_e1;
02663             point_max.w = 1;
02664 
02665             ada_append(Point, curve, point_min);
02666             ada_append(Point, curve, point_max);
02667 
02668             ada_append(Curve, grid.curves, curve);
02669         }
02670     } else if (!strncmp(plane, "ZY", 3) || !strncmp(plane, "zy", 3)) {
02671         for (int e1_index = 0; e1_index <= num_samples_e1; e1_index++) {
02672             Curve curve;
02673             ada_init_array(Point, curve);
02674             Point point_max = {0}, point_min = {0};
02675 
02676             point_min.x = third_direction_position;
```

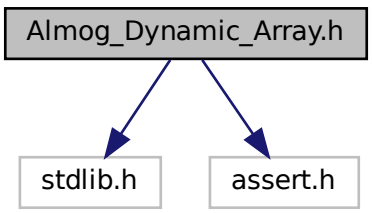
```
02677             point_min.y = min_e2;
02678             point_min.z = min_e1 + e1_index * del_e1;
02679             point_min.w = 1;
02680 
02681             point_max.x = third_direction_position;
02682             point_max.y = max_e2;
02683             point_max.z = min_e1 + e1_index * del_e1;
02684             point_max.w = 1;
02685 
02686             ada_append(Point, curve, point_min);
02687             ada_append(Point, curve, point_max);
02688 
02689             ada_append(Curve, grid.curves, curve);
02690         }
02691         for (int e2_index = 0; e2_index <= num_samples_e2; e2_index++) {
02692             Curve curve;
02693             ada_init_array(Point, curve);
02694             Point point_max = {0}, point_min = {0};
02695 
02696             point_min.x = third_direction_position;
02697             point_min.y = min_e2 + e2_index * del_e2;
02698             point_min.z = min_e1;
02699             point_min.w = 1;
02700 
02701             point_max.x = third_direction_position;
02702             point_max.y = min_e2 + e2_index * del_e2;
02703             point_max.z = max_e1;
02704             point_max.w = 1;
02705 
02706             ada_append(Point, curve, point_min);
02707             ada_append(Point, curve, point_max);
02708 
02709             ada_append(Curve, grid.curves, curve);
02710         }
02711     }
02712 
02713     return grid;
02714 }
02715 
02724 void adl_grid_draw(Mat2D_uint32 screen_mat, Grid grid, uint32_t color, Offset_zoom_param
       offset_zoom_param)
02725 {
02726     for (size_t curve_index = 0; curve_index < grid.curves.length; curve_index++) {
02727         adl_lines_draw(screen_mat, grid.curves.elements[curve_index].elements,
       grid.curves.elements[curve_index].length, color, offset_zoom_param);
02728     }
02729 }
02730 
02731 #endif /*ALMOG_DRAW_LIBRARY_IMPLEMENTATION*/
```

4.3 Almog_Dynamic_Array.h File Reference

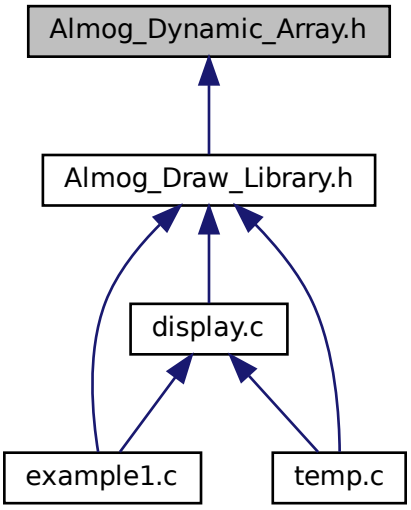
Header-only C macros that implement a simple dynamic array.

```
#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_appand (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_appand 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_appand(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_appand

```
#define ada_appand(
                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

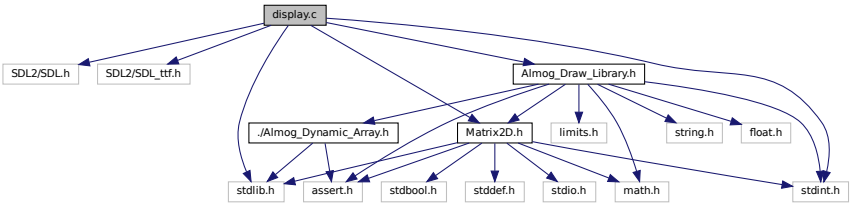
```
00001
00051 #ifndef ALMOG_DYNAMIC_ARRAY_H_
00052 #define ALMOG_DYNAMIC_ARRAY_H_
00053
00054 #include <stdlib.h>
00055 #include <assert.h>
00056
00057
00064 #define ADA_INIT_CAPACITY 10
00065
00073 #ifndef ADA_MALLOC
00074 #define ADA_MALLOC malloc
00075 #endif /*ADA_MALLOC*/
00076
00084 #ifndef ADA_REALLOC
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_*/
```

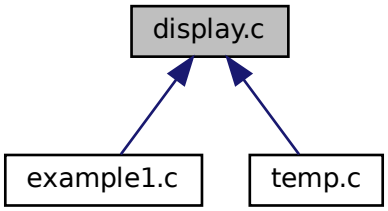
4.5 display.c File Reference

```
#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;
```

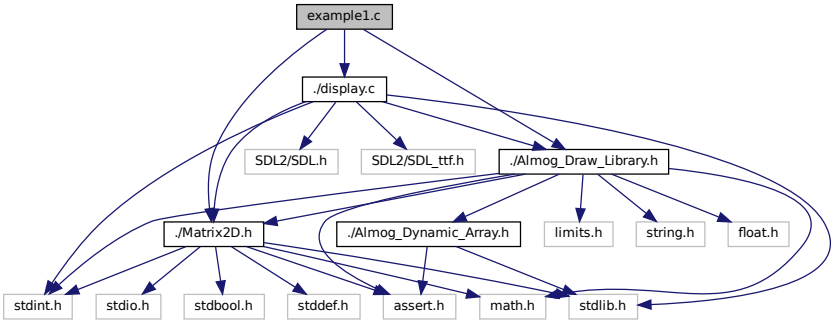
```
00218                         game_state->previous_frame_time = SDL_GetTicks();
00219                         game_state->space_bar_was_pressed = 0;
00220                         break;
00221                     }
00222                 }
00223                 if (event.key.keysym.sym == SDLK_w) {
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);
```

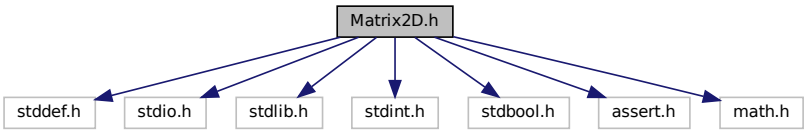
```
00098     adl_character_draw(game_state->window_pixels_mat, 'Z', 50, 100, 975 , 410, 0xFFFFFFFF,
      ADL_DEFAULT_OFFSET_ZOOM);
00099     adl_character_draw(game_state->window_pixels_mat, '.', 50, 100, 1030, 410, 0xFFFFFFFF,
      ADL_DEFAULT_OFFSET_ZOOM);
00100     adl_character_draw(game_state->window_pixels_mat, ':', 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

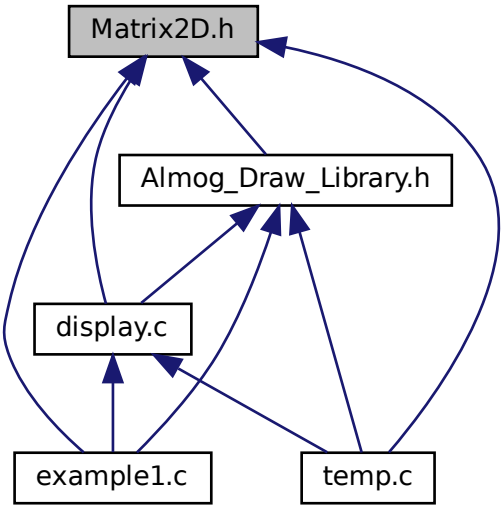
A single-header C library for simple 2D matrix operations on doubles and uint32_t, including allocation, basic arithmetic, linear algebra, and helpers (LUP, inverse, determinant, DCM, etc.).

```
#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);
```

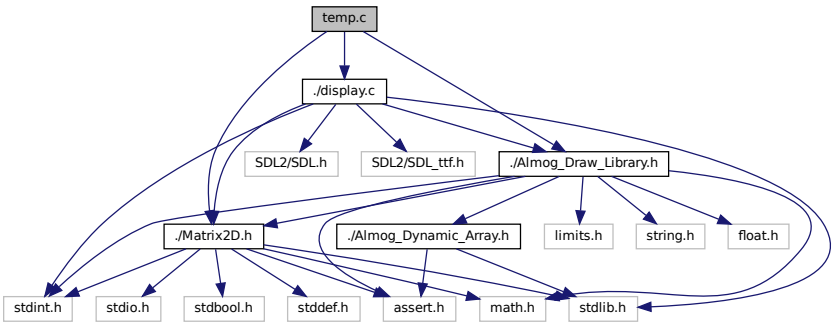
```
01267     mat2D_free(inv_l);
01268     mat2D_free(inv_u);
01269 }
01270
01279 Mat2D_Minor mat2D_minor_alloc_fill_from_mat(Mat2D ref_mat, size_t i, size_t j)
01280 {
01281     MATRIX2D_ASSERT(ref_mat.cols == ref_mat.rows && "minor is defined only for square matrix");
01282
01283     Mat2D_Minor mm;
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
```

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