Almog Engine

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:

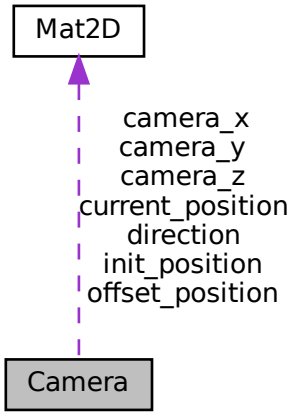
Chapter 3

Class Documentation

3.1 Camera Struct Reference

`#include <Almog_Engine.h>`

Collaboration diagram for Camera:



Public Attributes

- Mat2D init_position
- Mat2D current_position
- Mat2D offset_position
- Mat2D direction
- float z_near
- float z_far
- float fov_deg
- float aspect_ratio

- float roll_offset_deg
- float pitch_offset_deg
- float yaw_offset_deg
- Mat2D camera_x
- Mat2D camera_y
- Mat2D camera_z

3.1.1 Detailed Description

Definition at line 144 of file Almog_Engine.h.

3.1.2 Member Data Documentation

3.1.2.1 aspect_ratio

```
float Camera::aspect_ratio
```

Definition at line 152 of file Almog_Engine.h.

Referenced by ae_camera_init(), ae_scene_init(), check_window_mat_size(), and update().

3.1.2.2 camera_x

```
Mat2D Camera::camera_x
```

Definition at line 156 of file Almog_Engine.h.

Referenced by ae_camera_free(), ae_camera_init(), ae_camera_reset_pos(), and ae_view_mat_set().

3.1.2.3 camera_y

```
Mat2D Camera::camera_y
```

Definition at line 157 of file Almog_Engine.h.

Referenced by ae_camera_free(), ae_camera_init(), ae_camera_reset_pos(), and ae_view_mat_set().

3.1.2.4 camera_z

```
Mat2D Camera::camera_z
```

Definition at line 158 of file Almog_Engine.h.

Referenced by ae_camera_free(), ae_camera_init(), ae_camera_reset_pos(), and ae_view_mat_set().

3.1.2.5 current_position

```
Mat2D Camera::current_position
```

Definition at line 146 of file Almog_Engine.h.

Referenced by ae_camera_free(), ae_camera_init(), ae_camera_reset_pos(), ae_quad_calc_light_intensity(), ae_quad_project_world2screen(), ae_tri_calc_light_intensity(), ae_tri_project_world2screen(), and ae_view_mat_set().

3.1.2.6 direction

```
Mat2D Camera::direction
```

Definition at line 148 of file Almog_Engine.h.

Referenced by ae_camera_free(), ae_camera_init(), and ae_view_mat_set().

3.1.2.7 fov_deg

```
float Camera::fov_deg
```

Definition at line 151 of file Almog_Engine.h.

Referenced by ae_camera_init(), ae_scene_init(), and update().

3.1.2.8 init_position

```
Mat2D Camera::init_position
```

Definition at line 145 of file Almog_Engine.h.

Referenced by ae_camera_free(), ae_camera_init(), and ae_camera_reset_pos().

3.1.2.9 offset_position

```
Mat2D Camera::offset_position
```

Definition at line 147 of file Almog_Engine.h.

Referenced by ae_camera_free(), ae_camera_init(), ae_camera_reset_pos(), ae_view_mat_set(), and process_input_window().

3.1.2.10 pitch_offset_deg

```
float Camera::pitch_offset_deg
```

Definition at line 154 of file Almog_Engine.h.

Referenced by ae_camera_init(), ae_camera_reset_pos(), ae_view_mat_set(), and process_input_window().

3.1.2.11 roll_offset_deg

```
float Camera::roll_offset_deg
```

Definition at line 153 of file Almog_Engine.h.

Referenced by ae_camera_init(), ae_camera_reset_pos(), ae_view_mat_set(), and process_input_window().

3.1.2.12 yaw_offset_deg

```
float Camera::yaw_offset_deg
```

Definition at line 155 of file Almog_Engine.h.

Referenced by ae_camera_init(), ae_camera_reset_pos(), and ae_view_mat_set().

3.1.2.13 z_far

```
float Camera::z_far
```

Definition at line 150 of file Almog_Engine.h.

Referenced by ae_camera_init(), ae_scene_init(), and update().

3.1.2.14 z_near

```
float Camera::z_near
```

Definition at line 149 of file Almog_Engine.h.

Referenced by ae_camera_init(), ae_line_project_world2screen(), ae_quad_project_world2screen(), ae_scene_init(), ae_tri_project_world2screen(), and update().

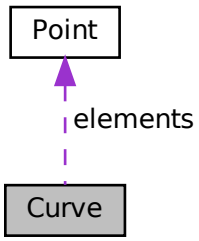
The documentation for this struct was generated from the following file:

- src/include/Almog_Engine.h

3.2 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

3.2.1 Detailed Description

Definition at line 60 of file Almog_Draw_Library.h.

3.2.2 Member Data Documentation

3.2.2.1 capacity

```
size_t Curve::capacity
```

Definition at line 63 of file Almog_Draw_Library.h.

3.2.2.2 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().

3.2.2.3 elements

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

Definition at line 64 of file Almog_Draw_Library.h.

Referenced by adl_curves_plot_on_figure(), adl_grid_draw(), ae_curve_copy(), ae_curve_project_world2screen(), ae_print_points(), and ae_tri_mesh_get_from_obj_file().

3.2.2.4 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(), ae_curve_copy(), ae_curve_project_world2screen(), and ae_print_points().

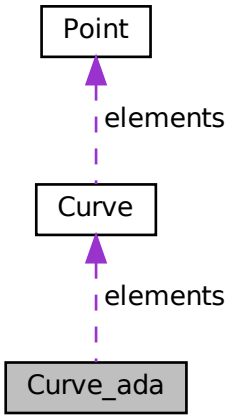
The documentation for this struct was generated from the following file:

- src/include/Almog_Draw_Library.h

3.3 Curve_ada Struct Reference

`#include <Almog_Draw_Library.h>`

Collaboration diagram for Curve_ada:



Public Attributes

- size_t length
- size_t capacity
- Curve * elements

3.3.1 Detailed Description

Definition at line 70 of file Almog_Draw_Library.h.

3.3.2 Member Data Documentation

3.3.2.1 capacity

`size_t Curve_ada::capacity`

Definition at line 72 of file Almog_Draw_Library.h.

3.3.2.2 elements

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

Definition at line 73 of file Almog_Draw_Library.h.

Referenced by adl_curves_plot_on_figure(), adl_grid_draw(), ae_curve_ada_project_world2screen(), and ae_grid_project_world2screen().

3.3.2.3 length

```
size_t Curve_ada::length
```

Definition at line 71 of file Almog_Draw_Library.h.

Referenced by adl_curves_plot_on_figure(), adl_grid_draw(), ae_curve_ada_project_world2screen(), and ae_grid_project_world2screen().

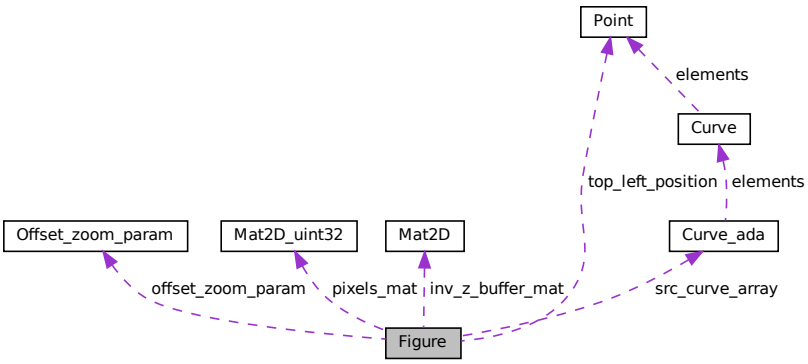
The documentation for this struct was generated from the following file:

- src/include/Almog_Draw_Library.h

3.4 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

3.4.1 Detailed Description

Definition at line 118 of file Almog_Draw_Library.h.

3.4.2 Member Data Documentation

3.4.2.1 background_color

```
uint32_t Figure::background_color
```

Definition at line 134 of file Almog_Draw_Library.h.

Referenced by adl_2Dscalar_interp_on_figure(), and adl_curves_plot_on_figure().

3.4.2.2 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().

3.4.2.3 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().

3.4.2.4 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().

3.4.2.5 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().

3.4.2.6 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().

3.4.2.7 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().

3.4.2.8 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().

3.4.2.9 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().

3.4.2.10 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().

3.4.2.11 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().

3.4.2.12 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().

3.4.2.13 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().

3.4.2.14 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(), and adl_curves_plot_on_figure().

3.4.2.15 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(), and adl_curves_plot_on_figure().

3.4.2.16 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().

3.4.2.17 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().

3.4.2.18 y_axis_head_size

```
int Figure::y_axis_head_size
```

Definition at line 128 of file Almog_Draw_Library.h.

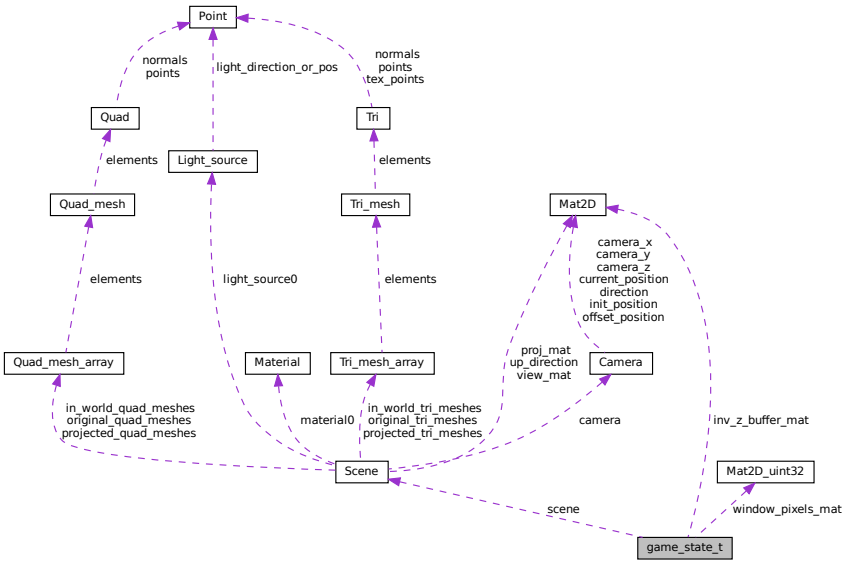
Referenced by adl_axis_draw_on_figure(), and adl_max_min_values_draw_on_figure().

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

- src/include/Almog_Draw_Library.h

3.5 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
- SDL_Surface * window_surface
- SDL_Texture * window_texture
- Mat2D_uint32 window_pixels_mat
- Mat2D inv_z_buffer_mat
- Scene scene

3.5.1 Detailed Description

Definition at line 38 of file display.c.

3.5.2 Member Data Documentation

3.5.2.1 a_was_pressed

```
int game_state_t::a_was_pressed
```

Definition at line 55 of file display.c.

Referenced by main().

3.5.2.2 const_fps

```
float game_state_t::const_fps
```

Definition at line 42 of file display.c.

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

3.5.2.3 d_was_pressed

```
int game_state_t::d_was_pressed
```

Definition at line 56 of file display.c.

Referenced by main().

3.5.2.4 delta_time

```
float game_state_t::delta_time
```

Definition at line 40 of file display.c.

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

3.5.2.5 e_was_pressed

```
int game_state_t::e_was_pressed
```

Definition at line 57 of file display.c.

Referenced by main().

3.5.2.6 elapsed_time

```
float game_state_t::elapsed_time
```

Definition at line 41 of file display.c.

Referenced by main(), and update_window().

3.5.2.7 fps

```
float game_state_t::fps
```

Definition at line 43 of file display.c.

Referenced by main(), and update_window().

3.5.2.8 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().

3.5.2.9 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().

3.5.2.10 inv_z_buffer_mat

```
Mat2D game_state_t::inv_z_buffer_mat
```

Definition at line 69 of file display.c.

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

3.5.2.11 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().

3.5.2.12 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().

3.5.2.13 q_was_pressed

```
int game_state_t::q_was_pressed
```

Definition at line 58 of file display.c.

Referenced by main().

3.5.2.14 renderer

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

Definition at line 63 of file display.c.

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

3.5.2.15 s_was_pressed

```
int game_state_t::s_was_pressed
```

Definition at line 54 of file display.c.

Referenced by main().

3.5.2.16 scene

```
Scene game_state_t::scene
```

Definition at line 71 of file display.c.

Referenced by check_window_mat_size(), destroy_window(), process_input_window(), render(), setup(), setup_window(), and update().

3.5.2.17 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().

3.5.2.18 to_clear_renderer

```
int game_state_t::to_clear_renderer
```

Definition at line 50 of file display.c.

Referenced by main(), and render_window().

3.5.2.19 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().

3.5.2.20 to_render

```
int game_state_t::to_render
```

Definition at line 45 of file display.c.

Referenced by main(), and process_input_window().

3.5.2.21 to_update

```
int game_state_t::to_update
```

Definition at line 46 of file display.c.

Referenced by main(), and process_input_window().

3.5.2.22 w_was_pressed

```
int game_state_t::w_was_pressed
```

Definition at line 53 of file display.c.

Referenced by main().

3.5.2.23 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().

3.5.2.24 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(), update(), and update_window().

3.5.2.25 window_pixels_mat

```
Mat2D_uint32 game_state_t::window_pixels_mat
```

Definition at line 68 of file display.c.

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

3.5.2.26 window_surface

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

Definition at line 65 of file display.c.

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

3.5.2.27 window_texture

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

Definition at line 66 of file display.c.

Referenced by destroy_window().

3.5.2.28 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(), update(), and update_window().

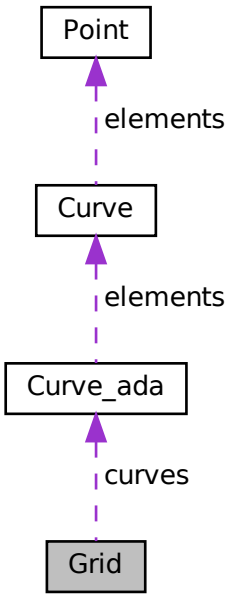
The documentation for this struct was generated from the following file:

- src/include/display.c

3.6 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]

3.6.1 Detailed Description

Definition at line 139 of file Almog_Draw_Library.h.

3.6.2 Member Data Documentation

3.6.2.1 curves

```
Curve_ada Grid::curves
```

Definition at line 140 of file Almog_Draw_Library.h.

Referenced by adl_cartesian_grid_create(), adl_grid_draw(), and ae_grid_project_world2screen().

3.6.2.2 de1

```
float Grid::de1
```

Definition at line 147 of file Almog_Draw_Library.h.

Referenced by adl_cartesian_grid_create().

3.6.2.3 de2

```
float Grid::de2
```

Definition at line 148 of file Almog_Draw_Library.h.

Referenced by adl_cartesian_grid_create().

3.6.2.4 max_e1

```
float Grid::max_e1
```

Definition at line 142 of file Almog_Draw_Library.h.

Referenced by adl_cartesian_grid_create().

3.6.2.5 max_e2

```
float Grid::max_e2
```

Definition at line 144 of file Almog_Draw_Library.h.

Referenced by adl_cartesian_grid_create().

3.6.2.6 min_e1

```
float Grid::min_e1
```

Definition at line 141 of file Almog_Draw_Library.h.

Referenced by adl_cartesian_grid_create().

3.6.2.7 min_e2

```
float Grid::min_e2
```

Definition at line 143 of file Almog_Draw_Library.h.

Referenced by adl_cartesian_grid_create().

3.6.2.8 num_samples_e1

```
int Grid::num_samples_e1
```

Definition at line 145 of file Almog_Draw_Library.h.

Referenced by adl_cartesian_grid_create().

3.6.2.9 num_samples_e2

```
int Grid::num_samples_e2
```

Definition at line 146 of file Almog_Draw_Library.h.

Referenced by adl_cartesian_grid_create().

3.6.2.10 plane

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

Definition at line 149 of file Almog_Draw_Library.h.

Referenced by adl_cartesian_grid_create().

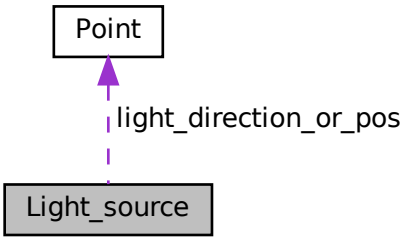
The documentation for this struct was generated from the following file:

- src/include/Almog_Draw_Library.h

3.7 Light_source Struct Reference

```
#include <Almog_Engine.h>
```

Collaboration diagram for Light_source:



Public Attributes

- Point light_direction_or_pos
- float light_intensity

3.7.1 Detailed Description

Definition at line 161 of file Almog_Engine.h.

3.7.2 Member Data Documentation

3.7.2.1 light_direction_or_pos

```
Point Light_source::light_direction_or_pos
```

Definition at line 162 of file Almog_Engine.h.

Referenced by ae_quad_calc_light_intensity(), ae_quad_project_world2screen(), ae_scene_init(), and ae_tri_calc_light_intensity().

3.7.2.2 light_intensity

```
float Light_source::light_intensity
```

Definition at line 163 of file Almog_Engine.h.

Referenced by ae_quad_calc_light_intensity(), ae_scene_init(), and ae_tri_calc_light_intensity().

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

- src/include/Almog_Engine.h

3.8 Mat2D Struct Reference

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

Public Attributes

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

3.8.1 Detailed Description

Definition at line 29 of file Matrix2D.h.

3.8.2 Member Data Documentation

3.8.2.1 cols

```
size_t Mat2D::cols
```

Definition at line 31 of file Matrix2D.h.

Referenced by adl_2Dscalar_interp_on_figure(), adl_curves_plot_on_figure(), adl_figure_alloc(), ae_point_to_mat2D(), ae_projection_mat_set(), ae_quad_calc_normal(), ae_tri_calc_normal(), ae_z_buffer_copy_to_screen(), 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(), and render_window().

3.8.2.2 elements

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

Definition at line 33 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().

3.8.2.3 rows

```
size_t Mat2D::rows
```

Definition at line 30 of file Matrix2D.h.

Referenced by adl_2Dscalar_interp_on_figure(), adl_curves_plot_on_figure(), adl_figure_alloc(), ae_point_to_mat2D(), ae_projection_mat_set(), ae_quad_calc_normal(), ae_tri_calc_normal(), ae_z_buffer_copy_to_screen(), 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(), and render_window().

3.8.2.4 stride_r

```
size_t Mat2D::stride_r
```

Definition at line 32 of file Matrix2D.h.

Referenced by mat2D_alloc(), and mat2D_offset2d().

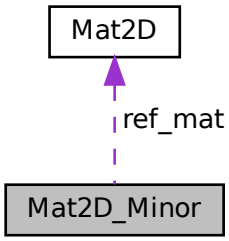
The documentation for this struct was generated from the following file:

- src/include/Matrix2D.h

3.9 Mat2D_Minor Struct Reference

```
#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

3.9.1 Detailed Description

Definition at line 43 of file Matrix2D.h.

3.9.2 Member Data Documentation

3.9.2.1 cols

```
size_t Mat2D_Minor::cols
```

Definition at line 45 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().

3.9.2.2 cols_list

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

Definition at line 48 of file Matrix2D.h.

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

3.9.2.3 ref_mat

```
Mat2D Mat2D_Minor::ref_mat
```

Definition at line 49 of file Matrix2D.h.

Referenced by mat2D_minor_alloc_fill_from_mat(), and mat2D_minor_alloc_fill_from_mat_minor().

3.9.2.4 rows

```
size_t Mat2D_Minor::rows
```

Definition at line 44 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().

3.9.2.5 rows_list

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

Definition at line 47 of file Matrix2D.h.

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

3.9.2.6 stride_r

```
size_t Mat2D_Minor::stride_r
```

Definition at line 46 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:

- src/include/Matrix2D.h

3.10 Mat2D_uint32 Struct Reference

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

Public Attributes

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

3.10.1 Detailed Description

Definition at line 36 of file Matrix2D.h.

3.10.2 Member Data Documentation

3.10.2.1 cols

```
size_t Mat2D_uint32::cols
```

Definition at line 38 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().

3.10.2.2 elements

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

Definition at line 40 of file Matrix2D.h.

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

3.10.2.3 rows

```
size_t Mat2D_uint32::rows
```

Definition at line 37 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().

3.10.2.4 stride_r

```
size_t Mat2D_uint32::stride_r
```

Definition at line 39 of file Matrix2D.h.

Referenced by mat2D_alloc_uint32(), and mat2D_offset2d_uint32().

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

- src/include/Matrix2D.h

3.11 Material Struct Reference

```
#include <Almog_Engine.h>
```

Public Attributes

- float specular_power_alpha
- float c_ambi
- float c_diff
- float c_spec

3.11.1 Detailed Description

Definition at line 166 of file Almog_Engine.h.

3.11.2 Member Data Documentation

3.11.2.1 c_ambi

```
float Material::c_ambi
```

Definition at line 168 of file Almog_Engine.h.

Referenced by ae_quad_calc_light_intensity(), ae_scene_init(), and ae_tri_calc_light_intensity().

3.11.2.2 c_diff

```
float Material::c_diff
```

Definition at line 169 of file Almog_Engine.h.

Referenced by ae_quad_calc_light_intensity(), ae_scene_init(), and ae_tri_calc_light_intensity().

3.11.2.3 c_spec

```
float Material::c_spec
```

Definition at line 170 of file Almog_Engine.h.

Referenced by ae_quad_calc_light_intensity(), ae_scene_init(), and ae_tri_calc_light_intensity().

3.11.2.4 specular_power_alpha

```
float Material::specular_power_alpha
```

Definition at line 167 of file Almog_Engine.h.

Referenced by ae_quad_calc_light_intensity(), ae_scene_init(), and ae_tri_calc_light_intensity().

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

- src/include/Almog_Engine.h

3.12 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

3.12.1 Detailed Description

Definition at line 40 of file Almog_Draw_Library.h.

3.12.2 Member Data Documentation

3.12.2.1 mouse_x

`int Offset_zoom_param::mouse_x`

Definition at line 44 of file Almog_Draw_Library.h.

3.12.2.2 mouse_y

`int Offset_zoom_param::mouse_y`

Definition at line 45 of file Almog_Draw_Library.h.

3.12.2.3 offset_x

`float Offset_zoom_param::offset_x`

Definition at line 42 of file Almog_Draw_Library.h.

Referenced by adl_line_draw(), and adl_point_draw().

3.12.2.4 offset_y

```
float Offset_zoom_param::offset_y
```

Definition at line 43 of file Almog_Draw_Library.h.

Referenced by adl_line_draw(), and adl_point_draw().

3.12.2.5 zoom_multiplier

```
float Offset_zoom_param::zoom_multiplier
```

Definition at line 41 of file Almog_Draw_Library.h.

Referenced by adl_line_draw(), and adl_point_draw().

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

- src/include/Almog_Draw_Library.h

3.13 Point Struct Reference

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

Public Attributes

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

3.13.1 Detailed Description

Definition at line 50 of file Almog_Draw_Library.h.

3.13.2 Member Data Documentation

3.13.2.1 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(),
adl_tri_fill_Pinedas_rasterizer_interpolate_normal(), ae_point_normalize_xyz(), ae_point_project_view2screen(),
ae_point_project_world2view(), ae_quad_calc_light_intensity(), ae_quad_clip_with_plane(), ae_quad_get_average_normal(),
ae_quad_get_average_point(), ae_quad_transform_to_view(), ae_scene_init(), ae_tri_calc_light_intensity(),
ae_tri_clip_with_plane(), ae_tri_get_average_normal(), ae_tri_get_average_point(), ae_tri_project_world2screen(),
and ae_tri_transform_to_view().

3.13.2.2 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(), adl_tri_fill_Pinedas_rasterizer_interpolate_normal(), ae_mat2D_to_point(),
ae_point_normalize_xyz(), ae_point_project_view2screen(), ae_point_project_world2view(), ae_point_to_mat2D(),
ae_print_points(), ae_print_tri(), ae_quad_get_average_normal(), ae_quad_get_average_point(), ae_quad_project_world2screen(),
ae_quad_transform_to_view(), ae_scene_init(), ae_signed_dist_point_and_plane(), ae_tri_clip_with_plane(),
ae_tri_get_average_normal(), ae_tri_get_average_point(), ae_tri_mesh_get_from_obj_file(), ae_tri_mesh_get_from_stl_file(),
ae_tri_mesh_normalize(), ae_tri_mesh_rotate_Euler_xyz(), ae_tri_mesh_set_bounding_box(), ae_tri_mesh_translate(),
ae_tri_project_world2screen(), and ae_tri_transform_to_view().

3.13.2.3 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(), adl_tri_fill_Pinedas_rasterizer_interpolate_normal(), ae_point_normalize_xyz(),
ae_point_project_view2screen(), ae_point_project_world2view(), ae_point_to_mat2D(), ae_print_points(),
ae_print_tri(), ae_quad_get_average_normal(), ae_quad_get_average_point(), ae_quad_project_world2screen(),
ae_quad_transform_to_view(), ae_scene_init(), ae_signed_dist_point_and_plane(), ae_tri_clip_with_plane(),
ae_tri_get_average_normal(), ae_tri_get_average_point(), ae_tri_mesh_get_from_obj_file(), ae_tri_mesh_get_from_stl_file(),
ae_tri_mesh_normalize(), ae_tri_mesh_rotate_Euler_xyz(), ae_tri_mesh_set_bounding_box(), ae_tri_mesh_translate(),
ae_tri_project_world2screen(), and ae_tri_transform_to_view().

3.13.2.4 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(), adl_tri_fill_Pinedas_rasterizer_interpolate_normal(), ae_point_normalize_xyz(), ae_point_project_view2screen(), ae_point_project_world2view(), ae_point_to_mat2D(), ae_print_points(), ae_print_tri(), ae_quad_get_average_normal(), ae_quad_get_average_point(), ae_quad_project_world2screen(), ae_quad_transform_to_view(), ae_scene_init(), ae_signed_dist_point_and_plane(), ae_tri_compare(), ae_tri_get_average_normal(), ae_tri_get_average_point(), ae_tri_mesh_get_from_obj_file(), ae_tri_mesh_get_from_stl_file(), ae_tri_mesh_normalize(), ae_tri_mesh_rotate_Euler_xyz(), ae_tri_mesh_set_bounding_box(), ae_tri_mesh_translate(), ae_tri_project_world2screen(), and ae_tri_transform_to_view().

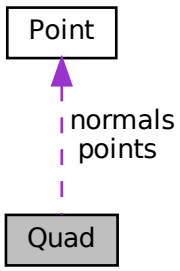
The documentation for this struct was generated from the following file:

- src/include/Almog_Draw_Library.h

3.14 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]

3.14.1 Detailed Description

Definition at line 91 of file Almog_Draw_Library.h.

3.14.2 Member Data Documentation

3.14.2.1 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(), ae_quad_clip_with_plane(), and ae_tri_mesh_get_from_quad_mesh().

3.14.2.2 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(), ae_quad_calc_light_intensity(), ae_quad_project_world2screen(), and ae_tri_mesh_get_from_quad_mesh().

3.14.2.3 normals

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

Definition at line 93 of file Almog_Draw_Library.h.

Referenced by ae_quad_calc_light_intensity(), ae_quad_get_average_normal(), ae_quad_project_world2screen(), ae_quad_set_normals(), and ae_tri_mesh_get_from_quad_mesh().

3.14.2.4 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_m adl_quad_fill_interpolate_normal_mean_value(), ae_quad_calc_light_intensity(), ae_quad_calc_normal(), ae_quad_clip_with_plane(), ae_quad_get_average_point(), ae_quad_project_world2screen(), ae_quad_set_normals(), ae_quad_transform_to_view(), and ae_tri_mesh_get_from_quad_mesh().

3.14.2.5 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(), ae_quad_project_world2screen(), and ae_tri_mesh_get_from_quad_mesh().

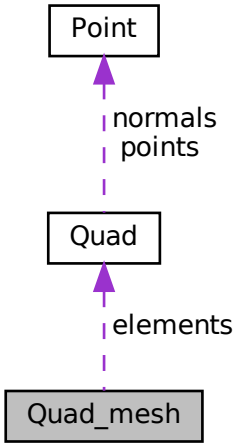
The documentation for this struct was generated from the following file:

- src/include/Almog_Draw_Library.h

3.15 Quad_mesh Struct Reference

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

Collaboration diagram for Quad_mesh:



Public Attributes

- size_t length
- size_t capacity
- Quad * elements

3.15.1 Detailed Description

Definition at line 111 of file Almog_Draw_Library.h.

3.15.2 Member Data Documentation

3.15.2.1 capacity

```
size_t Quad_mesh::capacity
```

Definition at line 113 of file Almog_Draw_Library.h.

3.15.2.2 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(), adl_quad_mesh_fill_interpolat
ae_quad_mesh_project_world2screen(), ae_quad_project_world2screen(), ae_scene_free(), and ae_tri_mesh_get_from_quad_mesh

3.15.2.3 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(), adl_quad_mesh_fill_interpolat
ae_quad_mesh_project_world2screen(), ae_quad_project_world2screen(), and ae_tri_mesh_get_from_quad_mesh().

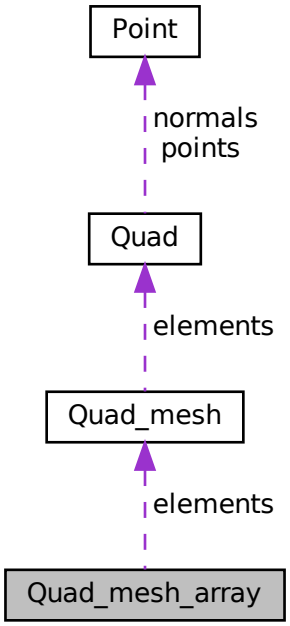
The documentation for this struct was generated from the following file:

- src/include/Almog_Draw_Library.h

3.16 Quad_mesh_array Struct Reference

`#include <Almog_Engine.h>`

Collaboration diagram for Quad_mesh_array:



Public Attributes

- size_t length
- size_t capacity
- Quad_mesh * elements

3.16.1 Detailed Description

Definition at line 137 of file Almog_Engine.h.

3.16.2 Member Data Documentation

3.16.2.1 capacity

```
size_t Quad_mesh_array::capacity
```

Definition at line 139 of file Almog_Engine.h.

3.16.2.2 elements

```
Quad_mesh* Quad_mesh_array::elements
```

Definition at line 140 of file Almog_Engine.h.

Referenced by ae_scene_free().

3.16.2.3 length

```
size_t Quad_mesh_array::length
```

Definition at line 138 of file Almog_Engine.h.

Referenced by ae_scene_free().

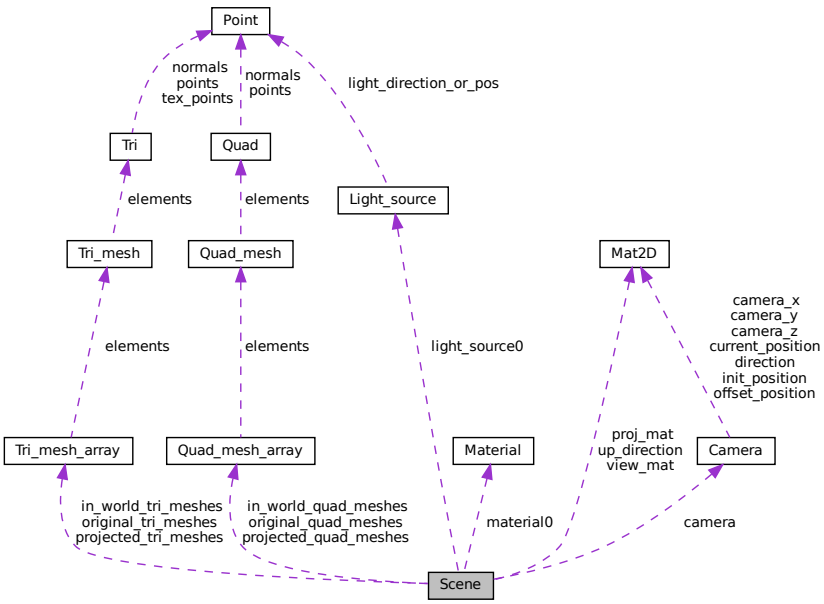
The documentation for this struct was generated from the following file:

- src/include/Almog_Engine.h

3.17 Scene Struct Reference

```
#include <Almog_Engine.h>
```

Collaboration diagram for Scene:



Public Attributes

- Tri_mesh_array in_world_tri_meshes
- Tri_mesh_array projected_tri_meshes
- Tri_mesh_array original_tri_meshes
- Quad_mesh_array in_world_quad_meshes
- Quad_mesh_array projected_quad_meshes
- Quad_mesh_array original_quad_meshes
- Camera camera
- Mat2D up_direction
- Mat2D proj_mat
- Mat2D view_mat
- Light_source light_source0
- Material material0

3.17.1 Detailed Description

Definition at line 173 of file Almog_Engine.h.

3.17.2 Member Data Documentation

3.17.2.1 camera

```
Camera Scene::camera
```

Definition at line 182 of file Almog_Engine.h.

Referenced by ae_camera_free(), ae_camera_init(), ae_camera_reset_pos(), ae_line_project_world2screen(), ae_quad_calc_light_intensity(), ae_quad_project_world2screen(), ae_scene_init(), ae_tri_calc_light_intensity(), ae_tri_project_world2screen(), check_window_mat_size(), process_input_window(), and update().

3.17.2.2 in_world_quad_meshes

```
Quad_mesh_array Scene::in_world_quad_meshes
```

Definition at line 178 of file Almog_Engine.h.

Referenced by ae_scene_free().

3.17.2.3 in_world_tri_meshes

```
Tri_mesh_array Scene::in_world_tri_meshes
```

Definition at line 174 of file Almog_Engine.h.

Referenced by ae_scene_free(), render(), setup(), and update().

3.17.2.4 light_source0

```
Light_source Scene::light_source0
```

Definition at line 187 of file Almog_Engine.h.

Referenced by ae_quad_calc_light_intensity(), ae_quad_project_world2screen(), ae_scene_init(), and ae_tri_calc_light_intensity().

3.17.2.5 material0

```
Material Scene::material0
```

Definition at line 188 of file Almog_Engine.h.

Referenced by ae_quad_calc_light_intensity(), ae_scene_init(), and ae_tri_calc_light_intensity().

3.17.2.6 original_quad_meshes

```
Quad_mesh_array Scene::original_quad_meshes
```

Definition at line 180 of file Almog_Engine.h.

Referenced by ae_scene_free().

3.17.2.7 original_tri_meshes

```
Tri_mesh_array Scene::original_tri_meshes
```

Definition at line 176 of file Almog_Engine.h.

Referenced by ae_scene_free(), and setup().

3.17.2.8 proj_mat

```
Mat2D Scene::proj_mat
```

Definition at line 184 of file Almog_Engine.h.

Referenced by ae_scene_free(), ae_scene_init(), and update().

3.17.2.9 projected_quad_meshes

```
Quad_mesh_array Scene::projected_quad_meshes
```

Definition at line 179 of file Almog_Engine.h.

Referenced by ae_scene_free().

3.17.2.10 projected_tri_meshes

```
Tri_mesh_array Scene::projected_tri_meshes
```

Definition at line 175 of file Almog_Engine.h.

Referenced by ae_scene_free(), render(), setup(), and update().

3.17.2.11 up_direction

```
Mat2D Scene::up_direction
```

Definition at line 183 of file Almog_Engine.h.

Referenced by ae_scene_free(), ae_scene_init(), and update().

3.17.2.12 view_mat

```
Mat2D Scene::view_mat
```

Definition at line 185 of file Almog_Engine.h.

Referenced by ae_scene_free(), ae_scene_init(), and update().

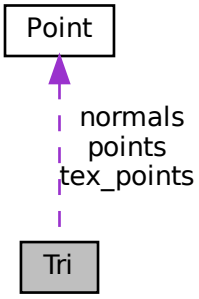
The documentation for this struct was generated from the following file:

- src/include/Almog_Engine.h

3.18 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]

3.18.1 Detailed Description

Definition at line 79 of file Almog_Draw_Library.h.

3.18.2 Member Data Documentation

3.18.2.1 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(), ae_tri_clip_with_plane(), ae_tri_mesh_flip_normals(), ae_tri_mesh_get_from_obj_file(), ae_tri_mesh_get_from_quad_mesh(), and ae_tri_mesh_get_from_stl_file().

3.18.2.2 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(), ae_tri_calc_light_intensity(), ae_tri_mesh_flip_normals(), ae_tri_mesh_get_from_obj_file(), ae_tri_mesh_get_from_quad_mesh(), ae_tri_mesh_get_from_stl_file(), and ae_tri_project_world2screen().

3.18.2.3 normals

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

Definition at line 82 of file Almog_Draw_Library.h.

Referenced by ae_tri_calc_light_intensity(), ae_tri_get_average_normal(), ae_tri_mesh_flip_normals(), ae_tri_mesh_get_from_quad_
ae_tri_mesh_get_from_stl_file(), ae_tri_project_world2screen(), and ae_tri_set_normals().

3.18.2.4 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(), ae_print_tri(), ae_tri_calc_light_intensity(), ae_tri_calc_normal(), ae_tri_clip_with_plane(), ae_tri_compare(), ae_tri_create(), ae_tri_get_average_point(), ae_tri_mesh_flip_normals(), ae_tri_mesh_get_from_obj_file(), ae_tri_mesh_get_from_quad_mesh(), ae_tri_mesh_get_from_stl_file(), ae_tri_mesh_normalize(), ae_tri_mesh_rotate_Euler_xyz(), ae_tri_mesh_set_bounding_box(), ae_tri_mesh_translate(), ae_tri_project_world2screen(), ae_tri_set_normals(), and ae_tri_transform_to_view().

3.18.2.5 tex_points

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

Definition at line 81 of file Almog_Draw_Library.h.

Referenced by ae_tri_clip_with_plane(), ae_tri_mesh_flip_normals(), and ae_tri_project_world2screen().

3.18.2.6 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(), ae_print_tri(), ae_tri_mesh_flip_normals(), ae_tri_mesh_get_from_obj_file
ae_tri_mesh_get_from_quad_mesh(), ae_tri_mesh_get_from_stl_file(), and ae_tri_project_world2screen().

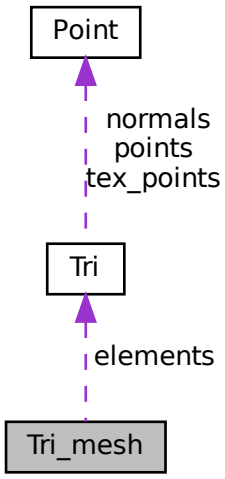
The documentation for this struct was generated from the following file:

- src/include/Almog_Draw_Library.h

3.19 Tri_mesh Struct Reference

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

Collaboration diagram for Tri_mesh:



Public Attributes

- size_t length
- size_t capacity
- Tri * elements

3.19.1 Detailed Description

Definition at line 102 of file Almog_Draw_Library.h.

3.19.2 Member Data Documentation

3.19.2.1 capacity

```
size_t Tri_mesh::capacity
```

Definition at line 104 of file Almog_Draw_Library.h.

3.19.2.2 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(), adl_tri_mesh_fill_Pinedas_rasterizer_interpolate_normal(), ae_print_tri_mesh(), ae_scene_free(), ae_tri_mesh_appand_copy(), ae_tri_mesh_flip_normals(), ae_tri_mesh_normalize(), ae_tri_mesh_project_world2screen(), ae_tri_mesh_rotate_Euler_xyz(), ae_tri_mesh_set_bounding_box(), ae_tri_mesh_set_normals(), ae_tri_mesh_translate(), and ae_tri_project_world2screen().

3.19.2.3 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(), adl_tri_mesh_fill_Pinedas_rasterizer_interpolate_normal(), ae_print_tri_mesh(), ae_tri_mesh_appand_copy(), ae_tri_mesh_create_copy(), ae_tri_mesh_flip_normals(), ae_tri_mesh_normalize(), ae_tri_mesh_project_world2screen(), ae_tri_mesh_rotate_Euler_xyz(), ae_tri_mesh_set_bounding_box(), ae_tri_mesh_set_normals(), ae_tri_mesh_translate(), ae_tri_project_world2screen(), render(), and setup().

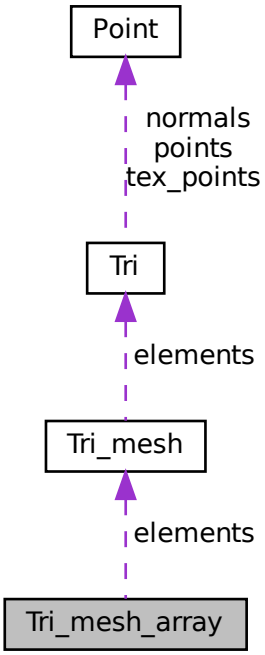
The documentation for this struct was generated from the following file:

- src/include/Almog_Draw_Library.h

3.20 Tri_mesh_array Struct Reference

`#include <Almog_Engine.h>`

Collaboration diagram for Tri_mesh_array:



Public Attributes

- size_t length
- size_t capacity
- Tri_mesh * elements

3.20.1 Detailed Description

Definition at line 128 of file Almog_Engine.h.

3.20.2 Member Data Documentation

3.20.2.1 capacity

```
size_t Tri_mesh_array::capacity
```

Definition at line 130 of file Almog_Engine.h.

3.20.2.2 elements

```
Tri_mesh* Tri_mesh_array::elements
```

Definition at line 131 of file Almog_Engine.h.

Referenced by ae_scene_free(), render(), setup(), and update().

3.20.2.3 length

```
size_t Tri_mesh_array::length
```

Definition at line 129 of file Almog_Engine.h.

Referenced by ae_scene_free(), render(), setup(), and update().

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

- src/include/Almog_Engine.h

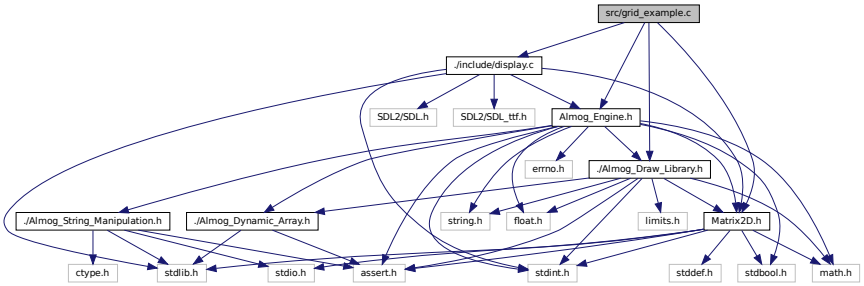
Chapter 4

File Documentation

4.1 src/grid_example.c File Reference

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

Include dependency graph for grid_example.c:



Macros

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

Functions

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

Variables

- Grid grid
- Grid grid_proj

4.1.1 Macro Definition Documentation

4.1.1.1 ALMOG_DRAW_LIBRARY_IMPLEMENTATION

```
#define ALMOG_DRAW_LIBRARY_IMPLEMENTATION
```

Definition at line 7 of file grid_example.c.

4.1.1.2 ALMOG_ENGINE_IMPLEMENTATION

```
#define ALMOG_ENGINE_IMPLEMENTATION
```

Definition at line 9 of file grid_example.c.

4.1.1.3 MATRIX2D_IMPLEMENTATION

```
#define MATRIX2D_IMPLEMENTATION
```

Definition at line 5 of file grid_example.c.

4.1.1.4 RENDER

```
#define RENDER
```

Definition at line 3 of file grid_example.c.

4.1.1.5 SETUP

```
#define SETUP
```

Definition at line 1 of file grid_example.c.

4.1.1.6 UPDATE

```
#define UPDATE
```

Definition at line 2 of file grid_example.c.

4.1.2 Function Documentation

4.1.2.1 render()

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

Definition at line 32 of file grid_example.c.

References ADL_DEFAULT_OFFSET_ZOOM, adl_grid_draw(), grid_proj, and game_state_t::window_pixels_mat.

4.1.2.2 setup()

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

Definition at line 14 of file grid_example.c.

References adl_cartesian_grid_create(), game_state_t::const_fps, grid, and grid_proj.

4.1.2.3 update()

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

Definition at line 23 of file grid_example.c.

References ae_grid_project_world2screen(), ae_projection_mat_set(), ae_view_mat_set(), Camera::aspect_ratio, Scene::camera, Camera::fov_deg, grid, grid_proj, Scene::proj_mat, game_state_t::scene, Scene::up_direction, Scene::view_mat, game_state_t::window_h, game_state_t::window_w, Camera::z_far, and Camera::z_near.

4.1.3 Variable Documentation

4.1.3.1 grid

```
Grid grid
```

Definition at line 12 of file grid_example.c.

Referenced by adl_cartesian_grid_create(), adl_grid_draw(), setup(), and update().

4.1.3.2 grid_proj

```
Grid grid_proj
```

Definition at line 13 of file grid_example.c.

Referenced by render(), setup(), and update().

4.2 grid_example.c

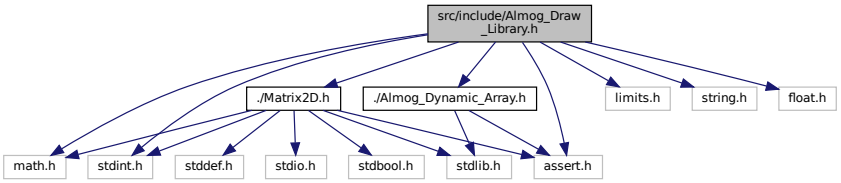
```
00001 #define SETUP
00002 #define UPDATE
00003 #define RENDER
00004 #include "./include/display.c"
00005 #define MATRIX2D_IMPLEMENTATION
00006 #include "./include/Matrix2D.h"
00007 #define ALMOG_DRAW_LIBRARY_IMPLEMENTATION
00008 #include "./include/Almog_Draw_Library.h"
00009 #define ALMOG_ENGINE_IMPLEMENTATION
00010 #include "./include/Almog_Engine.h"
00011
00012 Grid grid;
00013 Grid grid_proj;
00014 void setup(game_state_t *game_state)
00015 {
00016     // game_state->to_limit_fps = 0;
00017     game_state->const_fps = 500;
00018
00019     grid      = adl_cartesian_grid_create(-1, 1, -2, 2, 10, 20, "XZ", 1);
00020     grid_proj = adl_cartesian_grid_create(-1, 1, -2, 2, 10, 20, "XZ", 1);
00021 }
00022
00023 void update(game_state_t *game_state)
00024 {
00025     ae_projection_mat_set(game_state->scene.proj_mat, game_state->scene.camera.aspect_ratio,
      game_state->scene.camera.fov_deg, game_state->scene.camera.z_near, game_state->scene.camera.z_far);
00026     ae_view_mat_set(game_state->scene.view_mat, game_state->scene.camera,
      game_state->scene.up_direction);
00027
00028     ae_grid_project_world2screen(game_state->scene.proj_mat, game_state->scene.view_mat, grid_proj,
      grid, game_state->window_w, game_state->window_h, &(game_state->scene));
00029
00030 }
00031
00032 void render(game_state_t *game_state)
00033 {
00034     adl_grid_draw(game_state->window_pixels_mat, grid_proj, 0xffffffff, ADL_DEFAULT_OFFSET_ZOOM);
00035
00036 }
```

4.3 src/include/Almog_Draw_Library.h File Reference

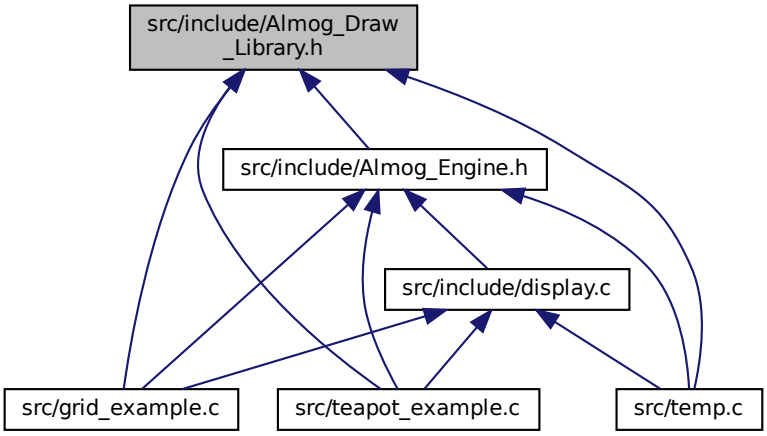
Immediate-mode 2D/3D raster helpers for drawing onto Mat2D_uint32 pixel buffers.

```
#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.

4.3.1 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.

4.3.2 Macro Definition Documentation

4.3.2.1 ADL_ASSERT

```
#define ADL_ASSERT assert
```

Definition at line 37 of file Almog_Draw_Library.h.

4.3.2.2 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.

4.3.2.3 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.

4.3.2.4 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.

4.3.2.5 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.

4.3.2.6 ADL_FIGURE_AXIS_COLOR

```
#define ADL_FIGURE_AXIS_COLOR 0xff000000
```

Definition at line 257 of file Almog_Draw_Library.h.

4.3.2.7 ADL_FIGURE_HEAD_ANGLE_DEG

```
#define ADL_FIGURE_HEAD_ANGLE_DEG 30
```

Definition at line 256 of file Almog_Draw_Library.h.

4.3.2.8 ADL_FIGURE_PADDING_PRECENTAGE

```
#define ADL_FIGURE_PADDING_PRECENTAGE 20
```

Definition at line 252 of file Almog_Draw_Library.h.

4.3.2.9 ADL_MAX_CHARACTER_OFFSET

```
#define ADL_MAX_CHARACTER_OFFSET 10
```

Definition at line 259 of file Almog_Draw_Library.h.

4.3.2.10 ADL_MAX_FIGURE_PADDING

```
#define ADL_MAX_FIGURE_PADDING 70
```

Definition at line 253 of file Almog_Draw_Library.h.

4.3.2.11 ADL_MAX_HEAD_SIZE

```
#define ADL_MAX_HEAD_SIZE 15
```

Definition at line 255 of file Almog_Draw_Library.h.

4.3.2.12 ADL_MAX_POINT_VAL

```
#define ADL_MAX_POINT_VAL 1e5
```

Definition at line 242 of file Almog_Draw_Library.h.

4.3.2.13 ADL_MAX_SENTENCE_LEN

```
#define ADL_MAX_SENTENCE_LEN 256
```

Definition at line 261 of file Almog_Draw_Library.h.

4.3.2.14 ADL_MAX_ZOOM

```
#define ADL_MAX_ZOOM 1e3
```

Definition at line 262 of file Almog_Draw_Library.h.

4.3.2.15 ADL_MIN_CHARACTER_OFFSET

```
#define ADL_MIN_CHARACTER_OFFSET 5
```

Definition at line 260 of file Almog_Draw_Library.h.

4.3.2.16 ADL_MIN_FIGURE_PADDING

```
#define ADL_MIN_FIGURE_PADDING 20
```

Definition at line 254 of file Almog_Draw_Library.h.

4.3.2.17 adl_offset2d

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

Definition at line 2227 of file Almog_Draw_Library.h.

4.3.2.18 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.

4.3.2.19 BLUE_hexARGB

```
#define BLUE_hexARGB 0xFF0000FF
```

Definition at line 232 of file Almog_Draw_Library.h.

4.3.2.20 CURVE

```
#define CURVE
```

Definition at line 59 of file Almog_Draw_Library.h.

4.3.2.21 CURVE_ADA

```
#define CURVE_ADA
```

Definition at line 69 of file Almog_Draw_Library.h.

4.3.2.22 CYAN_hexARGB

```
#define CYAN_hexARGB 0xFF00FFFF
```

Definition at line 234 of file Almog_Draw_Library.h.

4.3.2.23 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.

4.3.2.24 GREEN_hexARGB

```
#define GREEN_hexARGB 0xFF00FF00
```

Definition at line 231 of file Almog_Draw_Library.h.

4.3.2.25 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.

4.3.2.26 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.

4.3.2.27 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.

4.3.2.28 is_left_edge

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

Definition at line 239 of file Almog_Draw_Library.h.

4.3.2.29 is_top_edge

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

Definition at line 238 of file Almog_Draw_Library.h.

4.3.2.30 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.

4.3.2.31 POINT

```
#define POINT
```

Definition at line 49 of file Almog_Draw_Library.h.

4.3.2.32 PURPLE_hexARGB

```
#define PURPLE_hexARGB 0xFFFF00FF
```

Definition at line 233 of file Almog_Draw_Library.h.

4.3.2.33 QUAD

```
#define QUAD
```

Definition at line 90 of file Almog_Draw_Library.h.

4.3.2.34 QUAD_MESH

```
#define QUAD_MESH
```

Definition at line 110 of file Almog_Draw_Library.h.

4.3.2.35 RED_hexARGB

```
#define RED_hexARGB 0xFFFF0000
```

Definition at line 230 of file Almog_Draw_Library.h.

4.3.2.36 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.

4.3.2.37 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.

4.3.2.38 TRI

```
#define TRI
```

Definition at line 78 of file Almog_Draw_Library.h.

4.3.2.39 TRI_MESH

```
#define TRI_MESH
```

Definition at line 101 of file Almog_Draw_Library.h.

4.3.2.40 YELLOW_hexARGB

```
#define YELLOW_hexARGB 0xFFFFFF00
```

Definition at line 235 of file Almog_Draw_Library.h.

4.3.3 Function Documentation

4.3.3.1 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.

4.3.3.2 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().

4.3.3.3 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().

4.3.3.4 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, 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.

Referenced by setup().

4.3.3.5 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().

4.3.3.6 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().

4.3.3.7 adl_circle_fill()

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

Fill a circle.

Parameters

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

Definition at line 1382 of file Almog_Draw_Library.h.

References adl_point_draw().

4.3.3.8 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.

4.3.3.9 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.

4.3.3.10 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.

4.3.3.11 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.

4.3.3.12 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, grid, Curve::length, and Curve_ada::length.

Referenced by render().

4.3.3.13 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().

4.3.3.14 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().

4.3.3.15 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(), and adl_curves_plot_on_figure().

4.3.3.16 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().

4.3.3.17 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().

4.3.3.18 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().

Referenced by adl_grid_draw().

4.3.3.19 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().

Referenced by adl_quad_draw().

4.3.3.20 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().

4.3.3.21 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().

4.3.3.22 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().

4.3.3.23 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().

4.3.3.24 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.

4.3.3.25 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().

4.3.3.26 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().

4.3.3.27 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(), and adl_quad_mesh_fill_interpolate_color().

4.3.3.28 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().

4.3.3.29 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.

4.3.3.30 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.

4.3.3.31 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.

4.3.3.32 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.

4.3.3.33 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().

4.3.3.34 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().

4.3.3.35 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().

4.3.3.36 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().

4.3.3.37 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, Point::x, and Point::y.

Referenced by adl_tri_mesh_draw().

4.3.3.38 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, Point::w, Point::x, Point::y, and Point::z.

Referenced by adl_tri_mesh_fill_Pinedas_rasterizer().

4.3.3.39 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, Point::w, Point::x, Point::y, and Point::z.

Referenced by adl_tri_mesh_fill_Pinedas_rasterizer_interpolate_color().

4.3.3.40 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, Point::w, Point::x, Point::y, and Point::z.

Referenced by adl_tri_mesh_fill_Pinedas_rasterizer_interpolate_normal().

4.3.3.41 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, and Tri::to_draw.

4.3.3.42 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, and Tri::to_draw.

4.3.3.43 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, and Tri::to_draw.

4.3.3.44 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, and Tri::to_draw.

Referenced by render().

4.4 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)(0x01000000l*(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);
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,
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      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,
      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':
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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':
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);
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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);
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);
```

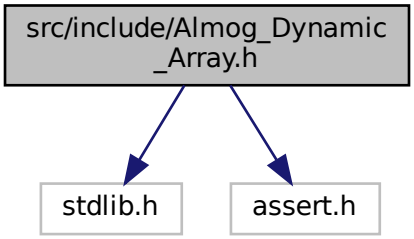
```
02584             ada_append(Point, curve, point_max);
02585
02586             ada_append(Curve, grid.curves, curve);
02587         }
02588     } else if (!strncmp(plane, "YZ", 3) || !strncmp(plane, "yz", 3)) {
02589         for (int e1_index = 0; e1_index <= num_samples_e1; e1_index++) {
02590             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*/
```

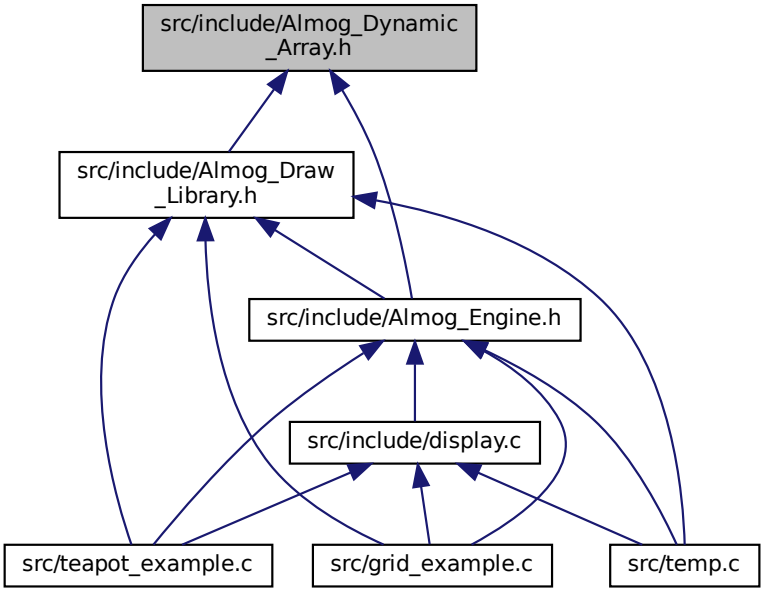
4.5 src/include/Almog_Dynamic_Array.h File Reference

```
#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 INIT_CAPACITY 10
- #define ADA_MALLOC malloc
- #define ADA_REALLOC realloc
- #define ADA_ASSERT assert
- #define ada_init_array(type, header)
- #define ada_resize(type, header, new_capacity)
- #define ada_append(type, header, value)
- #define ada_insert(type, header, value, index)

- #define ada_insert_unordered(type, header, value, index)
- #define ada_remove(type, header, index)
- #define ada_remove_unordered(type, header, index)

4.5.1 Macro Definition Documentation

4.5.1.1 ada_append

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

Value:

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

Definition at line 44 of file Almog_Dynamic_Array.h.

4.5.1.2 ADA_ASSERT

```
#define ADA_ASSERT assert
```

Definition at line 18 of file Almog_Dynamic_Array.h.

4.5.1.3 ada_init_array

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

Value:

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

Definition at line 27 of file Almog_Dynamic_Array.h.

4.5.1.4 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)
       \
```

Definition at line 52 of file Almog_Dynamic_Array.h.

4.5.1.5 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)
```

Definition at line 62 of file Almog_Dynamic_Array.h.

4.5.1.6 ADA_MALLOC

```
#define ADA_MALLOC malloc
```

Definition at line 10 of file Almog_Dynamic_Array.h.

4.5.1.7 ADA_REALLOC

```
#define ADA_REALLOC realloc
```

Definition at line 14 of file Almog_Dynamic_Array.h.

4.5.1.8 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)
```

Definition at line 73 of file Almog_Dynamic_Array.h.

4.5.1.9 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)
```

Definition at line 82 of file Almog_Dynamic_Array.h.

4.5.1.10 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)
       \
```

Definition at line 34 of file Almog_Dynamic_Array.h.

4.5.1.11 INIT_CAPACITY

```
#define INIT_CAPACITY 10
```

Definition at line 7 of file Almog_Dynamic_Array.h.

4.6 Almog_Dynamic_Array.h

```
00001 #ifndef ALMOG_DYNAMIC_ARRAY_H_
00002 #define ALMOG_DYNAMIC_ARRAY_H_
00003
00004 #include <stdlib.h>
00005 #include <assert.h>
00006
00007 #define INIT_CAPACITY 10
00008
00009 #ifndef ADA_MALLOC
00010 #define ADA_MALLOC malloc
00011 #endif /*ADA_MALLOC*/
00012
00013 #ifndef ADA_REALLOC
00014 #define ADA_REALLOC realloc
00015 #endif /*ADA_REALLOC*/
00016
00017 #ifndef ADA_ASSERT
00018 #define ADA_ASSERT assert
00019 #endif /*ADA_ASSERT*/
00020
00021 /* typedef struct {
00022     size_t length;
00023     size_t capacity;
00024     int* elements;
00025 } ada_int_array; */
00026
00027 #define ada_init_array(type, header) do {                                   \
00028         header.capacity = INIT_CAPACITY;                                    \
00029         header.length = 0;                                                  \
00030         header.elements = (type *)ADA_MALLOC(sizeof(type) * header.capacity);   \
00031         ADA_ASSERT(header.elements != NULL);                                \
00032     } while (0)                                                             \
00033
```

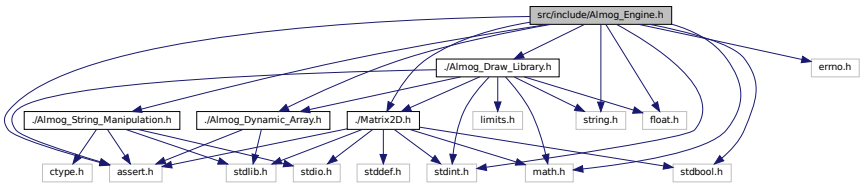
```
00034 #define ada_resize(type, header, new_capacity) do {
        \
00035         type *ada_temp_pointer = (type *)ADA_REALLOC((void *)(header.elements),
       new_capacity*sizeof(type)); \
00036         if (ada_temp_pointer == NULL) {
        \
00037             exit(1);
        \
00038         }
        \
00039         header.elements = ada_temp_pointer;
        \
00040         ADA_ASSERT(header.elements != NULL);
        \
00041         header.capacity = new_capacity;
        \
00042     } while (0)
        \
00043
00044 #define ada_append(type, header, value) do {                          \
00045         if (header.length >= header.capacity) {                       \
00046             ada_resize(type, header, (int)(header.capacity*1.5));     \
00047         }                                                             \
00048         header.elements[header.length] = value;                       \
00049         header.length++;                                              \
00050     } while (0)                                                       \
00051
00052 #define ada_insert(type, header, value, index) do {
        \
00053     ADA_ASSERT((int)(index) >= 0);
        \
00054     ADA_ASSERT((float)(index) - (int)(index) == 0);
        \
00055     ada_append(type, header, header.elements[header.length-1]);
        \
00056     for (size_t ada_for_loop_index = header.length-2; ada_for_loop_index > (index);
       ada_for_loop_index--) { \
00057         header.elements[ada_for_loop_index] = header.elements [ada_for_loop_index-1];
        \
00058     }
        \
00059     header.elements[(index)] = value;
        \
00060 } while (0)
        \
00061
00062 #define ada_insert_unordered(type, header, value, index) do {    \
00063     ADA_ASSERT((int)(index) >= 0);                               \
00064     ADA_ASSERT((float)(index) - (int)(index) == 0);              \
00065     if ((size_t)(index) == header.length) {                      \
00066         ada_append(type, header, value);                         \
00067     } else {                                                     \
00068         ada_append(type, header, header.elements[(index)]);      \
00069         header.elements[(index)] = value;                        \
00070     }                                                            \
00071 } while (0)
00072
00073 #define ada_remove(type, header, index) do {
        \
00074     ADA_ASSERT((int)(index) >= 0);
        \
00075     ADA_ASSERT((float)(index) - (int)(index) == 0);
        \
00076     for (size_t ada_for_loop_index = (index); ada_for_loop_index < header.length-1;
       ada_for_loop_index++) { \
00077         header.elements[ada_for_loop_index] = header.elements[ada_for_loop_index+1];
        \
00078     }
        \
00079     header.length--;
        \
00080 } while (0)
00081
00082 #define ada_remove_unordered(type, header, index) do {           \
00083     ADA_ASSERT((int)(index) >= 0);                               \
00084     ADA_ASSERT((float)(index) - (int)(index) == 0);              \
00085     header.elements[index] = header.elements[header.length-1];   \
00086     header.length--;                                             \
00087 } while (0)
00088
00089 #endif /*ALMOG_DYNAMIC_ARRAY_H_*/
```

4.7 src/include/Almog_Engine.h File Reference

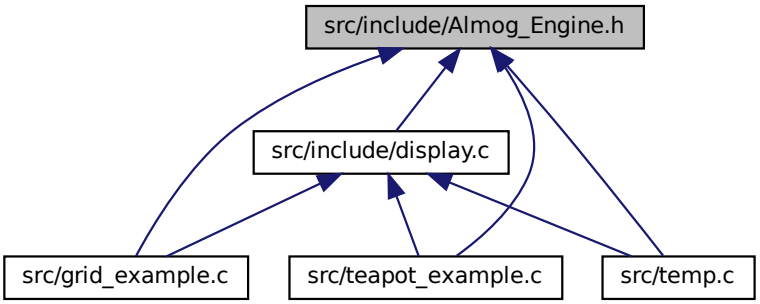
Software 3D rendering and scene utilities for meshes, camera, and projection.

```
#include "./Almog_Dynamic_Array.h"
#include "./Matrix2D.h"
#include "./Almog_Draw_Library.h"
#include "./Almog_String_Manipulation.h"
#include <assert.h>
#include <math.h>
#include <stdbool.h>
#include <float.h>
#include <stdint.h>
#include <errno.h>
#include <string.h>
```

Include dependency graph for Almog_Engine.h:



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



Classes

- struct Tri_mesh_array
- struct Quad_mesh_array
- struct Camera
- struct Light_source
- struct Material
- struct Scene

Macros

- #define ALMOG_STRING_MANIPULATION_IMPLEMENTATION
- #define AE_ASSERT assert
- #define STL_HEADER_SIZE 80
- #define STL_NUM_SIZE 4
- #define STL_SIZE_FOREACH_TRI 50
- #define STL_ATTRIBUTE_BITS_SIZE 2
- #define ARGB_hexARGB(a, r, g, b) 0x01000000l∗(uint8_t)(a) + 0x00010000∗(uint8_t)(r) + 0x00000100∗(uint8↩ _t)(g) + 0x00000001∗(uint8_t)(b)
- #define AE_MAX_POINT_VAL 1e5
- #define ae_assert_point_is_valid(p)
- #define ae_assert_tri_is_valid(tri)
- #define ae_assert_quad_is_valid(quad)
- #define ae_point_normalize_xyz_norma(p, norma)
- #define ae_point_calc_norma(p) sqrt(((p).x ∗ (p).x) + ((p).y ∗ (p).y) + ((p).z ∗ (p).z))
- #define ae_point_add_point(p, p1, p2)
- #define ae_point_sub_point(p, p1, p2)
- #define ae_point_dot_point(p1, p2) (((p1).x ∗ (p2).x) + ((p1).y ∗ (p2).y) + ((p1).z ∗ (p2).z))
- #define ae_point_mult(p, const)
- #define ae_points_equal(p1, p2) (p1).x == (p2).x && (p1).y == (p2).y && (p1).z == (p2).z
- #define TRI_MESH_ARRAY
- #define QUAD_MESH_ARRAY
- #define AE_PRINT_TRI(tri) ae_print_tri(tri, #tri, 0)
- #define AE_PRINT_MESH(mesh) ae_print_tri_mesh(mesh, #mesh, 0)

Enumerations

- enum Lighting_mode { AE_LIGHTING_FLAT , AE_LIGHTING_SMOOTH , AE_LIGHTING_MODE_LENGTH }

Functions

- Tri ae_tri_create (Point p1, Point p2, Point p3)

  Create a triangle from three points.
- void ae_tri_mesh_create_copy (Tri_mesh ∗des, Tri ∗src_elements, size_t len)

  Append copies of triangles to a destination Tri_mesh (resets destination length first).
- void ae_camera_init (Scene ∗scene, int window_h, int window_w)

  Initialize the camera part of a Scene.
- void ae_camera_free (Scene ∗scene)

  Free camera-related allocations in a Scene.
- Scene ae_scene_init (int window_h, int window_w)

  Create and initialize a Scene.
- void ae_scene_free (Scene ∗scene)

  Free all resources owned by a Scene.
- void ae_camera_reset_pos (Scene ∗scene)

  Reset camera orientation and position to initial state.
- void ae_point_to_mat2D (Point p, Mat2D m)

  Write a Point into a Mat2D vector.
- Point ae_mat2D_to_point (Mat2D m)

  Read a 3x1 Mat2D vector into a Point.

- Tri_mesh ae_tri_mesh_get_from_obj_file (char *file_path)

  Load a triangle mesh from a Wavefront OBJ file.
- Tri_mesh ae_tri_mesh_get_from_stl_file (char *file_path)

  Load a triangle mesh from a binary STL file.
- Tri_mesh ae_tri_mesh_get_from_file (char *file_path)

  Load a triangle mesh from a file (OBJ or STL).
- void ae_tri_mesh_append_copy (Tri_mesh_array *mesh_array, Tri_mesh mesh)

  Append a copy of a Tri_mesh into a Tri_mesh_array.
- Tri_mesh ae_tri_mesh_get_from_quad_mesh (Quad_mesh q_mesh)

  Convert a Quad_mesh into a Tri_mesh.
- void ae_print_points (Curve p)

  Print a list of points to stdout.
- void ae_print_tri (Tri tri, char *name, size_t padding)

  Print a triangle to stdout.
- void ae_print_tri_mesh (Tri_mesh mesh, char *name, size_t padding)

  Print all triangles in a mesh to stdout.
- Point ae_point_normalize_xyz (Point p)

  Normalize a point's xyz to unit length.
- void ae_tri_set_normals (Tri *tri)

  Compute and set per-vertex normals for a triangle.
- Point ae_tri_get_average_normal (Tri tri)

  Compute the average of the three vertex normals of a triangle.
- Point ae_tri_get_average_point (Tri tri)

  Compute the average of the three vertices of a triangle.
- void ae_tri_calc_normal (Mat2D normal, Tri tri)

  Compute the face normal of a triangle.
- void ae_tri_mesh_translate (Tri_mesh mesh, float x, float y, float z)

  Translate a triangle mesh by (x, y, z).
- void ae_tri_mesh_rotate_Euler_xyz (Tri_mesh mesh, float phi_deg, float theta_deg, float psi_deg)

  Rotate a triangle mesh using XYZ Euler angles (degrees).
- void ae_tri_mesh_set_bounding_box (Tri_mesh mesh, float *x_min, float *x_max, float *y_min, float *y_max, float *z_min, float *z_max)

  Compute the axis-aligned bounding box of a triangle mesh.
- void ae_tri_mesh_normalize (Tri_mesh mesh)

  Normalize mesh coordinates to [-1, 1], centered at origin.
- void ae_tri_mesh_flip_normals (Tri_mesh mesh)

  Flip triangle winding and recompute per-vertex normals.
- void ae_tri_mesh_set_normals (Tri_mesh mesh)

  Recompute per-vertex normals for all triangles in a mesh.
- void ae_quad_set_normals (Quad *quad)

  Compute and set per-vertex normals for a quad.
- Point ae_quad_get_average_normal (Quad quad)

  Compute the average of the four vertex normals of a quad.
- Point ae_quad_get_average_point (Quad quad)

  Compute the average of the four vertices of a quad.
- void ae_quad_calc_normal (Mat2D normal, Quad quad)

  Compute the face normal of a quad using the first three vertices.
- void ae_curve_copy (Curve *des, Curve src)

  Copy a Curve (ADA array of points).
- void ae_tri_calc_light_intensity (Tri *tri, Scene *scene, Lighting_mode lighting_mode)

  Compute per-vertex lighting intensity for a triangle.

- void ae_quad_calc_light_intensity (Quad *quad, Scene *scene, Lighting_mode lighting_mode)

  Compute per-vertex lighting intensity for a quad.
- Point ae_line_itersect_plane (Mat2D plane_p, Mat2D plane_n, Mat2D line_start, Mat2D line_end, float *t)

  Intersect a line segment with a plane.
- int ae_line_clip_with_plane (Point start_in, Point end_in, Mat2D plane_p, Mat2D plane_n, Point *start_out, Point *end_out)

  Clip a line segment against a plane.
- float ae_signed_dist_point_and_plane (Point p, Mat2D plane_p, Mat2D plane_n)

  Signed distance from a point to a plane.
- int ae_tri_clip_with_plane (Tri tri_in, Mat2D plane_p, Mat2D plane_n, Tri *tri_out1, Tri *tri_out2)

  Clip a triangle against a plane.
- int ae_quad_clip_with_plane (Quad quad_in, Mat2D plane_p, Mat2D plane_n, Quad *quad_out1, Quad *quad_out2)

  Clip a quad against a plane.
- void ae_projection_mat_set (Mat2D proj_mat, float aspect_ratio, float FOV_deg, float z_near, float z_far)

  Build a perspective projection matrix.
- void ae_view_mat_set (Mat2D view_mat, Camera camera, Mat2D up)

  Build a right-handed view matrix from a Camera and up vector.
- Point ae_point_project_world2screen (Mat2D view_mat, Mat2D proj_mat, Point src, int window_w, int window_h)

  Project a point from world space directly to screen space.
- Point ae_point_project_world2view (Mat2D view_mat, Point src)

  Transform a point from world space to view space.
- Point ae_point_project_view2screen (Mat2D proj_mat, Point src, int window_w, int window_h)

  Project a view-space point to screen space.
- void ae_line_project_world2screen (Mat2D view_mat, Mat2D proj_mat, Point start_src, Point end_src, int window_w, int window_h, Point *start_des, Point *end_des, Scene *scene)

  Project and near-clip a world-space line segment to screen space.
- Tri ae_tri_transform_to_view (Mat2D view_mat, Tri tri)

  Transform a triangle from world space to view space.
- Tri_mesh ae_tri_project_world2screen (Mat2D proj_mat, Mat2D view_mat, Tri tri, int window_w, int window_h, Scene *scene, Lighting_mode lighting_mode)

  Project a single world-space triangle to screen space with clipping.
- void ae_tri_mesh_project_world2screen (Mat2D proj_mat, Mat2D view_mat, Tri_mesh *des, Tri_mesh src, int window_w, int window_h, Scene *scene, Lighting_mode lighting_mode)

  Project a triangle mesh from world to screen space with clipping.
- Quad ae_quad_transform_to_view (Mat2D view_mat, Quad quad)

  Transform a quad from world space to view space.
- Quad_mesh ae_quad_project_world2screen (Mat2D proj_mat, Mat2D view_mat, Quad quad, int window_w, int window_h, Scene *scene, Lighting_mode lighting_mode)

  Project a single world-space quad to screen space with clipping.
- void ae_quad_mesh_project_world2screen (Mat2D proj_mat, Mat2D view_mat, Quad_mesh *des, Quad_mesh src, int window_w, int window_h, Scene *scene, Lighting_mode lighting_mode)

  Project a quad mesh from world to screen space with clipping.
- void ae_curve_project_world2screen (Mat2D proj_mat, Mat2D view_mat, Curve *des, Curve src, int window_w, int window_h, Scene *scene)

  Project and clip a polyline (Curve) from world to screen space.
- void ae_curve_ada_project_world2screen (Mat2D proj_mat, Mat2D view_mat, Curve_ada *des, Curve_ada src, int window_w, int window_h, Scene *scene)

  Project and clip an array of polylines from world to screen space.
- void ae_grid_project_world2screen (Mat2D proj_mat, Mat2D view_mat, Grid des, Grid src, int window_w, int window_h, Scene *scene)

Project and clip all polylines in a Grid from world to screen.

- void ae_tri_swap (Tri *v, int i, int j)

  Swap two triangles in an array.

- bool ae_tri_compare (Tri t1, Tri t2)

  Compare two triangles for sorting by depth.

- void ae_tri_qsort (Tri *v, int left, int right)

  Quicksort an array of triangles by depth.

- double ae_linear_map (double s, double min_in, double max_in, double min_out, double max_out)

  Linearly map a scalar from one range to another.

- void ae_z_buffer_copy_to_screen (Mat2D_uint32 screen_mat, Mat2D inv_z_buffer)

  Visualize an inverse-z buffer by writing a grayscale image.

4.7.1 Detailed Description

Software 3D rendering and scene utilities for meshes, camera, and projection.

A small, header-driven 3D engine providing:

- Scene and camera setup (projection/view matrices, Euler navigation).
- Triangle and quad mesh loading (OBJ/ASCII+binary STL), normalization, transforms, and per-vertex/face normals.
- Back-face culling, near-plane and screen-space polygon clipping.
- Perspective projection (world->view->screen) and line/grid helpers.
- Basic Phong-like lighting (ambient, diffuse, specular) with flat/smooth modes.
- Simple z-buffer visualization utility.

Inspiration This code is heavily inspired by the 3D engine of 'OneLoneCoder' in C++. You can find the source code in: https://github.com/OneLoneCoder/Javidx9/tree/master/ConsoleGameEngine/↩BiggerProjects/Engine3D . featured in this video of his: https://youtu.be/ih20l3pJoe↩U?si=CzQ8rjk5ZEOlqEHN.

Note

- Depends on Almog_Dynamic_Array.h, Matrix2D.h, Almog_Draw_Library.h, and Almog_String_Manipulation.h for math, containers, and I/O utilities.

- All public functions are prefixed with 'ae_'.

- Define ALMOG_ENGINE_IMPLEMENTATION in exactly one translation unit to compile the function bodies.

Definition in file Almog_Engine.h.

4.7.2 Macro Definition Documentation

4.7.2.1 AE_ASSERT

```
#define AE_ASSERT assert
```

Definition at line 44 of file Almog_Engine.h.

4.7.2.2 ae_assert_point_is_valid

```
#define ae_assert_point_is_valid(
              p )
```

Value:

```
AE_ASSERT(isfinite((p).x) && isfinite((p).y) && isfinite((p).z) && isfinite((p).w));    \
AE_ASSERT((p).x > -AE_MAX_POINT_VAL && (p).x < AE_MAX_POINT_VAL);
                                    \
AE_ASSERT((p).y > -AE_MAX_POINT_VAL && (p).y < AE_MAX_POINT_VAL);
                                    \
AE_ASSERT((p).z > -AE_MAX_POINT_VAL && (p).z < AE_MAX_POINT_VAL);
                                    \
AE_ASSERT((p).w > -AE_MAX_POINT_VAL && (p).w < AE_MAX_POINT_VAL);
```

Definition at line 89 of file Almog_Engine.h.

4.7.2.3 ae_assert_quad_is_valid

```
#define ae_assert_quad_is_valid(
              quad )
```

Value:

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

Definition at line 97 of file Almog_Engine.h.

4.7.2.4 ae_assert_tri_is_valid

```
#define ae_assert_tri_is_valid(
              tri )
```

Value:

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

Definition at line 94 of file Almog_Engine.h.

4.7.2.5 AE_MAX_POINT_VAL

```
#define AE_MAX_POINT_VAL 1e5
```

Definition at line 88 of file Almog_Engine.h.

4.7.2.6 ae_point_add_point

```
#define ae_point_add_point(
              p,
              p1,
              p2 )
```

Value:

```
(p).x = (p1).x + (p2).x;  \
(p).y = (p1).y + (p2).y;                                \
(p).z = (p1).z + (p2).z;                                \
(p).w = (p1).w + (p2).w
```

Definition at line 105 of file Almog_Engine.h.

4.7.2.7 ae_point_calc_norma

```
#define ae_point_calc_norma(
              p ) sqrt(((p).x * (p).x) + ((p).y * (p).y) + ((p).z * (p).z))
```

Definition at line 104 of file Almog_Engine.h.

4.7.2.8 ae_point_dot_point

```
#define ae_point_dot_point(
              p1,
              p2 ) (((p1).x * (p2).x) + ((p1).y * (p2).y) + ((p1).z * (p2).z))
```

Definition at line 113 of file Almog_Engine.h.

4.7.2.9 ae_point_mult

```
#define ae_point_mult(
              p,
              const )
```

Value:

```
(p).x *= const; \
(p).y *= const;                         \
(p).z *= const
```

Definition at line 114 of file Almog_Engine.h.

4.7.2.10 ae_point_normalize_xyz_norma

```
#define ae_point_normalize_xyz_norma(
              p,
              norma )
```

Value:

```
(p).x = (p).x / norma;  \
(p).y = (p).y / norma;                    \
(p).z = (p).z / norma
```

Definition at line 101 of file Almog_Engine.h.

4.7.2.11 ae_point_sub_point

```
#define ae_point_sub_point(
              p,
              p1,
              p2 )
```

Value:

```
(p).x = (p1).x - (p2).x;  \
(p).y = (p1).y - (p2).y;                                \
(p).z = (p1).z - (p2).z;                                \
(p).w = (p1).w - (p2).w
```

Definition at line 109 of file Almog_Engine.h.

4.7.2.12 ae_points_equal

```
#define ae_points_equal(
              p1,
              p2 ) (p1).x == (p2).x && (p1).y == (p2).y && (p1).z == (p2).z
```

Definition at line 117 of file Almog_Engine.h.

4.7.2.13 AE_PRINT_MESH

```
#define AE_PRINT_MESH(
              mesh ) ae_print_tri_mesh(mesh, #mesh, 0)
```

Definition at line 267 of file Almog_Engine.h.

4.7.2.14 AE_PRINT_TRI

```
#define AE_PRINT_TRI(
              tri ) ae_print_tri(tri, #tri, 0)
```

Definition at line 266 of file Almog_Engine.h.

4.7.2.15 ALMOG_STRING_MANIPULATION_IMPLEMENTATION

```
#define ALMOG_STRING_MANIPULATION_IMPLEMENTATION
```

Definition at line 38 of file Almog_Engine.h.

4.7.2.16 ARGB_hexARGB

```
#define ARGB_hexARGB(
              a,
              r,
              g,
              b ) 0x01000000l*(uint8_t)(a) + 0x00010000*(uint8_t)(r) + 0x00000100*(uint8_t)(g)
+ 0x00000001*(uint8_t)(b)
```

Definition at line 83 of file Almog_Engine.h.

4.7.2.17 QUAD_MESH_ARRAY

```
#define QUAD_MESH_ARRAY
```

Definition at line 136 of file Almog_Engine.h.

4.7.2.18 STL_ATTRIBUTE_BITS_SIZE

```
#define STL_ATTRIBUTE_BITS_SIZE 2
```

Definition at line 71 of file Almog_Engine.h.

4.7.2.19 STL_HEADER_SIZE

```
#define STL_HEADER_SIZE 80
```

Definition at line 59 of file Almog_Engine.h.

4.7.2.20 STL_NUM_SIZE

```
#define STL_NUM_SIZE 4
```

Definition at line 63 of file Almog_Engine.h.

4.7.2.21 STL_SIZE_FOREACH_TRI

```
#define STL_SIZE_FOREACH_TRI 50
```

Definition at line 67 of file Almog_Engine.h.

4.7.2.22 TRI_MESH_ARRAY

```
#define TRI_MESH_ARRAY
```

Definition at line 127 of file Almog_Engine.h.

4.7.3 Enumeration Type Documentation

4.7.3.1 Lighting_mode

```
enum Lighting_mode
```

Enumerator

AE_LIGHTING_FLAT	
AE_LIGHTING_SMOOTH	
AE_LIGHTING_MODE_LENGTH	

Definition at line 120 of file Almog_Engine.h.

4.7.4 Function Documentation

4.7.4.1 ae_camera_free()

```
void ae_camera_free (
            Scene * scene )
```

Free camera-related allocations in a Scene.

Frees all Mat2D objects owned by scene->camera (init_position, current_position, offset_position, direction, camera_x/y/z).

Parameters

scene	Scene whose camera resources will be freed.

Definition at line 366 of file Almog_Engine.h.

References Scene::camera, Camera::camera_x, Camera::camera_y, Camera::camera_z, Camera::current_position, Camera::direction, Camera::init_position, mat2D_free(), and Camera::offset_position.

Referenced by ae_scene_free().

4.7.4.2 ae_camera_init()

```
void ae_camera_init (
            Scene * scene,
            int window_h,
            int window_w )
```

Initialize the camera part of a Scene.

Sets perspective parameters (z_near, z_far, fov, aspect_ratio), allocates camera matrices/vectors, and sets initial position and orientation. The aspect ratio is computed as window_h / window_w.

Parameters

scene	Scene whose camera will be initialized.
window_h	Window height in pixels.
window_w	Window width in pixels.

Definition at line 320 of file Almog_Engine.h.

References Camera::aspect_ratio, Scene::camera, Camera::camera_x, Camera::camera_y, Camera::camera_z, Camera::current_position, Camera::direction, Camera::fov_deg, Camera::init_position, mat2D_alloc(), MAT2D_AT,

mat2D_copy(), mat2D_fill(), Camera::offset_position, Camera::pitch_offset_deg, Camera::roll_offset_deg, Camera::yaw_offset_deg, Camera::z_far, and Camera::z_near.

Referenced by ae_scene_init().

4.7.4.3 ae_camera_reset_pos()

```
void ae_camera_reset_pos (
            Scene * scene )
```

Reset camera orientation and position to initial state.

Resets roll/pitch/yaw to zero, clears offset_position, restores camera basis vectors to identity, and copies current↩ _position from init_position.

Parameters

scene	Scene containing the camera to reset.

Definition at line 472 of file Almog_Engine.h.

References Scene::camera, Camera::camera_x, Camera::camera_y, Camera::camera_z, Camera::current_position, Camera::init_position, MAT2D_AT, mat2D_copy(), mat2D_fill(), Camera::offset_position, Camera::pitch_offset_deg, Camera::roll_offset_deg, and Camera::yaw_offset_deg.

Referenced by process_input_window().

4.7.4.4 ae_curve_ada_project_world2screen()

```
void ae_curve_ada_project_world2screen (
            Mat2D proj_mat,
            Mat2D view_mat,
            Curve_ada * des,
            Curve_ada src,
            int window_w,
            int window_h,
            Scene * scene )
```

Project and clip an array of polylines from world to screen space.

Applies ae_curve_project_world2screen to each element in src and writes into the corresponding element in des. Arrays must be the same length.

Parameters

proj_mat	Projection matrix (4x4).
view_mat	View matrix (4x4).
des	Output array of curves (each overwritten).
src	Input array of world-space curves.
window↩ _w	Screen width in pixels.
window↩ _h	Screen height in pixels.
scene	Scene (camera for near plane).

Definition at line 3670 of file Almog_Engine.h.

References ae_curve_project_world2screen(), Curve_ada::elements, and Curve_ada::length.

4.7.4.5 ae_curve_copy()

```
void ae_curve_copy (
            Curve * des,
            Curve src )
```

Copy a Curve (ADA array of points).

Clears destination length and appends all points from src.

Parameters

des	Destination curve (modified/grown as needed).
src	Source curve.

Definition at line 1461 of file Almog_Engine.h.

References ada_append, Curve::elements, and Curve::length.

Referenced by ae_curve_project_world2screen().

4.7.4.6 ae_curve_project_world2screen()

```
void ae_curve_project_world2screen (
            Mat2D proj_mat,
            Mat2D view_mat,
            Curve * des,
            Curve src,
            int window_w,
            int window_h,
            Scene * scene )
```

Project and clip a polyline (Curve) from world to screen space.

Projects each segment with near-plane clipping and screen-edge clipping. Segments fully outside are removed. The destination curve is overwritten.

Note

This solution is not prefect. It sometimes delete one more edge then necessary, but I think that it won't brake.

Parameters

proj_mat	Projection matrix (4x4).

Parameters

view_mat	View matrix (4x4).
des	Output curve (overwritten; ADA array grown as needed).
src	Input world-space curve.
window_w	Screen width in pixels.
window_h	Screen height in pixels.
scene	Scene (camera for near plane).

Definition at line 3558 of file Almog_Engine.h.

References ada_remove, ae_curve_copy(), ae_line_clip_with_plane(), ae_line_project_world2screen(), ae_points_equal, Curve::elements, Curve::length, mat2D_alloc(), MAT2D_AT, mat2D_fill(), and mat2D_free().

Referenced by ae_curve_ada_project_world2screen(), and ae_grid_project_world2screen().

4.7.4.7 ae_grid_project_world2screen()

```
void ae_grid_project_world2screen (
            Mat2D proj_mat,
            Mat2D view_mat,
            Grid des,
            Grid src,
            int window_w,
            int window_h,
            Scene * scene )
```

Project and clip all polylines in a Grid from world to screen.

Applies ae_curve_project_world2screen to each curve in the grid.

Parameters

proj_mat	Projection matrix (4x4).
view_mat	View matrix (4x4).
des	Output grid (curves overwritten).
src	Input world-space grid.
window_w	Screen width in pixels.
window_h	Screen height in pixels.
scene	Scene (camera for near plane).

Definition at line 3691 of file Almog_Engine.h.

References ae_curve_project_world2screen(), Grid::curves, Curve_ada::elements, and Curve_ada::length.

Referenced by update().

4.7.4.8 ae_line_clip_with_plane()

```
int ae_line_clip_with_plane (
            Point start_in,
            Point end_in,
            Mat2D plane_p,
            Mat2D plane_n,
            Point * start_out,
            Point * end_out )
```

Clip a line segment against a plane.

Returns the portion of the line segment [start_in, end_in] that lies on or inside the plane (signed distance >= 0). plane_n is normalized inside the function.

Parameters

start_in	Input start point (world or view space).
end_in	Input end point.
plane_p	Plane reference point (3x1).
plane_n	Plane normal (3x1).
start_out	Output clipped start point (if visible).
end_out	Output clipped end point (if visible).

Returns

int 0 if fully outside, 1 if fully or partially inside (outputs are valid), -1 on error.

Definition at line 1720 of file Almog_Engine.h.

References ae_assert_point_is_valid, ae_line_itersect_plane(), ae_point_to_mat2D(), ae_signed_dist_point_and_plane(), mat2D_alloc(), mat2D_free(), and mat2D_normalize.

Referenced by ae_curve_project_world2screen(), and ae_line_project_world2screen().

4.7.4.9 ae_line_itersect_plane()

```
Point ae_line_itersect_plane (
            Mat2D plane_p,
            Mat2D plane_n,
            Mat2D line_start,
            Mat2D line_end,
            float * t )
```

Intersect a line segment with a plane.

Computes intersection of segment [line_start, line_end] with the plane defined by point plane_p and normal plane_n. plane_n is normalized inside the function. The parameter t in [0, 1] is returned via out-parameter.

Note

The Mat2D objects line_start and line_end are temporarily modified internally; pass copies if you must preserve their values.

Parameters

plane_p	Plane reference point (3x1).
plane_n	Plane normal (3x1).
line_start	Segment start point (3x1).
line_end	Segment end point (3x1).
t	Output parametric distance along the segment (0=start, 1=end).

Returns

Point Intersection point in 3D.

Definition at line 1680 of file Almog_Engine.h.

References ae_mat2D_to_point(), mat2D_add(), mat2D_alloc(), mat2D_dot_product(), mat2D_fill(), mat2D_free(), mat2D_mult(), mat2D_normalize, and mat2D_sub().

Referenced by ae_line_clip_with_plane(), ae_quad_clip_with_plane(), and ae_tri_clip_with_plane().

4.7.4.10 ae_line_project_world2screen()

```
void ae_line_project_world2screen (
            Mat2D view_mat,
            Mat2D proj_mat,
            Point start_src,
            Point end_src,
            int window_w,
            int window_h,
            Point * start_des,
            Point * end_des,
            Scene * scene )
```

Project and near-clip a world-space line segment to screen space.

Transforms the segment to view space, clips it against the near plane at z = z_near + 0.01, then projects to screen space. If fully clipped, both outputs are set to the sentinel (-1, -1, 1, 1).

Parameters

view_mat	View matrix (4x4).
proj_mat	Projection matrix (4x4).
start_src	World-space start point.
end_src	World-space end point.
window_w	Screen width in pixels.
window_h	Screen height in pixels.
start_des	Output screen-space start point (or sentinel).
end_des	Output screen-space end point (or sentinel).
scene	Scene (used for near plane distance).

Definition at line 2933 of file Almog_Engine.h.

References ae_line_clip_with_plane(), ae_point_project_view2screen(), ae_point_project_world2view(), Scene::camera, mat2D_alloc(), MAT2D_AT, mat2D_fill(), mat2D_free(), and Camera::z_near.

Referenced by ae_curve_project_world2screen().

4.7.4.11 ae_linear_map()

```
double ae_linear_map (
            double s,
            double min_in,
            double max_in,
            double min_out,
            double max_out )
```

Linearly map a scalar from one range to another.

Computes min_out + (s - min_in) * (max_out - min_out) / (max_in - min_in).

Parameters

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

Returns

double Mapped scalar.

Definition at line 3770 of file Almog_Engine.h.

Referenced by ae_z_buffer_copy_to_screen().

4.7.4.12 ae_mat2D_to_point()

```
Point ae_mat2D_to_point (
            Mat2D m )
```

Read a 3x1 Mat2D vector into a Point.

Reads x, y, z from m(0..2,0) and returns a Point with w=1.

Parameters

m	Source matrix (3x1).

Returns

Point The corresponding point with w=1.

Definition at line 522 of file Almog_Engine.h.

References MAT2D_AT, and Point::x.

Referenced by ae_line_itersect_plane(), ae_quad_calc_light_intensity(), ae_quad_set_normals(), ae_tri_calc_light_intensity(), and ae_tri_set_normals().

4.7.4.13 ae_point_normalize_xyz()

```
Point ae_point_normalize_xyz (
            Point p )
```

Normalize a point's xyz to unit length.

Divides x, y, z by their Euclidean norm. w is preserved unchanged.

Parameters

p	Input point.

Returns

Point Unit-length point (xyz), with original w.

Definition at line 976 of file Almog_Engine.h.

References ae_point_calc_norma, Point::w, Point::x, Point::y, and Point::z.

Referenced by ae_quad_calc_light_intensity(), ae_quad_get_average_normal(), ae_scene_init(), ae_tri_calc_light_intensity(), and ae_tri_get_average_normal().

4.7.4.14 ae_point_project_view2screen()

```
Point ae_point_project_view2screen (
            Mat2D proj_mat,
            Point src,
            int window_w,
            int window_h )
```

Project a view-space point to screen space.

Applies the projection matrix, performs perspective divide if $|w| > 1e\text{-}3$, maps normalized device coords to pixel coordinates: x_screen = (x_ndc + 1) $*$ 0.5 $*$ window_w y_screen = (y_ndc + 1) $*$ 0.5 $*$ window_h

z is z_ndc, w is the clip-space w (or 1 if the original w $\sim$ 0).

Parameters

proj_mat	Projection matrix (4x4).
src	View-space point.
window_w	Screen width in pixels.
window_h	Screen height in pixels.

Returns

Point Screen-space point.

Definition at line 2870 of file Almog_Engine.h.

References ae_assert_point_is_valid, mat2D_alloc(), MAT2D_AT, mat2D_dot(), mat2D_free(), Point::w, Point::x, Point::y, and Point::z.

Referenced by ae_line_project_world2screen(), ae_point_project_world2screen(), ae_quad_project_world2screen(), and ae_tri_project_world2screen().

4.7.4.15 ae_point_project_world2screen()

```
Point ae_point_project_world2screen (
            Mat2D view_mat,
            Mat2D proj_mat,
            Point src,
            int window_w,
            int window_h )
```

Project a point from world space directly to screen space.

Combines ae_point_project_world2view and ae_point_project_view2screen.

Parameters

view_mat	View matrix (4x4).
proj_mat	Projection matrix (4x4).
src	World-space point.
window_w	Screen width in pixels.
window_h	Screen height in pixels.

Returns

Point Screen-space point (x,y in pixels). z is post-projection z/w, w is clip-space w.

Definition at line 2806 of file Almog_Engine.h.

References ae_point_project_view2screen(), and ae_point_project_world2view().

4.7.4.16 ae_point_project_world2view()

```
Point ae_point_project_world2view (
            Mat2D view_mat,
            Point src )
```

Transform a point from world space to view space.

Multiplies [x y z 1] by view_mat (row-vector convention in this code). Returns the resulting view-space point; w should be 1.

Parameters

view_mat	View matrix (4x4).
src	World-space point.

Returns

Point View-space point (w=1).

Definition at line 2824 of file Almog_Engine.h.

References AE_ASSERT, ae_assert_point_is_valid, mat2D_alloc(), MAT2D_AT, mat2D_dot(), mat2D_free(), Point::w, Point::x, Point::y, and Point::z.

Referenced by ae_line_project_world2screen(), and ae_point_project_world2screen().

4.7.4.17 ae_point_to_mat2D()

```
void ae_point_to_mat2D (
            Point p,
            Mat2D m )
```

Write a Point into a Mat2D vector.

Writes p into m. m must be either 3x1 or 1x3. Only x, y, z are written.

Parameters

p	Source point (x, y, z used; w ignored).
m	Destination matrix (3x1 or 1x3).

Definition at line 498 of file Almog_Engine.h.

References Mat2D::cols, MAT2D_AT, MATRIX2D_ASSERT, Mat2D::rows, Point::x, Point::y, and Point::z.

Referenced by ae_line_clip_with_plane(), ae_quad_calc_normal(), ae_quad_clip_with_plane(), ae_quad_project_world2screen(), ae_quad_set_normals(), ae_tri_calc_normal(), ae_tri_clip_with_plane(), ae_tri_project_world2screen(), and ae_tri_set_normals().

4.7.4.18 ae_print_points()

```
void ae_print_points (
            Curve p )
```

Print a list of points to stdout.

Each point is printed as: "point i: (x, y, z)".

Parameters

p	Curve of points to print.

Definition at line 925 of file Almog_Engine.h.

References Curve::elements, Curve::length, Point::x, Point::y, and Point::z.

4.7.4.19 ae_print_tri()

```
void ae_print_tri (
            Tri tri,
            char * name,
            size_t padding )
```

Print a triangle to stdout.

Prints the triangle's vertices and draw flag, with an optional name and indentation padding (spaces).

Parameters

tri	Triangle to print.
name	Label to print before the triangle.
padding	Number of leading spaces for indentation.

Definition at line 942 of file Almog_Engine.h.

References Tri::points, Tri::to_draw, Point::x, Point::y, and Point::z.

Referenced by ae_print_tri_mesh().

4.7.4.20 ae_print_tri_mesh()

```
void ae_print_tri_mesh (
            Tri_mesh mesh,
            char * name,
            size_t padding )
```

Print all triangles in a mesh to stdout.

Each triangle is printed via ae_print_tri with the given padding.

Parameters

mesh	Triangle mesh to print.
name	Label for the mesh.
padding	Number of leading spaces for indentation.

Definition at line 958 of file Almog_Engine.h.

References ae_print_tri(), Tri_mesh::elements, and Tri_mesh::length.

4.7.4.21 ae_projection_mat_set()

```
void ae_projection_mat_set (
            Mat2D proj_mat,
            float aspect_ratio,
            float FOV_deg,
            float z_near,
            float z_far )
```

Build a perspective projection matrix.

proj_mat must be 4x4. FOV is in degrees. The matrix maps view-space to clip space consistent with the engine's pipeline; z is mapped using z_far/(z_far - z_near).

Parameters

proj_mat	Output 4x4 projection matrix.
aspect_ratio	aspect = window_h / window_w.
FOV_deg	Vertical field of view in degrees (must be $>$ 0).
z_near	Near clipping plane distance ($>$ 0).
z_far	Far clipping plane distance ($>$ z_near).

Definition at line 2682 of file Almog_Engine.h.

References AE_ASSERT, Mat2D::cols, MAT2D_AT, mat2D_fill(), PI, and Mat2D::rows.

Referenced by ae_scene_init(), and update().

4.7.4.22 ae_quad_calc_light_intensity()

```
void ae_quad_calc_light_intensity (
            Quad * quad,
            Scene * scene,
            Lighting_mode lighting_mode )
```

Compute per-vertex lighting intensity for a quad.

Same model as ae_tri_calc_light_intensity, applied to four vertices. Results are clamped to [0, 1].

Parameters

quad	Quad to update (quad->light_intensity[i] is written).
scene	Scene providing light and material parameters.
lighting_mode	Flat or smooth lighting mode.

Definition at line 1580 of file Almog_Engine.h.

References AE_LIGHTING_FLAT, AE_LIGHTING_SMOOTH, ae_mat2D_to_point(), ae_point_add_point, ae_point_dot_point, ae_point_mult, ae_point_normalize_xyz(), ae_point_sub_point, ae_quad_get_average_normal(), ae_quad_get_average_point(), Material::c_ambi, Material::c_diff, Material::c_spec, Scene::camera, Camera::current_position, Light_source::light_direction_or_pos, Quad::light_intensity, Light_source::light_intensity, Scene::light_source0, Scene::material0, Quad::normals, Quad::points, Material::specular_power_alpha, and Point::w.

Referenced by ae_quad_project_world2screen().

4.7.4.23 ae_quad_calc_normal()

```
void ae_quad_calc_normal (
            Mat2D normal,
            Quad quad )
```

Compute the face normal of a quad using the first three vertices.

normal must be a 3x1 vector. The function writes the normalized cross product of (p1 - p0) x (p2 - p0) into normal.

Parameters

normal	Output 3x1 vector for the face normal.
quad	Input quad.

Definition at line 1428 of file Almog_Engine.h.

References AE_ASSERT, ae_assert_quad_is_valid, ae_point_to_mat2D(), Mat2D::cols, mat2D_alloc(), mat2D_calc_norma(), mat2D_cross(), mat2D_free(), mat2D_mult(), mat2D_sub(), Quad::points, and Mat2D::rows.

4.7.4.24 ae_quad_clip_with_plane()

```
int ae_quad_clip_with_plane (
              Quad quad_in,
              Mat2D plane_p,
              Mat2D plane_n,
              Quad * quad_out1,
              Quad * quad_out2 )
```

Clip a quad against a plane.

Splits or discards the quad quad_in against the plane defined by (plane_p, plane_n). plane_n is normalized inside the function.

Parameters

quad_in	Input quad.
plane_p	Plane reference point (3x1).
plane_n	Plane normal (3x1).
quad_out1	First output quad (if any). When output count is 2, this holds one of the resulting polygons (possibly as a quad composed from intersections).
quad_out2	Second output quad (if split).

Returns

int Number of output polygons: 0 (culled), 1, or 2. Returns -1 on error.

Definition at line 2181 of file Almog_Engine.h.

References ae_assert_quad_is_valid, ae_line_itersect_plane(), ae_point_to_mat2D(), ae_signed_dist_point_and_plane(), Quad::colors, mat2D_alloc(), mat2D_free(), mat2D_normalize, Quad::points, and Point::w.

Referenced by ae_quad_mesh_project_world2screen(), and ae_quad_project_world2screen().

4.7.4.25 ae_quad_get_average_normal()

```
Point ae_quad_get_average_normal (
              Quad quad )
```

Compute the average of the four vertex normals of a quad.

Averages the four vertex normals and normalizes the result.

Parameters

quad	Input quad.

Returns

Point The averaged, normalized normal.

Definition at line 1379 of file Almog_Engine.h.

References ae_point_normalize_xyz(), Quad::normals, Point::w, Point::x, Point::y, and Point::z.

Referenced by ae_quad_calc_light_intensity(), and ae_quad_project_world2screen().

4.7.4.26 ae_quad_get_average_point()

```
Point ae_quad_get_average_point (
            Quad quad )
```

Compute the average of the four vertices of a quad.

Parameters

quad	Input quad.

Returns

Point The average point (x, y, z, w are simple averages).

Definition at line 1403 of file Almog_Engine.h.

References Quad::points, Point::w, Point::x, Point::y, and Point::z.

Referenced by ae_quad_calc_light_intensity().

4.7.4.27 ae_quad_mesh_project_world2screen()

```
void ae_quad_mesh_project_world2screen (
            Mat2D proj_mat,
            Mat2D view_mat,
            Quad_mesh * des,
            Quad_mesh src,
            int window_w,
            int window_h,
            Scene * scene,
            Lighting_mode lighting_mode )
```

Project a quad mesh from world to screen space with clipping.

Iterates over all quads, applies near-plane and screen-edge clipping, and writes results into des. Quads can be split by clipping, so des may end up with more elements than src.

Parameters

proj_mat	Projection matrix (4x4).
view_mat	View matrix (4x4).
des	Output mesh (cleared and filled; ADA array grown as needed).
src	Input world-space quad mesh.
window_w	Screen width in pixels.
window_h	Screen height in pixels.
scene	Scene (camera/light/material).
lighting_mode	Flat or smooth lighting mode.

Definition at line 3434 of file Almog_Engine.h.

References ada_append, ada_insert_unordered, ada_remove_unordered, ae_assert_quad_is_valid, ae_quad_clip_with_plane(), ae_quad_project_world2screen(), Quad_mesh::elements, Quad_mesh::length, mat2D_alloc(), MAT2D_AT, mat2D_fill(), and mat2D_free().

4.7.4.28 ae_quad_project_world2screen()

```
Quad_mesh ae_quad_project_world2screen (
            Mat2D proj_mat,
            Mat2D view_mat,
            Quad quad,
            int window_w,
            int window_h,
            Scene * scene,
            Lighting_mode lighting_mode )
```

Project a single world-space quad to screen space with clipping.

Computes lighting and visibility, transforms to view space, clips against near plane, and projects to screen space. A quad may produce one or two quads after clipping.

Parameters

proj_mat	Projection matrix (4x4).
view_mat	View matrix (4x4).
quad	World-space quad.
window_w	Screen width in pixels.
window_h	Screen height in pixels.
scene	Scene (camera/light/material).
lighting_mode	Flat or smooth lighting mode.

Returns

Quad_mesh An ADA array of resulting screen-space quads. Caller must free result.elements.

Definition at line 3321 of file Almog_Engine.h.

References ada_append, ada_init_array, ae_assert_quad_is_valid, ae_point_project_view2screen(), ae_point_to_mat2D(), ae_quad_calc_light_intensity(), ae_quad_clip_with_plane(), ae_quad_get_average_normal(), ae_quad_transform_to_view(), Scene::camera, Camera::current_position, Quad_mesh::elements, Quad_mesh::length, Light_source::light_direction_or_pos, Quad::light_intensity, Scene::light_source0, mat2D_alloc(), MAT2D_AT, mat2D_fill(), mat2D_free(), mat2D_sub(), Quad::normals, Quad::points, Quad::to_draw, Point::x, Point::y, Point::z, and Camera::z_near.

Referenced by ae_quad_mesh_project_world2screen().

4.7.4.29 ae_quad_set_normals()

```
void ae_quad_set_normals (
            Quad * quad )
```

Compute and set per-vertex normals for a quad.

For each vertex, computes the cross product of adjacent edges and normalizes the result. Results are stored in quad->normals[i].

Parameters

quad	Quad whose normals will be computed and written.

Definition at line 1336 of file Almog_Engine.h.

References ae_assert_quad_is_valid, ae_mat2D_to_point(), ae_point_to_mat2D(), mat2D_alloc(), mat2D_copy(), mat2D_cross(), mat2D_free(), mat2D_normalize, mat2D_sub(), Quad::normals, and Quad::points.

4.7.4.30 ae_quad_transform_to_view()

```
Quad ae_quad_transform_to_view (
            Mat2D view_mat,
            Quad quad )
```

Transform a quad from world space to view space.

Applies view_mat to each vertex (homogeneous multiply with w=1). Returns the transformed quad; normals are not changed.

Parameters

view_mat	View matrix (4x4).
quad	World-space quad.

Returns

Quad View-space quad.

Definition at line 3271 of file Almog_Engine.h.

References AE_ASSERT, ae_assert_quad_is_valid, mat2D_alloc(), MAT2D_AT, mat2D_dot(), mat2D_free(), Quad::points, Point::w, Point::x, Point::y, and Point::z.

Referenced by ae_quad_project_world2screen().

4.7.4.31 ae_scene_free()

```
void ae_scene_free (
            Scene * scene )
```

Free all resources owned by a Scene.

Frees camera, matrices, and any allocated meshes in the in_world, projected, and original mesh arrays (triangles and quads). Does not free the Scene struct itself when passed by pointer.

Parameters

scene	Scene to free.

Note

Assumes the game_state was initialized with zeros.

Definition at line 429 of file Almog_Engine.h.

References ae_camera_free(), Tri_mesh::elements, Quad_mesh::elements, Tri_mesh_array::elements, Quad_mesh_array::elements, Scene::in_world_quad_meshes, Scene::in_world_tri_meshes, Tri_mesh_array::length, Quad_mesh_array::length, mat2D_free(), Scene::original_quad_meshes, Scene::original_tri_meshes, Scene::proj_mat, Scene::projected_quad_meshes, Scene::projected_tri_meshes, Scene::up_direction, and Scene::view_mat.

Referenced by destroy_window().

4.7.4.32 ae_scene_init()

```
Scene ae_scene_init (
            int window_h,
            int window_w )
```

Create and initialize a Scene.

Initializes camera, up direction, default light and material, and allocates projection and view matrices. Caller must release resources with ae_scene_free.

Parameters

window_h	Window height in pixels.
window_w	Window width in pixels.

Returns

Scene An initialized scene object.

Definition at line 388 of file Almog_Engine.h.

References ae_camera_init(), ae_point_normalize_xyz(), ae_projection_mat_set(), ae_view_mat_set(), Camera::aspect_ratio, Material::c_ambi, Material::c_diff, Material::c_spec, Scene::camera, Camera::fov_deg, Light_source::light_direction_or_pos, Light_source::light_intensity, Scene::light_source0, mat2D_alloc(), MAT2D_AT, mat2D_fill(), Scene::material0, Scene::proj_mat, Material::specular_power_alpha, Scene::up_direction, Scene::view_mat, Point::w, Point::x, Point::y, Point::z, Camera::z_far, and Camera::z_near.

Referenced by setup_window().

4.7.4.33 ae_signed_dist_point_and_plane()

```
float ae_signed_dist_point_and_plane (
            Point p,
            Mat2D plane_p,
            Mat2D plane_n )
```

Signed distance from a point to a plane.

Computes dot(n, p) - dot(n, plane_p). The normal is not normalized internally; pass a normalized plane_n for distances in consistent units.

Parameters

p	Point to evaluate.
plane_p	Plane reference point (3x1).
plane_n	Plane normal (3x1).

Returns

float Signed distance (>=0 is on the "inside" of the plane).

Definition at line 1807 of file Almog_Engine.h.

References ae_assert_point_is_valid, MAT2D_AT, Point::x, Point::y, and Point::z.

Referenced by ae_line_clip_with_plane(), ae_quad_clip_with_plane(), and ae_tri_clip_with_plane().

4.7.4.34 ae_tri_calc_light_intensity()

```
void ae_tri_calc_light_intensity (
            Tri * tri,
            Scene * scene,
            Lighting_mode lighting_mode )
```

Compute per-vertex lighting intensity for a triangle.

Implements a Phong-like model with ambient, diffuse, and specular terms, using material0 and light_source0 from the scene. When lighting_mode is AE_LIGHTING_FLAT, the average normal and triangle centroid are used for all vertices; when AE_LIGHTING_SMOOTH, each vertex normal and position is used. For directional light, light_↩ direction_or_pos.w == 0; for point light, w != 0. Results are clamped to [0, 1].

Parameters

tri	Triangle to update (tri->light_intensity[i] is written).
scene	Scene providing light and material parameters.
lighting_mode	Flat or smooth lighting mode.

Definition at line 1487 of file Almog_Engine.h.

References AE_LIGHTING_FLAT, AE_LIGHTING_SMOOTH, ae_mat2D_to_point(), ae_point_add_point, ae_point_dot_point, ae_point_mult, ae_point_normalize_xyz(), ae_point_sub_point, ae_tri_get_average_normal(), ae_tri_get_average_point(), Material::c_ambi, Material::c_diff, Material::c_spec, Scene::camera, Camera::current_position, Light_source::light_direction_or_pos, Tri::light_intensity, Light_source::light_intensity, Scene::light_source0, Scene::material0, Tri::normals, Tri::points, Material::specular_power_alpha, and Point::w.

Referenced by ae_tri_project_world2screen().

4.7.4.35 ae_tri_calc_normal()

```
void ae_tri_calc_normal (
            Mat2D normal,
            Tri tri )
```

Compute the face normal of a triangle.

normal must be a 3x1 vector. The function writes the normalized cross product of (p1 - p0) x (p2 - p0) into normal.

Parameters

normal	Output 3x1 vector for the face normal.
tri	Input triangle.

Definition at line 1086 of file Almog_Engine.h.

References AE_ASSERT, ae_assert_tri_is_valid, ae_point_to_mat2D(), Mat2D::cols, mat2D_alloc(), mat2D_calc_norma(), mat2D_cross(), mat2D_free(), mat2D_mult(), mat2D_sub(), Tri::points, and Mat2D::rows.

Referenced by ae_tri_project_world2screen().

4.7.4.36 ae_tri_clip_with_plane()

```
int ae_tri_clip_with_plane (
            Tri tri_in,
            Mat2D plane_p,
            Mat2D plane_n,
            Tri * tri_out1,
            Tri * tri_out2 )
```

Clip a triangle against a plane.

Splits or discards the triangle tri_in against the plane defined by (plane_p, plane_n). plane_n is normalized inside the function.

Parameters

tri_in	Input triangle.
plane_p	Plane reference point (3x1).
plane_n	Plane normal (3x1).
tri_out1	First output triangle (if any).
tri_out2	Second output triangle (if split).

Returns

int Number of output triangles: 0 (culled), 1, or 2. Returns -1 on error.

Definition at line 1838 of file Almog_Engine.h.

References ae_assert_tri_is_valid, ae_line_itersect_plane(), ae_point_to_mat2D(), ae_signed_dist_point_and_plane(), Tri::colors, mat2D_alloc(), mat2D_free(), mat2D_normalize, Tri::points, Tri::tex_points, Point::w, Point::x, and Point::y.

Referenced by ae_tri_mesh_project_world2screen(), and ae_tri_project_world2screen().

4.7.4.37 ae_tri_compare()

```
bool ae_tri_compare (
            Tri t1,
            Tri t2 )
```

Compare two triangles for sorting by depth.

Returns true if t1 should come before t2 when sorting by the maximum z of their vertices (descending order).

Parameters

t1	First triangle.
t2	Second triangle.

Returns

bool true if t1 precedes t2, false otherwise.

Definition at line 3725 of file Almog_Engine.h.

References Tri::points, and Point::z.

Referenced by ae_tri_qsort().

4.7.4.38 ae_tri_create()

```
Tri ae_tri_create (
              Point p1,
              Point p2,
              Point p3 )
```

Create a triangle from three points.

Parameters

p1	First vertex (world space).
p2	Second vertex (world space).
p3	Third vertex (world space).

Returns

Tri The created triangle with vertices set. Other fields are left uninitialized.

Definition at line 278 of file Almog_Engine.h.

References Tri::points.

4.7.4.39 ae_tri_get_average_normal()

```
Point ae_tri_get_average_normal (
              Tri tri )
```

Compute the average of the three vertex normals of a triangle.

Averages the three vertex normals and normalizes the result.

Parameters

tri	Input triangle.

Returns

Point The averaged, normalized normal (w averaged but unused).

Definition at line 1041 of file Almog_Engine.h.

References ae_point_normalize_xyz(), Tri::normals, Point::w, Point::x, Point::y, and Point::z.

Referenced by ae_tri_calc_light_intensity().

4.7.4.40 ae_tri_get_average_point()

```
Point ae_tri_get_average_point (
            Tri tri )
```

Compute the average of the three vertices of a triangle.

Parameters

tri	Input triangle.

Returns

Point The average point (x, y, z, w are simple averages).

Definition at line 1062 of file Almog_Engine.h.

References Tri::points, Point::w, Point::x, Point::y, and Point::z.

Referenced by ae_tri_calc_light_intensity().

4.7.4.41 ae_tri_mesh_append_copy()

```
void ae_tri_mesh_append_copy (
            Tri_mesh_array * mesh_array,
            Tri_mesh mesh )
```

Append a copy of a Tri_mesh into a Tri_mesh_array.

Creates a deep copy of mesh (triangles by value) and appends it to mesh_array (ADA array of meshes).

Parameters

mesh_array	Destination mesh array to append into.
mesh	Source triangle mesh to copy.

Definition at line 851 of file Almog_Engine.h.

References ada_append, ada_init_array, Tri_mesh::elements, and Tri_mesh::length.

Referenced by setup().

4.7.4.42 ae_tri_mesh_create_copy()

```
void ae_tri_mesh_create_copy (
            Tri_mesh * des,
            Tri * src_elements,
            size_t len )
```

Append copies of triangles to a destination Tri_mesh (resets destination length first).

Appends len triangles from src_elements into the destination ADA array pointed by des.

Parameters

des	Destination triangle mesh (ADA array). Will grow as needed.
src_elements	Source array of triangles to copy from.
len	Number of triangles to copy from src_elements.

Definition at line 299 of file Almog_Engine.h.

References ada_append, and Tri_mesh::length.

4.7.4.43 ae_tri_mesh_flip_normals()

```
void ae_tri_mesh_flip_normals (
            Tri_mesh mesh )
```

Flip triangle winding and recompute per-vertex normals.

Swaps vertex order to invert winding, copies attributes accordingly, and recomputes normals.

Parameters

mesh	Mesh to flip (modified in place).

Definition at line 1283 of file Almog_Engine.h.

References ae_tri_set_normals(), Tri::colors, Tri_mesh::elements, Tri_mesh::length, Tri::light_intensity, Tri::normals, Tri::points, Tri::tex_points, and Tri::to_draw.

4.7.4.44 ae_tri_mesh_get_from_file()

```
Tri_mesh ae_tri_mesh_get_from_file (
            char * file_path )
```

Load a triangle mesh from a file (OBJ or STL).

Dispatches to ae_tri_mesh_get_from_obj_file or ae_tri_mesh_get_from_stl_file based on file extension.

Parameters

file_path	Path to the file (.obj, .stl, .STL).

Returns

Tri_mesh The loaded triangle mesh. Caller must free mesh.elements when done.

Definition at line 816 of file Almog_Engine.h.

References ae_tri_mesh_get_from_obj_file(), ae_tri_mesh_get_from_stl_file(), asm_get_word_and_cut(), asm_str_in_str(), and MAX_LEN_LINE.

Referenced by setup().

4.7.4.45 ae_tri_mesh_get_from_obj_file()

```
Tri_mesh ae_tri_mesh_get_from_obj_file (
            char * file_path )
```

Load a triangle mesh from a Wavefront OBJ file.

Supports vertex positions (v). Face lines (f) with 3 or 4 vertices are parsed. Texture coordinates and normals in the file are ignored (a warning is printed once if present). Quads are triangulated as (0,1,2) and (2,3,0). Colors are set to white and to_draw is set to true.

Parameters

file_path	Path to the OBJ file.

Returns

Tri_mesh The loaded triangle mesh. Caller must free mesh.elements when done.

Definition at line 540 of file Almog_Engine.h.

References ada_append, ada_init_array, asm_get_line(), asm_get_next_word_from_line(), asm_get_word_and_cut(), asm_length(), asm_str_in_str(), Tri::colors, Curve::elements, Tri::light_intensity, MAX_LEN_LINE, Tri::points, Tri::to_draw, Point::x, Point::y, and Point::z.

Referenced by ae_tri_mesh_get_from_file().

4.7.4.46 ae_tri_mesh_get_from_quad_mesh()

```
Tri_mesh ae_tri_mesh_get_from_quad_mesh (
            Quad_mesh q_mesh )
```

Convert a Quad_mesh into a Tri_mesh.

Splits each quad into two triangles: (0,1,2) and (2,3,0), copying per-vertex attributes (points, colors, normals, light intensities).

Parameters

q_mesh	Input quad mesh.

Returns

Tri_mesh Resulting triangle mesh. Caller must free mesh.elements when done.

Definition at line 875 of file Almog_Engine.h.

References ada_append, ada_init_array, Tri::colors, Quad::colors, Quad_mesh::elements, Quad_mesh::length, Tri::light_intensity, Quad::light_intensity, Tri::normals, Quad::normals, Tri::points, Quad::points, Tri::to_draw, and Quad::to_draw.

4.7.4.47 ae_tri_mesh_get_from_stl_file()

```
Tri_mesh ae_tri_mesh_get_from_stl_file (
            char * file_path )
```

Load a triangle mesh from a binary STL file.

Reads binary STL (little-endian). Per-triangle normals from the file are negated to match the engine's convention and copied to each vertex normal. Colors are set to white and to_draw is set to true.

Parameters

file_path	Path to the binary STL file.

Returns

Tri_mesh The loaded triangle mesh. Caller must free mesh.elements when done.

Definition at line 743 of file Almog_Engine.h.

References ada_append, ada_init_array, Tri::colors, Tri::light_intensity, Tri::normals, Tri::points, STL_ATTRIBUTE_BITS_SIZE, STL_HEADER_SIZE, STL_NUM_SIZE, Tri::to_draw, Point::x, Point::y, and Point::z.

Referenced by ae_tri_mesh_get_from_file().

4.7.4.48 ae_tri_mesh_normalize()

```
void ae_tri_mesh_normalize (
            Tri_mesh mesh )
```

Normalize mesh coordinates to [-1, 1], centered at origin.

Uniformly scales and recenters the mesh so that the largest axis fits exactly into [-1, 1]. Other axes are scaled proportionally. Updates all vertices in place.

Parameters

mesh	Triangle mesh to normalize (modified in place).

Definition at line 1244 of file Almog_Engine.h.

References ae_tri_mesh_set_bounding_box(), Tri_mesh::elements, Tri_mesh::length, Tri::points, Point::x, Point::y, and Point::z.

Referenced by setup().

4.7.4.49 ae_tri_mesh_project_world2screen()

```
void ae_tri_mesh_project_world2screen (
            Mat2D proj_mat,
            Mat2D view_mat,
            Tri_mesh * des,
            Tri_mesh src,
            int window_w,
            int window_h,
            Scene * scene,
            Lighting_mode lighting_mode )
```

Project a triangle mesh from world to screen space with clipping.

Iterates over all triangles, applies near-plane and screen-edge clipping (top/right/bottom/left), and writes results into des. Triangles can be split by clipping, so des may end up with more elements than src.

Parameters

proj_mat	Projection matrix (4x4).
view_mat	View matrix (4x4).
des	Output mesh (cleared and filled; ADA array grown as needed).
src	Input world-space triangle mesh.
window_w	Screen width in pixels.
window_h	Screen height in pixels.
scene	Scene (camera/light/material).
lighting_mode	Flat or smooth lighting mode.

Definition at line 3151 of file Almog_Engine.h.

References ada_append, ada_insert_unordered, ada_remove_unordered, ae_assert_tri_is_valid, ae_tri_clip_with_plane(), ae_tri_project_world2screen(), Tri_mesh::elements, Tri_mesh::length, mat2D_alloc(), MAT2D_AT, mat2D_fill(), and mat2D_free().

Referenced by update().

4.7.4.50 ae_tri_mesh_rotate_Euler_xyz()

```
void ae_tri_mesh_rotate_Euler_xyz (
            Tri_mesh mesh,
            float phi_deg,
            float theta_deg,
            float psi_deg )
```

Rotate a triangle mesh using XYZ Euler angles (degrees).

Applies DCM = Cz(psi_deg) ∗ Cy(theta_deg) ∗ Cx(phi_deg) to each vertex. Recomputes per-vertex normals afterward.

Parameters

mesh	Triangle mesh to rotate (modified in place).
phi_deg	Rotation about X axis, degrees.
theta_deg	Rotation about Y axis, degrees.
psi_deg	Rotation about Z axis, degrees.

Definition at line 1143 of file Almog_Engine.h.

References ae_tri_mesh_set_normals(), Tri_mesh::elements, Tri_mesh::length, mat2D_alloc(), MAT2D_AT, mat2D_dot(), mat2D_free(), mat2D_set_rot_mat_x(), mat2D_set_rot_mat_y(), mat2D_set_rot_mat_z(), Tri::points, Point::x, Point::y, and Point::z.

Referenced by setup().

4.7.4.51 ae_tri_mesh_set_bounding_box()

```
void ae_tri_mesh_set_bounding_box (
            Tri_mesh mesh,
            float * x_min,
            float * x_max,
            float * y_min,
            float * y_max,
            float * z_min,
            float * z_max )
```

Compute the axis-aligned bounding box of a triangle mesh.

Writes min/max for x, y, z across all vertices in the mesh.

Parameters

mesh	Input triangle mesh.
x_min	Output minimum x.
x_max	Output maximum x.
y_min	Output minimum y.
y_max	Output maximum y.
z_min	Output minimum z.
z_max	Output maximum z.

Definition at line 1206 of file Almog_Engine.h.

References Tri_mesh::elements, Tri_mesh::length, Tri::points, Point::x, Point::y, and Point::z.

Referenced by ae_tri_mesh_normalize().

4.7.4.52 ae_tri_mesh_set_normals()

```
void ae_tri_mesh_set_normals (
            Tri_mesh mesh )
```

Recompute per-vertex normals for all triangles in a mesh.

Calls ae_tri_set_normals on each triangle.

Parameters

mesh	Mesh to update (modified in place).

Definition at line 1321 of file Almog_Engine.h.

References ae_tri_set_normals(), Tri_mesh::elements, and Tri_mesh::length.

Referenced by ae_tri_mesh_rotate_Euler_xyz().

4.7.4.53 ae_tri_mesh_translate()

```
void ae_tri_mesh_translate (
            Tri_mesh mesh,
            float x,
            float y,
            float z )
```

Translate a triangle mesh by (x, y, z).

Adds the given offsets to each vertex in the mesh.

Parameters

mesh	Triangle mesh to translate (modified in place).
x	X-axis offset.
y	Y-axis offset.
z	Z-axis offset.

Definition at line 1121 of file Almog_Engine.h.

References Tri_mesh::elements, Tri_mesh::length, Tri::points, Point::x, Point::y, and Point::z.

4.7.4.54 ae_tri_project_world2screen()

```
Tri_mesh ae_tri_project_world2screen (
            Mat2D proj_mat,
            Mat2D view_mat,
            Tri tri,
            int window_w,
            int window_h,
            Scene * scene,
            Lighting_mode lighting_mode )
```

Project a single world-space triangle to screen space with clipping.

Computes lighting, back-face visibility, transforms to view space, clips against near plane, and projects to screen space. If clipping splits the triangle, multiple triangles may be returned.

Parameters

proj_mat	Projection matrix (4x4).
view_mat	View matrix (4x4).
tri	World-space triangle.
window_w	Screen width in pixels.
window_h	Screen height in pixels.
scene	Scene (camera for near plane, light/material for lighting).
lighting_mode	Flat or smooth lighting mode.

Returns

Tri_mesh An ADA array of resulting screen-space triangles. Caller must free result.elements.

Definition at line 3038 of file Almog_Engine.h.

References ada_append, ada_init_array, ae_assert_tri_is_valid, ae_point_project_view2screen(), ae_point_to_mat2D(), ae_tri_calc_light_intensity(), ae_tri_calc_normal(), ae_tri_clip_with_plane(), ae_tri_transform_to_view(), Scene::camera, Camera::current_position, Tri_mesh::elements, Tri_mesh::length, Tri::light_intensity, mat2D_alloc(), MAT2D_AT, mat2D_fill(), mat2D_free(), mat2D_sub(), mat2D_transpose(), Tri::normals, Tri::points, Tri::tex_points, Tri::to_draw, Point::w, Point::x, Point::y, Point::z, and Camera::z_near.

Referenced by ae_tri_mesh_project_world2screen().

4.7.4.55 ae_tri_qsort()

```
void ae_tri_qsort (
            Tri * v,
            int left,
            int right )
```

Quicksort an array of triangles by depth.

Sorts v[left..right] using ae_tri_compare (descending by max z).

Parameters

v	Array of triangles to sort.
left	Left index (inclusive).
right	Right index (inclusive).

Definition at line 3742 of file Almog_Engine.h.

References ae_tri_compare(), and ae_tri_swap().

4.7.4.56 ae_tri_set_normals()

```
void ae_tri_set_normals (
            Tri * tri )
```

Compute and set per-vertex normals for a triangle.

For each vertex, computes the cross product of the adjacent edges around that vertex and normalizes it. Results are stored in tri->normals[i].

Parameters

tri	Triangle whose normals will be computed and written.

Definition at line 998 of file Almog_Engine.h.

References ae_assert_tri_is_valid, ae_mat2D_to_point(), ae_point_to_mat2D(), mat2D_alloc(), mat2D_copy(), mat2D_cross(), mat2D_free(), mat2D_normalize, mat2D_sub(), Tri::normals, and Tri::points.

Referenced by ae_tri_mesh_flip_normals(), and ae_tri_mesh_set_normals().

4.7.4.57 ae_tri_swap()

```
void ae_tri_swap (
            Tri * v,
            int i,
            int j )
```

Swap two triangles in an array.

Parameters

v	Array of triangles.
i	Index of first element.
j	Index of second element.

Definition at line 3706 of file Almog_Engine.h.

Referenced by ae_tri_qsort().

4.7.4.58 ae_tri_transform_to_view()

```
Tri ae_tri_transform_to_view (
            Mat2D view_mat,
            Tri tri )
```

Transform a triangle from world space to view space.

Applies view_mat to each vertex (homogeneous multiply with w=1). Returns the transformed triangle; normals are not changed.

Parameters

view_mat	View matrix (4x4).
tri	World-space triangle.

Returns

Tri View-space triangle.

Definition at line 2988 of file Almog_Engine.h.

References AE_ASSERT, ae_assert_tri_is_valid, mat2D_alloc(), MAT2D_AT, mat2D_dot(), mat2D_free(), Tri::points, Point::w, Point::x, Point::y, and Point::z.

Referenced by ae_tri_project_world2screen().

4.7.4.59 ae_view_mat_set()

```
void ae_view_mat_set (
            Mat2D view_mat,
            Camera camera,
            Mat2D up )
```

Build a right-handed view matrix from a Camera and up vector.

Computes camera basis (right, up, forward) from yaw/pitch/roll offsets and direction, applies offset_position along those axes to update current_position, then zeroes offset_position. Writes the resulting 4x4 view matrix.

Note

Although camera is passed by value, its Mat2D members (e.g. current_position, offset_position, camera_↩ x/y/z) are modified in place due to internal pointer semantics of Mat2D.

Parameters

view_mat	Output 4x4 view matrix.
camera	Camera state (basis vectors and positions updated).
up	World up direction (3x1).

Definition at line 2716 of file Almog_Engine.h.

References Camera::camera_x, Camera::camera_y, Camera::camera_z, Camera::current_position, Camera::direction, mat2D_add(), mat2D_alloc(), MAT2D_AT, mat2D_calc_norma(), mat2D_copy(), mat2D_cross(), mat2D_dot(), mat2D_dot_product(), mat2D_fill(), mat2D_free(), mat2D_mult(), mat2D_set_DCM_zyx(), mat2D_sub(), mat2D_transpose(), Camera::offset_position, Camera::pitch_offset_deg, Camera::roll_offset_deg, and Camera::yaw_offset_deg.

Referenced by ae_scene_init(), and update().

4.7.4.60 ae_z_buffer_copy_to_screen()

```
void ae_z_buffer_copy_to_screen (
            Mat2D_uint32 screen_mat,
            Mat2D inv_z_buffer )
```

Visualize an inverse-z buffer by writing a grayscale image.

Finds the min positive and max inverse-z in inv_z_buffer, maps the range to [0.1, 1.0], and writes an RGB grayscale value into screen_mat at each pixel. Values <= 0 are clamped to the minimum positive.

Parameters

screen_mat	Output RGB image (Mat2D_uint32) 0xRRGGBB per pixel.
inv_z_buffer	Input inverse-z values (Mat2D of doubles).

Definition at line 3785 of file Almog_Engine.h.

References ae_linear_map(), Mat2D::cols, MAT2D_AT, MAT2D_AT_UINT32, RGB_hexRGB, and Mat2D::rows.

4.8 Almog_Engine.h

```
00001
00030 #ifndef ALMOG_ENGINE_H_
00031 #define ALMOG_ENGINE_H_
00032
00033 #include "./Almog_Dynamic_Array.h"
00034 #include "./Matrix2D.h"
00035 #include "./Almog_Draw_Library.h"
00036
00037 #ifndef ALMOG_STRING_MANIPULATION_IMPLEMENTATION
00038 #define ALMOG_STRING_MANIPULATION_IMPLEMENTATION
00039 #endif
00040 #include "./Almog_String_Manipulation.h"
00041
00042 #ifndef AE_ASSERT
00043 #include <assert.h>
00044 #define AE_ASSERT assert
00045 #endif
00046
00047 #include <math.h>
00048 #include <stdbool.h>
00049 #include <float.h>
00050 #include <stdint.h>
00051 #include <errno.h>
00052 #include <string.h>
00053
00054 #ifndef PI
00055 #define PI M_PI
00056 #endif
00057
00058 #ifndef STL_HEADER_SIZE
00059 #define STL_HEADER_SIZE 80
00060 #endif
00061
00062 #ifndef STL_NUM_SIZE
00063 #define STL_NUM_SIZE 4
00064 #endif
00065
00066 #ifndef STL_SIZE_FOREACH_TRI
00067 #define STL_SIZE_FOREACH_TRI 50
00068 #endif
00069
00070 #ifndef STL_ATTRIBUTE_BITS_SIZE
00071 #define STL_ATTRIBUTE_BITS_SIZE 2
00072 #endif
00073
00074 #ifndef HexARGB_RGBA
00075 #define HexARGB_RGBA(x) ((x)»(8*2)&0xFF), ((x)»(8*1)&0xFF), ((x)»(8*0)&0xFF), ((x)»(8*3)&0xFF)
00076 #endif
00077 #ifndef HexARGB_RGB_VAR
00078 #define HexARGB_RGB_VAR(x, r, g, b) r = ((x)»(8*2)&0xFF); g = ((x)»(8*1)&0xFF); b = ((x)»(8*0)&0xFF);
00079 #endif
00080 #ifndef HexARGB_RGBA_VAR
00081 #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)
00082 #endif
00083 #define ARGB_hexARGB(a, r, g, b) 0x010000001*(uint8_t)(a) + 0x00010000*(uint8_t)(r) +
       0x00000100*(uint8_t)(g) + 0x00000001*(uint8_t)(b)
00084 #ifndef RGB_hexRGB
00085 #define RGB_hexRGB(r, g, b) (int)(0x010000*(int)(r) + 0x000100*(int)(g) + 0x000001*(int)(b))
00086 #endif
00087
00088 #define AE_MAX_POINT_VAL 1e5
00089 #define ae_assert_point_is_valid(p) AE_ASSERT(isfinite((p).x) && isfinite((p).y) && isfinite((p).z) &&
       isfinite((p).w));    \
00090         AE_ASSERT((p).x > -AE_MAX_POINT_VAL && (p).x < AE_MAX_POINT_VAL);
                                                \
```

```
00091         AE_ASSERT((p).y > -AE_MAX_POINT_VAL && (p).y < AE_MAX_POINT_VAL);
                                    \
00092         AE_ASSERT((p).z > -AE_MAX_POINT_VAL && (p).z < AE_MAX_POINT_VAL);
                                    \
00093         AE_ASSERT((p).w > -AE_MAX_POINT_VAL && (p).w < AE_MAX_POINT_VAL);
00094 #define ae_assert_tri_is_valid(tri) ae_assert_point_is_valid((tri).points[0]);  \
00095         ae_assert_point_is_valid((tri).points[1]);                                \
00096         ae_assert_point_is_valid((tri).points[2])
00097 #define ae_assert_quad_is_valid(quad) ae_assert_point_is_valid((quad).points[0]);   \
00098         ae_assert_point_is_valid((quad).points[1]);                                  \
00099         ae_assert_point_is_valid((quad).points[2]);                                  \
00100         ae_assert_point_is_valid((quad).points[3])
00101 #define ae_point_normalize_xyz_norma(p, norma) (p).x = (p).x / norma;  \
00102         (p).y = (p).y / norma;                          \
00103         (p).z = (p).z / norma
00104 #define ae_point_calc_norma(p) sqrt(((p).x * (p).x) + ((p).y * (p).y) + ((p).z * (p).z))
00105 #define ae_point_add_point(p, p1, p2) (p).x = (p1).x + (p2).x;  \
00106         (p).y = (p1).y + (p2).y;                                  \
00107         (p).z = (p1).z + (p2).z;                                  \
00108         (p).w = (p1).w + (p2).w
00109 #define ae_point_sub_point(p, p1, p2) (p).x = (p1).x - (p2).x;  \
00110         (p).y = (p1).y - (p2).y;                                  \
00111         (p).z = (p1).z - (p2).z;                                  \
00112         (p).w = (p1).w - (p2).w
00113 #define ae_point_dot_point(p1, p2) (((p1).x * (p2).x) + ((p1).y * (p2).y) + ((p1).z * (p2).z))
00114 #define ae_point_mult(p, const) (p).x *= const; \
00115         (p).y *= const;                           \
00116         (p).z *= const
00117 #define ae_points_equal(p1, p2) (p1).x == (p2).x && (p1).y == (p2).y && (p1).z == (p2).z
00118
00119
00120 typedef enum {
00121     AE_LIGHTING_FLAT,
00122     AE_LIGHTING_SMOOTH,
00123     AE_LIGHTING_MODE_LENGTH
00124 } Lighting_mode;
00125
00126 #ifndef TRI_MESH_ARRAY
00127 #define TRI_MESH_ARRAY
00128 typedef struct {
00129     size_t length;
00130     size_t capacity;
00131     Tri_mesh *elements;
00132 } Tri_mesh_array; /* Tri_mesh ada array */
00133 #endif
00134
00135 #ifndef QUAD_MESH_ARRAY
00136 #define QUAD_MESH_ARRAY
00137 typedef struct {
00138     size_t length;
00139     size_t capacity;
00140     Quad_mesh *elements;
00141 } Quad_mesh_array; /* Quad_mesh ada array */
00142 #endif
00143
00144 typedef struct {
00145     Mat2D init_position;
00146     Mat2D current_position;
00147     Mat2D offset_position;
00148     Mat2D direction;
00149     float z_near;
00150     float z_far;
00151     float fov_deg;
00152     float aspect_ratio;
00153     float roll_offset_deg;
00154     float pitch_offset_deg;
00155     float yaw_offset_deg;
00156     Mat2D camera_x;
00157     Mat2D camera_y;
00158     Mat2D camera_z;
00159 } Camera;
00160
00161 typedef struct {
00162     Point light_direction_or_pos;
00163     float light_intensity;
00164 } Light_source;
00165
00166 typedef struct {
00167     float specular_power_alpha;
00168     float c_ambi;
00169     float c_diff;
00170     float c_spec;
00171 } Material;
00172
00173 typedef struct {
00174     Tri_mesh_array in_world_tri_meshes;
00175     Tri_mesh_array projected_tri_meshes;
```

```
00176     Tri_mesh_array original_tri_meshes;
00177
00178     Quad_mesh_array in_world_quad_meshes;
00179     Quad_mesh_array projected_quad_meshes;
00180     Quad_mesh_array original_quad_meshes;
00181
00182     Camera camera;
00183     Mat2D up_direction;
00184     Mat2D proj_mat;
00185     Mat2D view_mat;
00186
00187     Light_source light_source0;
00188     Material material0;
00189 } Scene;
00190
00191 Tri         ae_tri_create(Point p1, Point p2, Point p3);
00192 void        ae_tri_mesh_create_copy(Tri_mesh *des, Tri *src_elements, size_t len);
00193
00194 void        ae_camera_init(Scene *scene, int window_h, int window_w);
00195 void        ae_camera_free(Scene *scene);
00196 Scene       ae_scene_init(int window_h, int window_w);
00197 void        ae_scene_free(Scene *scene);
00198 void        ae_camera_reset_pos(Scene *scene);
00199
00200 void        ae_point_to_mat2D(Point p, Mat2D m);
00201 Point       ae_mat2D_to_point(Mat2D m);
00202
00203 Tri_mesh    ae_tri_mesh_get_from_obj_file(char *file_path);
00204 Tri_mesh    ae_tri_mesh_get_from_stl_file(char *file_path);
00205 Tri_mesh    ae_tri_mesh_get_from_file(char *file_path);
00206 void        ae_tri_mesh_append_copy(Tri_mesh_array *mesh_array, Tri_mesh mesh);
00207 Tri_mesh    ae_tri_mesh_get_from_quad_mesh(Quad_mesh q_mesh);
00208
00209 void        ae_print_points(Curve p);
00210 void        ae_print_tri(Tri tri, char *name, size_t padding);
00211 void        ae_print_tri_mesh(Tri_mesh mesh, char *name, size_t padding);
00212
00213 Point       ae_point_normalize_xyz(Point p);
00214 void        ae_tri_set_normals(Tri *tri);
00215 Point       ae_tri_get_average_normal(Tri tri);
00216 Point       ae_tri_get_average_point(Tri tri);
00217 void        ae_tri_calc_normal(Mat2D normal, Tri tri);
00218 void        ae_tri_mesh_translate(Tri_mesh mesh, float x, float y, float z);
00219 void        ae_tri_mesh_rotate_Euler_xyz(Tri_mesh mesh, float phi_deg, float theta_deg, float
       psi_deg);
00220 void        ae_tri_mesh_set_bounding_box(Tri_mesh mesh, float *x_min, float *x_max, float *y_min,
       float *y_max, float *z_min, float *z_max);
00221 void        ae_tri_mesh_normalize(Tri_mesh mesh);
00222 void        ae_tri_mesh_flip_normals(Tri_mesh mesh);
00223 void        ae_tri_mesh_set_normals(Tri_mesh mesh);
00224 void        ae_quad_set_normals(Quad *quad);
00225 Point       ae_quad_get_average_normal(Quad quad);
00226 Point       ae_quad_get_average_point(Quad quad);
00227 void        ae_quad_calc_normal(Mat2D normal, Quad quad);
00228 void        ae_curve_copy(Curve *des, Curve src);
00229
00230 void        ae_tri_calc_light_intensity(Tri *tri, Scene *scene, Lighting_mode lighting_mode);
00231 void        ae_quad_calc_light_intensity(Quad *quad, Scene *scene, Lighting_mode lighting_mode);
00232
00233 Point       ae_line_itersect_plane(Mat2D plane_p, Mat2D plane_n, Mat2D line_start, Mat2D line_end,
       float *t);
00234 int         ae_line_clip_with_plane(Point start_in, Point end_in, Mat2D plane_p, Mat2D plane_n, Point
       *start_out, Point *end_out);
00235 float       ae_signed_dist_point_and_plane(Point p, Mat2D plane_p, Mat2D plane_n);
00236 int         ae_tri_clip_with_plane(Tri tri_in, Mat2D plane_p, Mat2D plane_n, Tri *tri_out1, Tri
       *tri_out2);
00237 int         ae_quad_clip_with_plane(Quad quad_in, Mat2D plane_p, Mat2D plane_n, Quad *quad_out1, Quad
       *quad_out2);
00238
00239 void        ae_projection_mat_set(Mat2D proj_mat,float aspect_ratio, float FOV_deg, float z_near,
       float z_far);
00240 void        ae_view_mat_set(Mat2D view_mat, Camera camera, Mat2D up);
00241 Point       ae_point_project_world2screen(Mat2D view_mat, Mat2D proj_mat, Point src, int window_w, int
       window_h);
00242 Point       ae_point_project_world2view(Mat2D view_mat, Point src);
00243 Point       ae_point_project_view2screen(Mat2D proj_mat, Point src, int window_w, int window_h);
00244 void        ae_line_project_world2screen(Mat2D view_mat, Mat2D proj_mat, Point start_src, Point
       end_src, int window_w, int window_h, Point *start_des, Point *end_des, Scene *scene);
00245 Tri         ae_tri_transform_to_view(Mat2D view_mat, Tri tri);
00246 Tri_mesh    ae_tri_project_world2screen(Mat2D proj_mat, Mat2D view_mat, Tri tri, int window_w, int
       window_h, Scene *scene, Lighting_mode lighting_mode);
00247 void        ae_tri_mesh_project_world2screen(Mat2D proj_mat, Mat2D view_mat, Tri_mesh *des, Tri_mesh
       src, int window_w, int window_h, Scene *scene, Lighting_mode lighting_mode);
00248 Quad        ae_quad_transform_to_view(Mat2D view_mat, Quad quad);
00249 Quad_mesh   ae_quad_project_world2screen(Mat2D proj_mat, Mat2D view_mat, Quad quad, int window_w, int
       window_h, Scene *scene, Lighting_mode lighting_mode);
00250 void        ae_quad_mesh_project_world2screen(Mat2D proj_mat, Mat2D view_mat, Quad_mesh *des,
```

```
      Quad_mesh src, int window_w, int window_h, Scene *scene, Lighting_mode lighting_mode);
00251 void        ae_curve_project_world2screen(Mat2D proj_mat, Mat2D view_mat, Curve *des, Curve src, int
      window_w, int window_h, Scene *scene);
00252 void        ae_curve_ada_project_world2screen(Mat2D proj_mat, Mat2D view_mat, Curve_ada *des,
      Curve_ada src, int window_w, int window_h, Scene *scene);
00253 void        ae_grid_project_world2screen(Mat2D proj_mat, Mat2D view_mat, Grid des, Grid src, int
      window_w, int window_h, Scene *scene);
00254
00255 void        ae_tri_swap(Tri *v, int i, int j);
00256 bool        ae_tri_compare(Tri t1, Tri t2);
00257 void        ae_tri_qsort(Tri *v, int left, int right);
00258 double      ae_linear_map(double s, double min_in, double max_in, double min_out, double max_out);
00259 void        ae_z_buffer_copy_to_screen(Mat2D_uint32 screen_mat, Mat2D inv_z_buffer);
00260
00261 #endif /* ALMOG_ENGINE_H_ */
00262
00263 #ifdef ALMOG_ENGINE_IMPLEMENTATION
00264 #undef ALMOG_ENGINE_IMPLEMENTATION
00265
00266 #define AE_PRINT_TRI(tri) ae_print_tri(tri, #tri, 0)
00267 #define AE_PRINT_MESH(mesh) ae_print_tri_mesh(mesh, #mesh, 0)
00268
00278 Tri ae_tri_create(Point p1, Point p2, Point p3)
00279 {
00280     Tri tri;
00281
00282     tri.points[0] = p1;
00283     tri.points[1] = p2;
00284     tri.points[2] = p3;
00285
00286     return tri;
00287 }
00288
00299 void ae_tri_mesh_create_copy(Tri_mesh *des, Tri *src_elements, size_t len)
00300 {
00301     Tri_mesh temp_des = *des;
00302     temp_des.length = 0;
00303     for (size_t i = 0; i < len; i++) {
00304         ada_append(Tri, temp_des, src_elements[i]);
00305     }
00306     *des = temp_des;
00307 }
00308
00320 void ae_camera_init(Scene *scene, int window_h, int window_w)
00321 {
00322     scene->camera.z_near       = 0.1;
00323     scene->camera.z_far        = 1000;
00324     scene->camera.fov_deg      = 60;
00325     scene->camera.aspect_ratio = (float)window_h / (float)window_w;
00326
00327     scene->camera.init_position = mat2D_alloc(3, 1);
00328     mat2D_fill(scene->camera.init_position, 0);
00329     MAT2D_AT(scene->camera.init_position, 2, 0) = -4;
00330
00331     scene->camera.current_position = mat2D_alloc(3, 1);
00332     mat2D_copy(scene->camera.current_position, scene->camera.init_position);
00333
00334     scene->camera.offset_position = mat2D_alloc(3, 1);
00335     mat2D_fill(scene->camera.offset_position, 0);
00336
00337     scene->camera.roll_offset_deg = 0;
00338     scene->camera.pitch_offset_deg = 0;
00339     scene->camera.yaw_offset_deg = 0;
00340
00341     scene->camera.direction = mat2D_alloc(3, 1);
00342     mat2D_fill(scene->camera.direction, 0);
00343     MAT2D_AT(scene->camera.direction, 2, 0) = 1;
00344
00345     scene->camera.camera_x = mat2D_alloc(3, 1);
00346     mat2D_fill(scene->camera.camera_x, 0);
00347     MAT2D_AT(scene->camera.camera_x, 0, 0) = 1;
00348
00349     scene->camera.camera_y = mat2D_alloc(3, 1);
00350     mat2D_fill(scene->camera.camera_y, 0);
00351     MAT2D_AT(scene->camera.camera_y, 1, 0) = 1;
00352
00353     scene->camera.camera_z = mat2D_alloc(3, 1);
00354     mat2D_fill(scene->camera.camera_z, 0);
00355     MAT2D_AT(scene->camera.camera_z, 2, 0) = 1;
00356 }
00357
00366 void ae_camera_free(Scene *scene)
00367 {
00368     mat2D_free(scene->camera.init_position);
00369     mat2D_free(scene->camera.current_position);
00370     mat2D_free(scene->camera.offset_position);
00371     mat2D_free(scene->camera.direction);
```

```
00372     mat2D_free(scene->camera.camera_x);
00373     mat2D_free(scene->camera.camera_y);
00374     mat2D_free(scene->camera.camera_z);
00375 }
00376
00388 Scene ae_scene_init(int window_h, int window_w)
00389 {
00390     Scene scene = {0};
00391     ae_camera_init(&(scene), window_h, window_w);
00392
00393     scene.up_direction = mat2D_alloc(3, 1);
00394     mat2D_fill(scene.up_direction, 0);
00395     MAT2D_AT(scene.up_direction, 1, 0) = 1;
00396
00397     scene.light_source0.light_direction_or_pos.x = 0.5;
00398     scene.light_source0.light_direction_or_pos.y = 1;
00399     scene.light_source0.light_direction_or_pos.z = 1;
00400     scene.light_source0.light_direction_or_pos.w = 0;
00401     scene.light_source0.light_direction_or_pos =
      ae_point_normalize_xyz(scene.light_source0.light_direction_or_pos);
00402     scene.light_source0.light_intensity = 1;
00403
00404     scene.material0.specular_power_alpha = 1;
00405     scene.material0.c_ambi = 0.2;
00406     scene.material0.c_diff = 0.6;
00407     scene.material0.c_spec = 0.2;
00408
00409     scene.proj_mat = mat2D_alloc(4, 4);
00410     ae_projection_mat_set(scene.proj_mat, scene.camera.aspect_ratio, scene.camera.fov_deg,
      scene.camera.z_near, scene.camera.z_far);
00411
00412     scene.view_mat = mat2D_alloc(4, 4);
00413     ae_view_mat_set(scene.view_mat, scene.camera, scene.up_direction);
00414
00415     return scene;
00416 }
00417
00429 void ae_scene_free(Scene *scene)
00430 {
00431     ae_camera_free(scene);
00432     mat2D_free(scene->up_direction);
00433     mat2D_free(scene->proj_mat);
00434     mat2D_free(scene->view_mat);
00435
00436     for (size_t i = 0; i < scene->in_world_tri_meshes.length; i++) {
00437         free(scene->in_world_tri_meshes.elements[i].elements);
00438     }
00439     for (size_t i = 0; i < scene->projected_tri_meshes.length; i++) {
00440         free(scene->projected_tri_meshes.elements[i].elements);
00441     }
00442     for (size_t i = 0; i < scene->original_tri_meshes.length; i++) {
00443         free(scene->original_tri_meshes.elements[i].elements);
00444     }
00445     if (scene->in_world_tri_meshes.elements) free(scene->in_world_tri_meshes.elements);
00446     if (scene->projected_tri_meshes.elements) free(scene->projected_tri_meshes.elements);
00447     if (scene->original_tri_meshes.elements) free(scene->original_tri_meshes.elements);
00448
00449     for (size_t i = 0; i < scene->in_world_quad_meshes.length; i++) {
00450         free(scene->in_world_quad_meshes.elements[i].elements);
00451     }
00452     for (size_t i = 0; i < scene->projected_quad_meshes.length; i++) {
00453         free(scene->projected_quad_meshes.elements[i].elements);
00454     }
00455     for (size_t i = 0; i < scene->original_quad_meshes.length; i++) {
00456         free(scene->original_quad_meshes.elements[i].elements);
00457     }
00458     if (scene->in_world_quad_meshes.elements) free(scene->in_world_quad_meshes.elements);
00459     if (scene->projected_quad_meshes.elements) free(scene->projected_quad_meshes.elements);
00460     if (scene->original_quad_meshes.elements) free(scene->original_quad_meshes.elements);
00461 }
00462
00472 void ae_camera_reset_pos(Scene *scene)
00473 {
00474     scene->camera.roll_offset_deg = 0;
00475     scene->camera.pitch_offset_deg = 0;
00476     scene->camera.yaw_offset_deg = 0;
00477
00478     mat2D_fill(scene->camera.offset_position, 0);
00479
00480     mat2D_fill(scene->camera.camera_x, 0);
00481     MAT2D_AT(scene->camera.camera_x, 0, 0) = 1;
00482     mat2D_fill(scene->camera.camera_y, 0);
00483     MAT2D_AT(scene->camera.camera_y, 1, 0) = 1;
00484     mat2D_fill(scene->camera.camera_z, 0);
00485     MAT2D_AT(scene->camera.camera_z, 2, 0) = 1;
00486
00487     mat2D_copy(scene->camera.current_position, scene->camera.init_position);
```

```
00488 }
00489
00498 void ae_point_to_mat2D(Point p, Mat2D m)
00499 {
00500     MATRIX2D_ASSERT((3 == m.rows && 1 == m.cols) || (1 == m.rows && 3 == m.cols));
00501
00502     if (3 == m.rows) {
00503         MAT2D_AT(m, 0, 0) = p.x;
00504         MAT2D_AT(m, 1, 0) = p.y;
00505         MAT2D_AT(m, 2, 0) = p.z;
00506     }
00507     if (3 == m.cols) {
00508         MAT2D_AT(m, 0, 0) = p.x;
00509         MAT2D_AT(m, 0, 1) = p.y;
00510         MAT2D_AT(m, 0, 2) = p.z;
00511     }
00512 }
00513
00522 Point ae_mat2D_to_point(Mat2D m)
00523 {
00524     Point res = {.x = MAT2D_AT(m, 0, 0), .y = MAT2D_AT(m, 1, 0), .z = MAT2D_AT(m, 2, 0), .w = 1};
00525     return res;
00526 }
00527
00540 Tri_mesh ae_tri_mesh_get_from_obj_file(char *file_path)
00541 {
00542     char current_line[MAX_LEN_LINE], current_word[MAX_LEN_LINE], current_num_str[MAX_LEN_LINE];
00543     char file_name[MAX_LEN_LINE], file_extention[MAX_LEN_LINE], mesh_name[MAX_LEN_LINE];
00544     int texture_warning_was_printed = 0;
00545
00546     strncpy(file_name, file_path, MAX_LEN_LINE);
00547     strncpy(file_extention, file_name, MAX_LEN_LINE);
00548
00549     /* check if file is an obj file*/
00550     asm_get_word_and_cut(file_name, file_extention, '.');
00551     asm_get_word_and_cut(file_name, file_extention, '.');
00552     if (strncmp(file_extention, ".obj", MAX_LEN_LINE)) {
00553         fprintf(stderr, "%s:%d: [Error] unsupported file format: '%s'\n", __FILE__, __LINE__,
      file_name);
00554         exit(1);
00555     }
00556
00557     strncpy(mesh_name, file_name, MAX_LEN_LINE);
00558     while(asm_length(mesh_name)) {
00559         asm_get_word_and_cut(current_word, mesh_name, '/');
00560     }
00561
00562     strncpy(mesh_name, current_word, MAX_LEN_LINE);
00563
00564     strncpy(current_word, ".", MAX_LEN_LINE);
00565     strncat(file_name, ".obj", MAX_LEN_LINE/2);
00566     strncat(current_word, file_name, MAX_LEN_LINE/2);
00567
00568     FILE *fp_input = fopen(current_word, "rt");
00569     if (fp_input == NULL) {
00570         fprintf(stderr, "%s:%d: [Error] failed to open input file: '%s', %s\n", __FILE__, __LINE__,
      current_word, strerror(errno));
00571         exit(1);
00572     }
00573
00574     // strncpy(output_file_name, "./build/", MAX_LEN_LINE);
00575     // strncat(output_file_name, mesh_name, MAX_LEN_LINE/2);
00576     // strncat(output_file_name, ".c", MAX_LEN_LINE/2);
00577     // FILE *fp_output = fopen(output_file_name, "wt");
00578     // if (fp_input == NULL) {
00579     //     fprintf(stderr, "%s:%d: [Error] failed to open output file: '%s'. %s\n", __FILE__,
      __LINE__, output_file_name, strerror(errno));
00580     //     exit(1);
00581     // }
00582
00583     /* parsing data from file */
00584     Curve points = {0};
00585     ada_init_array(Point, points);
00586     Tri_mesh mesh;
00587     ada_init_array(Tri, mesh);
00588
00589     int line_len;
00590
00591     while ((line_len = asm_get_line(fp_input, current_line)) != -1) {
00592         asm_get_next_word_from_line(current_word, current_line, ' ');
00593         if (!strncmp(current_word, "v", 1)) {
00594             Point p;
00595             asm_get_word_and_cut(current_word, current_line, ' ');
00596             asm_get_word_and_cut(current_word, current_line, ' ');
00597             p.x = atof(current_word);
00598             asm_get_word_and_cut(current_word, current_line, ' ');
00599             p.y = atof(current_word);
```

```
00600             asm_get_word_and_cut(current_word, current_line, ' ');
00601             p.z = atof(current_word);
00602             // printf("current word: %s\n", current_word);
00603             ada_append(Point, points, p);
00604             // break;
00605         }
00606         if (!strncmp(current_word, "f", 1)) {
00607             Tri tri1 = {0}, tri2 = {0};
00608 
00609             // printf("line: %s\nword: %s, %d\n", current_line, current_word, atoi(current_word));
00610             asm_get_word_and_cut(current_word, current_line, ' ');
00611             // printf("line: %s\nword: %s, %d\n", current_line, current_word, atoi(current_word));
00612 
00613             int number_of_spaces = asm_str_in_str(current_line, " ");
00614             // printf("%d\n", number_of_spaces);
00615             // exit(1);
00616             if (!(number_of_spaces == 3 || number_of_spaces == 4 || number_of_spaces == 5)) {
00617                 fprintf(stderr, "%s:%d: [Error] there is unsupported number of vertices for a face:
    %d\n", __FILE__, __LINE__, number_of_spaces);
00618                 exit(1);
00619             }
00620             if (number_of_spaces == 3) {
00621                 /* there are 3 vertices for the face. */
00622                 asm_get_word_and_cut(current_word, current_line, ' ');
00623                 // printf("line: %s\nword: %s, %d\n", current_line, current_word, atoi(current_word));
00624                 int number_of_backslash = asm_str_in_str(current_word, "/");
00625                 if (number_of_backslash == 0) {
00626                     tri1.points[0] = points.elements[atoi(current_word)-1];
00627                     asm_get_word_and_cut(current_word, current_line, ' ');
00628                     tri1.points[1] = points.elements[atoi(current_word)-1];
00629                     asm_get_word_and_cut(current_word, current_line, ' ');
00630                     tri1.points[2] = points.elements[atoi(current_word)-1];
00631                 }
00632                 if (number_of_backslash == 2) {
00633                     if (!texture_warning_was_printed) {
00634                         fprintf(stderr, "%s:%d [Warning] texture and normals data ignored of file at -
    '%s'\n", __FILE__, __LINE__, file_path);
00635                         texture_warning_was_printed = 1;
00636                     }
00637 
00638                     asm_get_word_and_cut(current_num_str, current_word, '/');
00639                     // printf("line: %s\nword: %s\nnum str: %s, %d\n", current_line, current_word,
    current_num_str, atoi(current_num_str));
00640                     tri1.points[0] = points.elements[atoi(current_num_str)-1];
00641 
00642                     asm_get_word_and_cut(current_word, current_line, ' ');
00643                     asm_get_word_and_cut(current_num_str, current_word, '/');
00644                     // printf("line: %s\nword: %s\nnum str: %s, %d\n", current_line, current_word,
    current_num_str, atoi(current_num_str));
00645                     tri1.points[1] = points.elements[atoi(current_num_str)-1];
00646 
00647                     asm_get_word_and_cut(current_word, current_line, ' ');
00648                     asm_get_word_and_cut(current_num_str, current_word, '/');
00649                     // printf("line: %s\nword: %s\nnum str: %s, %d\n", current_line, current_word,
    current_num_str, atoi(current_num_str));
00650                     tri1.points[2] = points.elements[atoi(current_num_str)-1];
00651                 }
00652 
00653                 tri1.to_draw = true;
00654                 tri1.light_intensity[0] = 1;
00655                 tri1.light_intensity[1] = 1;
00656                 tri1.light_intensity[2] = 1;
00657                 tri1.colors[0] = 0xFFFFFFFF;
00658                 tri1.colors[1] = 0xFFFFFFFF;
00659                 tri1.colors[2] = 0xFFFFFFFF;
00660 
00661                 ada_append(Tri, mesh, tri1);
00662                 // AE_PRINT_TRI(tri1);
00663             } else if (number_of_spaces == 5 || number_of_spaces == 4) {
00664                 /* there are 4 vertices for the face. */
00665                 /* sometimes there is a space in the end */
00666                 asm_get_word_and_cut(current_word, current_line, ' ');
00667                 // printf("line: %s\nword: %s, %d\n", current_line, current_word, atoi(current_word));
00668                 int number_of_backslash = asm_str_in_str(current_word, "/");
00669                 if (number_of_backslash == 0) {
00670                     tri1.points[0] = points.elements[atoi(current_word)-1];
00671                     asm_get_word_and_cut(current_word, current_line, ' ');
00672                     tri1.points[1] = points.elements[atoi(current_word)-1];
00673                     asm_get_word_and_cut(current_word, current_line, ' ');
00674                     tri1.points[2] = points.elements[atoi(current_word)-1];
00675                 }
00676                 if (number_of_backslash == 2 || number_of_backslash == 1) {
00677                     if (!texture_warning_was_printed) {
00678                         fprintf(stderr, "%s:%d [Warning] texture and normals data ignored of file at -
    '%s'\n", __FILE__, __LINE__, file_path);
00679                         texture_warning_was_printed = 1;
00680                     }
```

```
00681
00682                   asm_get_word_and_cut(current_num_str, current_word, '/');
00683                   // printf("line: %s\nword: %s\nnum str: %s, %d\n", current_line, current_word,
      current_num_str, atoi(current_num_str));
00684                   tri1.points[0] = points.elements[atoi(current_num_str)-1];
00685                   tri2.points[2] = points.elements[atoi(current_num_str)-1];
00686
00687                   asm_get_word_and_cut(current_word, current_line, ' ');
00688                   asm_get_word_and_cut(current_num_str, current_word, '/');
00689                   // printf("line: %s\nword: %s\nnum str: %s, %d\n", current_line, current_word,
      current_num_str, atoi(current_num_str));
00690                   tri1.points[1] = points.elements[atoi(current_num_str)-1];
00691
00692                   asm_get_word_and_cut(current_word, current_line, ' ');
00693                   asm_get_word_and_cut(current_num_str, current_word, '/');
00694                   // printf("line: %s\nword: %s\nnum str: %s, %d\n", current_line, current_word,
      current_num_str, atoi(current_num_str));
00695                   tri1.points[2] = points.elements[atoi(current_num_str)-1];
00696                   tri2.points[0] = points.elements[atoi(current_num_str)-1];
00697
00698                   asm_get_word_and_cut(current_word, current_line, ' ');
00699                   asm_get_word_and_cut(current_num_str, current_word, '/');
00700                   // printf("line: %s\nword: %s\nnum str: %s, %d\n", current_line, current_word,
      current_num_str, atoi(current_num_str));
00701                   tri2.points[1] = points.elements[atoi(current_num_str)-1];
00702               }
00703
00704               tri1.to_draw = true;
00705               tri1.light_intensity[0] = 1;
00706               tri1.light_intensity[1] = 1;
00707               tri1.light_intensity[2] = 1;
00708               tri1.colors[0] = 0xFFFFFFFF;
00709               tri1.colors[1] = 0xFFFFFFFF;
00710               tri1.colors[2] = 0xFFFFFFFF;
00711
00712               tri2.to_draw = true;
00713               tri2.light_intensity[0] = 1;
00714               tri2.light_intensity[1] = 1;
00715               tri2.light_intensity[2] = 1;
00716               tri2.colors[0] = 0xFFFFFFFF;
00717               tri2.colors[1] = 0xFFFFFFFF;
00718               tri2.colors[2] = 0xFFFFFFFF;
00719
00720               ada_append(Tri, mesh, tri1);
00721               ada_append(Tri, mesh, tri2);
00722               // AE_PRINT_TRI(tri1);
00723               // AE_PRINT_TRI(tri2);
00724           }
00725           // exit(2);
00726       }
00727   }
00728
00729   return mesh;
00730 }
00731
00743 Tri_mesh ae_tri_mesh_get_from_stl_file(char *file_path)
00744 {
00745   FILE *file;
00746   file = fopen(file_path, "rb");
00747   if (file == NULL) {
00748       fprintf(stderr, "%s:%d: [Error] failed to open input file: '%s', %s\n", __FILE__, __LINE__,
      file_path, strerror(errno));
00749       exit(1);
00750   }
00751
00752   char header[STL_HEADER_SIZE];
00753   fread(header, STL_HEADER_SIZE, 1, file);
00754   // dprintSTRING(header);
00755
00756   uint32_t num_of_tri;
00757   fread(&num_of_tri, STL_NUM_SIZE, 1, file);
00758   // dprintINT(num_of_tri);
00759
00760   Tri_mesh mesh;
00761   ada_init_array(Tri, mesh);
00762   for (size_t i = 0; i < num_of_tri; i++) {
00763       Tri temp_tri = {0};
00764
00765       fread(&(temp_tri.normals[0].x), STL_NUM_SIZE, 1, file);
00766       fread(&(temp_tri.normals[0].y), STL_NUM_SIZE, 1, file);
00767       fread(&(temp_tri.normals[0].z), STL_NUM_SIZE, 1, file);
00768
00769       temp_tri.normals[0].x = - temp_tri.normals[0].x;
00770       temp_tri.normals[0].y = - temp_tri.normals[0].y;
00771       temp_tri.normals[0].z = - temp_tri.normals[0].z;
00772
00773       temp_tri.normals[1] = temp_tri.normals[0];
```

```
00774         temp_tri.normals[2] = temp_tri.normals[0];
00775
00776         fread(&(temp_tri.points[0].x), STL_NUM_SIZE, 1, file);
00777         fread(&(temp_tri.points[0].y), STL_NUM_SIZE, 1, file);
00778         fread(&(temp_tri.points[0].z), STL_NUM_SIZE, 1, file);
00779
00780         fread(&(temp_tri.points[1].x), STL_NUM_SIZE, 1, file);
00781         fread(&(temp_tri.points[1].y), STL_NUM_SIZE, 1, file);
00782         fread(&(temp_tri.points[1].z), STL_NUM_SIZE, 1, file);
00783
00784         fread(&(temp_tri.points[2].x), STL_NUM_SIZE, 1, file);
00785         fread(&(temp_tri.points[2].y), STL_NUM_SIZE, 1, file);
00786         fread(&(temp_tri.points[2].z), STL_NUM_SIZE, 1, file);
00787
00788         fseek(file, STL_ATTRIBUTE_BITS_SIZE, SEEK_CUR);
00789
00790         temp_tri.to_draw = true;
00791         temp_tri.light_intensity[0] = 1;
00792         temp_tri.light_intensity[1] = 1;
00793         temp_tri.light_intensity[2] = 1;
00794         temp_tri.colors[0] = 0xFFFFFFFF;
00795         temp_tri.colors[1] = 0xFFFFFFFF;
00796         temp_tri.colors[2] = 0xFFFFFFFF;
00797
00798         // ae_tri_set_normals(&temp_tri);
00799
00800         ada_append(Tri, mesh, temp_tri);
00801     }
00802
00803     return mesh;
00804 }
00805
00816 Tri_mesh ae_tri_mesh_get_from_file(char *file_path)
00817 {
00818     char file_extention[MAX_LEN_LINE], temp_word[MAX_LEN_LINE];
00819
00820     strncpy(file_extention, file_path, MAX_LEN_LINE);
00821
00822     int num_of_dots;
00823     while ((num_of_dots = asm_str_in_str(file_extention, ".")) >= 1) {
00824         asm_get_word_and_cut(temp_word, file_extention, '.');
00825     }
00826
00827     if (!(!strncmp(file_extention, "obj", 3) || !strncmp(file_extention, "STL", 3) ||
       !strncmp(file_extention, "stl", 3))) {
00828         fprintf(stderr, "%s:%d: [Error] unsupported file format: '%s'\n", __FILE__, __LINE__,
       file_path);
00829         exit(1);
00830     }
00831
00832     if (!strncmp(file_extention, "STL", 3) || !strncmp(file_extention, "stl", 3)) {
00833         return ae_tri_mesh_get_from_stl_file(file_path);
00834     } else if (!strncmp(file_extention, "obj", 3)) {
00835         return ae_tri_mesh_get_from_obj_file(file_path);
00836     }
00837
00838     Tri_mesh null_mesh = {0};
00839     return null_mesh;
00840 }
00841
00851 void ae_tri_mesh_append_copy(Tri_mesh_array *mesh_array, Tri_mesh mesh)
00852 {
00853     Tri_mesh_array temp_mesh_array = *mesh_array;
00854     Tri_mesh temp_mesh;
00855     ada_init_array(Tri, temp_mesh);
00856     for (size_t i = 0; i < mesh.length; i++) {
00857         ada_append(Tri, temp_mesh, mesh.elements[i]);
00858     }
00859     ada_append(Tri_mesh, temp_mesh_array, temp_mesh);
00860
00861
00862     *mesh_array = temp_mesh_array;
00863 }
00864
00875 Tri_mesh ae_tri_mesh_get_from_quad_mesh(Quad_mesh q_mesh)
00876 {
00877     Tri_mesh t_mesh;
00878     ada_init_array(Tri, t_mesh);
00879
00880     for (size_t q_index = 0; q_index < q_mesh.length; q_index++) {
00881         Quad current_q = q_mesh.elements[q_index];
00882         Tri temp_t = {.to_draw = current_q.to_draw};
00883
00884         temp_t.points[0] = current_q.points[0];
00885         temp_t.colors[0] = current_q.colors[0];
00886         temp_t.normals[0] = current_q.normals[0];
00887         temp_t.light_intensity[0] = current_q.light_intensity[0];
```

```
00888         temp_t.points[1] = current_q.points[1];
00889         temp_t.colors[1] = current_q.colors[1];
00890         temp_t.normals[1] = current_q.normals[1];
00891         temp_t.light_intensity[1] = current_q.light_intensity[1];
00892         temp_t.points[2] = current_q.points[2];
00893         temp_t.colors[2] = current_q.colors[2];
00894         temp_t.normals[2] = current_q.normals[2];
00895         temp_t.light_intensity[2] = current_q.light_intensity[2];
00896 
00897         ada_append(Tri, t_mesh, temp_t);
00898 
00899         temp_t.points[0] = current_q.points[2];
00900         temp_t.colors[0] = current_q.colors[2];
00901         temp_t.normals[0] = current_q.normals[2];
00902         temp_t.light_intensity[0] = current_q.light_intensity[2];
00903         temp_t.points[1] = current_q.points[3];
00904         temp_t.colors[1] = current_q.colors[3];
00905         temp_t.normals[1] = current_q.normals[3];
00906         temp_t.light_intensity[1] = current_q.light_intensity[3];
00907         temp_t.points[2] = current_q.points[0];
00908         temp_t.colors[2] = current_q.colors[0];
00909         temp_t.normals[2] = current_q.normals[0];
00910         temp_t.light_intensity[2] = current_q.light_intensity[0];
00911 
00912         ada_append(Tri, t_mesh, temp_t);
00913     }
00914 
00915     return t_mesh;
00916 }
00917 
00925 void ae_print_points(Curve p)
00926 {
00927     for (size_t i = 0; i < p.length; i++) {
00928         printf("point %3zu: (%5f, %5f, %5f)\n", i, p.elements[i].x, p.elements[i].y, p.elements[i].z);
00929     }
00930 }
00931 
00942 void ae_print_tri(Tri tri, char *name, size_t padding)
00943 {
00944     printf("%*s%s:\n", (int) padding, "", name);
00945     printf("%*s    (%f, %f, %f)\n%*s    (%f, %f, %f)\n%*s    (%f, %f, %f)\n", (int) padding, "",
       tri.points[0].x, tri.points[0].y, tri.points[0].z, (int) padding, "", tri.points[1].x,
       tri.points[1].y, tri.points[1].z, (int) padding, "", tri.points[2].x, tri.points[2].y,
       tri.points[2].z);
00946     printf("%*s    draw? %d\n", (int)padding, "", tri.to_draw);
00947 }
00948 
00958 void ae_print_tri_mesh(Tri_mesh mesh, char *name, size_t padding)
00959 {
00960     char tri_name[256];
00961     printf("%*s%s:\n", (int) padding, "", name);
00962     for (size_t i = 0; i < mesh.length; i++) {
00963         snprintf(tri_name, 256, "tri %zu", i);
00964         ae_print_tri(mesh.elements[i], tri_name, 4);
00965     }
00966 }
00967 
00976 Point ae_point_normalize_xyz(Point p)
00977 {
00978     Point res = {0};
00979 
00980     float norma = ae_point_calc_norma(p);
00981 
00982     res.x = p.x / norma;
00983     res.y = p.y / norma;
00984     res.z = p.z / norma;
00985     res.w = p.w;
00986 
00987     return res;
00988 }
00989 
00998 void ae_tri_set_normals(Tri *tri)
00999 {
01000     ae_assert_tri_is_valid(*tri);
01001 
01002     Mat2D point  = mat2D_alloc(3, 1);
01003     Mat2D to_p   = mat2D_alloc(3, 1);
01004     Mat2D from_p = mat2D_alloc(3, 1);
01005     Mat2D normal = mat2D_alloc(3, 1);
01006 
01007     for (int i = 0; i < 3; i++) {
01008         int current_index  = i;
01009         int next_index     = (i + 1) % 3;
01010         int previous_index = (i - 1 + 3) % 3;
01011         ae_point_to_mat2D(tri->points[current_index], point);
01012         ae_point_to_mat2D(tri->points[next_index], from_p);
01013         ae_point_to_mat2D(tri->points[previous_index], to_p);
```

```
01014
01015         mat2D_sub(from_p, point);
01016         mat2D_sub(point, to_p);
01017
01018         mat2D_copy(to_p, point);
01019
01020         mat2D_cross(normal, to_p, from_p);
01021         // mat2D_cross(normal, from_p, to_p);
01022         mat2D_normalize(normal);
01023
01024         tri->normals[current_index] = ae_mat2D_to_point(normal);
01025     }
01026
01027     mat2D_free(point);
01028     mat2D_free(to_p);
01029     mat2D_free(from_p);
01030     mat2D_free(normal);
01031 }
01032
01041 Point ae_tri_get_average_normal(Tri tri)
01042 {
01043     Point normal0 = tri.normals[0];
01044     Point normal1 = tri.normals[1];
01045     Point normal2 = tri.normals[2];
01046
01047     Point res;
01048     res.x = (normal0.x + normal1.x + normal2.x) / 3;
01049     res.y = (normal0.y + normal1.y + normal2.y) / 3;
01050     res.z = (normal0.z + normal1.z + normal2.z) / 3;
01051     res.w = (normal0.w + normal1.w + normal2.w) / 3;
01052
01053     return ae_point_normalize_xyz(res);
01054 }
01055
01062 Point ae_tri_get_average_point(Tri tri)
01063 {
01064     Point point0 = tri.points[0];
01065     Point point1 = tri.points[1];
01066     Point point2 = tri.points[2];
01067
01068     Point res;
01069     res.x = (point0.x + point1.x + point2.x) / 3;
01070     res.y = (point0.y + point1.y + point2.y) / 3;
01071     res.z = (point0.z + point1.z + point2.z) / 3;
01072     res.w = (point0.w + point1.w + point2.w) / 3;
01073
01074     return res;
01075 }
01076
01086 void ae_tri_calc_normal(Mat2D normal, Tri tri)
01087 {
01088     AE_ASSERT(3 == normal.rows && 1 == normal.cols);
01089     ae_assert_tri_is_valid(tri);
01090
01091     Mat2D a = mat2D_alloc(3, 1);
01092     Mat2D b = mat2D_alloc(3, 1);
01093     Mat2D c = mat2D_alloc(3, 1);
01094
01095     ae_point_to_mat2D(tri.points[0], a);
01096     ae_point_to_mat2D(tri.points[1], b);
01097     ae_point_to_mat2D(tri.points[2], c);
01098
01099     mat2D_sub(b, a);
01100     mat2D_sub(c, a);
01101
01102     mat2D_cross(normal, b, c);
01103
01104     mat2D_mult(normal, 1/mat2D_calc_norma(normal));
01105
01106     mat2D_free(a);
01107     mat2D_free(b);
01108     mat2D_free(c);
01109 }
01110
01121 void ae_tri_mesh_translate(Tri_mesh mesh, float x, float y, float z)
01122 {
01123     for (size_t i = 0; i < mesh.length; i++) {
01124         for (int j = 0; j < 3; j++) {
01125             mesh.elements[i].points[j].x += x;
01126             mesh.elements[i].points[j].y += y;
01127             mesh.elements[i].points[j].z += z;
01128         }
01129     }
01130 }
01131
01143 void ae_tri_mesh_rotate_Euler_xyz(Tri_mesh mesh, float phi_deg, float theta_deg, float psi_deg)
01144 {
```

```
01145     Mat2D RotZ = mat2D_alloc(3,3);
01146     mat2D_set_rot_mat_z(RotZ, psi_deg);
01147     Mat2D RotY = mat2D_alloc(3,3);
01148     mat2D_set_rot_mat_y(RotY, theta_deg);
01149     Mat2D RotX = mat2D_alloc(3,3);
01150     mat2D_set_rot_mat_x(RotX, phi_deg);
01151     Mat2D DCM = mat2D_alloc(3,3);
01152     // mat2D_fill(DCM,0);
01153     Mat2D temp = mat2D_alloc(3,3);
01154     // mat2D_fill(temp,0);
01155     mat2D_dot(temp, RotY, RotZ);
01156     mat2D_dot(DCM, RotX, temp); /* I have a DCM */
01157
01158     Mat2D src_point_mat = mat2D_alloc(3,1);
01159     Mat2D des_point_mat = mat2D_alloc(3,1);
01160
01161     for (size_t i = 0; i < mesh.length; i++) {
01162         for (int j = 0; j < 3; j++) {
01163             // mat2D_fill(src_point_mat, 0);
01164             // mat2D_fill(des_point_mat, 0);
01165             Point des;
01166             Point src = mesh.elements[i].points[j];
01167
01168             MAT2D_AT(src_point_mat, 0, 0) = src.x;
01169             MAT2D_AT(src_point_mat, 1, 0) = src.y;
01170             MAT2D_AT(src_point_mat, 2, 0) = src.z;
01171
01172             mat2D_dot(des_point_mat, DCM, src_point_mat);
01173
01174             des.x = MAT2D_AT(des_point_mat, 0, 0);
01175             des.y = MAT2D_AT(des_point_mat, 1, 0);
01176             des.z = MAT2D_AT(des_point_mat, 2, 0);
01177
01178             mesh.elements[i].points[j] = des;
01179         }
01180     }
01181
01182     ae_tri_mesh_set_normals(mesh);
01183
01184     mat2D_free(RotZ);
01185     mat2D_free(RotY);
01186     mat2D_free(RotX);
01187     mat2D_free(DCM);
01188     mat2D_free(temp);
01189     mat2D_free(src_point_mat);
01190     mat2D_free(des_point_mat);
01191 }
01192
01206 void ae_tri_mesh_set_bounding_box(Tri_mesh mesh, float *x_min, float *x_max, float *y_min, float
       *y_max, float *z_min, float *z_max)
01207 {
01208     float xmin = FLT_MAX, xmax = FLT_MIN;
01209     float ymin = FLT_MAX, ymax = FLT_MIN;
01210     float zmin = FLT_MAX, zmax = FLT_MIN;
01211
01212     float x, y, z;
01213
01214     for (size_t t = 0; t < mesh.length; t++) {
01215         for (size_t p = 0; p < 3; p++) {
01216             x = mesh.elements[t].points[p].x;
01217             y = mesh.elements[t].points[p].y;
01218             z = mesh.elements[t].points[p].z;
01219             if (x > xmax) xmax = x;
01220             if (x < xmin) xmin = x;
01221             if (y > ymax) ymax = y;
01222             if (y < ymin) ymin = y;
01223             if (z > zmax) zmax = z;
01224             if (z < zmin) zmin = z;
01225         }
01226     }
01227     *x_min = xmin;
01228     *x_max = xmax;
01229     *y_min = ymin;
01230     *y_max = ymax;
01231     *z_min = zmin;
01232     *z_max = zmax;
01233 }
01234
01244 void ae_tri_mesh_normalize(Tri_mesh mesh)
01245 {
01246     float xmax, xmin, ymax, ymin, zmax, zmin;
01247     ae_tri_mesh_set_bounding_box(mesh, &xmin, &xmax, &ymin, &ymax, &zmin, &zmax);
01248
01249     for (size_t t = 0; t < mesh.length; t++) {
01250         for (size_t p = 0; p < 3; p++) {
01251             float x, y, z;
01252             x = mesh.elements[t].points[p].x;
```

```
01253             y = mesh.elements[t].points[p].y;
01254             z = mesh.elements[t].points[p].z;
01255
01256             float xdiff = xmax-xmin;
01257             float ydiff = ymax-ymin;
01258             float zdiff = zmax-zmin;
01259             float max_diff = fmax(xdiff, fmax(ydiff, zdiff));
01260             float xfactor = xdiff/max_diff;
01261             float yfactor = ydiff/max_diff;
01262             float zfactor = zdiff/max_diff;
01263
01264             x = (((x - xmin) / (xdiff)) * 2 - 1) * xfactor;
01265             y = (((y - ymin) / (ydiff)) * 2 - 1) * yfactor;
01266             z = (((z - zmin) / (zdiff)) * 2 - 1) * zfactor;
01267
01268             mesh.elements[t].points[p].x = x;
01269             mesh.elements[t].points[p].y = y;
01270             mesh.elements[t].points[p].z = z;
01271         }
01272     }
01273 }
01274
01283 void ae_tri_mesh_flip_normals(Tri_mesh mesh)
01284 {
01285     for (size_t i = 0; i < mesh.length; i++) {
01286         Tri res_tri, tri = mesh.elements[i];
01287
01288         res_tri.to_draw = tri.to_draw;
01289
01290         res_tri.colors[0]          = tri.colors[2];
01291         res_tri.light_intensity[0] = tri.light_intensity[2];
01292         res_tri.normals[0]         = tri.normals[2];
01293         res_tri.points[0]          = tri.points[2];
01294         res_tri.tex_points[0]      = tri.tex_points[2];
01295
01296         res_tri.colors[1]          = tri.colors[1];
01297         res_tri.light_intensity[1] = tri.light_intensity[1];
01298         res_tri.normals[1]         = tri.normals[1];
01299         res_tri.points[1]          = tri.points[1];
01300         res_tri.tex_points[1]      = tri.tex_points[1];
01301
01302         res_tri.colors[2]          = tri.colors[0];
01303         res_tri.light_intensity[2] = tri.light_intensity[0];
01304         res_tri.normals[2]         = tri.normals[0];
01305         res_tri.points[2]          = tri.points[0];
01306         res_tri.tex_points[2]      = tri.tex_points[0];
01307
01308         ae_tri_set_normals(&res_tri);
01309
01310         mesh.elements[i] = res_tri;
01311     }
01312 }
01313
01321 void ae_tri_mesh_set_normals(Tri_mesh mesh)
01322 {
01323     for (size_t i = 0; i < mesh.length; i++) {
01324         ae_tri_set_normals(&(mesh.elements[i]));
01325     }
01326 }
01327
01336 void ae_quad_set_normals(Quad *quad)
01337 {
01338     ae_assert_quad_is_valid(*quad);
01339
01340     Mat2D point  = mat2D_alloc(3, 1);
01341     Mat2D to_p   = mat2D_alloc(3, 1);
01342     Mat2D from_p = mat2D_alloc(3, 1);
01343     Mat2D normal = mat2D_alloc(3, 1);
01344
01345     for (int i = 0; i < 4; i++) {
01346         int current_index  = i;
01347         int next_index     = (i + 1) % 4;
01348         int previous_index = (i - 1 + 4) % 4;
01349         ae_point_to_mat2D(quad->points[current_index], point);
01350         ae_point_to_mat2D(quad->points[next_index], from_p);
01351         ae_point_to_mat2D(quad->points[previous_index], to_p);
01352
01353         mat2D_sub(from_p, point);
01354         mat2D_sub(point, to_p);
01355
01356         mat2D_copy(to_p, point);
01357
01358         mat2D_cross(normal, to_p, from_p);
01359         mat2D_normalize(normal);
01360
01361         quad->normals[current_index] = ae_mat2D_to_point(normal);
01362     }
```

```
01363
01364     mat2D_free(point);
01365     mat2D_free(to_p);
01366     mat2D_free(from_p);
01367     mat2D_free(normal);
01368
01369 }
01370
01379 Point ae_quad_get_average_normal(Quad quad)
01380 {
01381     Point normal0 = quad.normals[0];
01382     Point normal1 = quad.normals[1];
01383     Point normal2 = quad.normals[2];
01384     Point normal3 = quad.normals[3];
01385
01386     Point res;
01387     res.x = (normal0.x + normal1.x + normal2.x + normal3.x) / 4;
01388     res.y = (normal0.y + normal1.y + normal2.y + normal3.y) / 4;
01389     res.z = (normal0.z + normal1.z + normal2.z + normal3.z) / 4;
01390     res.w = (normal0.w + normal1.w + normal2.w + normal3.w) / 4;
01391
01392     res = ae_point_normalize_xyz(res);
01393
01394     return res;
01395 }
01396
01403 Point ae_quad_get_average_point(Quad quad)
01404 {
01405     Point point0 = quad.points[0];
01406     Point point1 = quad.points[1];
01407     Point point2 = quad.points[2];
01408     Point point3 = quad.points[3];
01409
01410     Point res;
01411     res.x = (point0.x + point1.x + point2.x + point3.x) / 4;
01412     res.y = (point0.y + point1.y + point2.y + point3.y) / 4;
01413     res.z = (point0.z + point1.z + point2.z + point3.z) / 4;
01414     res.w = (point0.w + point1.w + point2.w + point3.w) / 4;
01415
01416     return res;
01417 }
01418
01428 void ae_quad_calc_normal(Mat2D normal, Quad quad)
01429 {
01430     AE_ASSERT(3 == normal.rows && 1 == normal.cols);
01431     ae_assert_quad_is_valid(quad);
01432
01433     Mat2D a = mat2D_alloc(3, 1);
01434     Mat2D b = mat2D_alloc(3, 1);
01435     Mat2D c = mat2D_alloc(3, 1);
01436
01437     ae_point_to_mat2D(quad.points[0], a);
01438     ae_point_to_mat2D(quad.points[1], b);
01439     ae_point_to_mat2D(quad.points[2], c);
01440
01441     mat2D_sub(b, a);
01442     mat2D_sub(c, a);
01443
01444     mat2D_cross(normal, b, c);
01445
01446     mat2D_mult(normal, 1/mat2D_calc_norma(normal));
01447
01448     mat2D_free(a);
01449     mat2D_free(b);
01450     mat2D_free(c);
01451 }
01452
01461 void ae_curve_copy(Curve *des, Curve src)
01462 {
01463     Curve temp_des = *des;
01464     temp_des.length = 0;
01465
01466     for (size_t i = 0; i < src.length; i++) {
01467         ada_append(Point, temp_des, src.elements[i]);
01468     }
01469
01470     *des = temp_des;
01471 }
01472
01487 void ae_tri_calc_light_intensity(Tri *tri, Scene *scene, Lighting_mode lighting_mode)
01488 {
01489     /* based on the lighting model described in: 'Alexandru C. Telea-Data Visualization_ Principles
       and Practice-A K Peters_CRC Press (2014)' Pg.29 */
01490     Point L = {0};
01491     Point r = {0};
01492     Point v = {0};
01493     Point mL = {0};
```

```
01494     Point pml = {0};
01495     Point mLn2n = {0};
01496     Point ave_norm = ae_tri_get_average_normal(*tri);
01497     Point camera_pos = ae_mat2D_to_point(scene->camera.current_position);
01498 
01499     float c_ambi = scene->material0.c_ambi;
01500     float c_diff = scene->material0.c_diff;
01501     float c_spec = scene->material0.c_spec;
01502     float alpha  = scene->material0.specular_power_alpha;
01503 
01504     switch (lighting_mode) {
01505     case AE_LIGHTING_FLAT:
01506         for (int i = 0; i < 3; i++) {
01507             if (scene->light_source0.light_direction_or_pos.w == 0) {
01508                 L = scene->light_source0.light_direction_or_pos;
01509                 L = ae_point_normalize_xyz(L);
01510                 mL = L;
01511                 ae_point_mult(mL, -1);
01512             } else {
01513                 Point l = scene->light_source0.light_direction_or_pos;
01514                 Point p = tri->points[i];
01515                 ae_point_sub_point(pml, p, l);
01516                 pml = ae_point_normalize_xyz(pml);
01517                 L = pml;
01518                 L.w = 0;
01519                 mL = L;
01520                 ae_point_mult(mL, -1);
01521             }
01522 
01523             ae_point_sub_point(v, camera_pos, ae_tri_get_average_point(*tri));
01524             float mL_dot_norm = ae_point_dot_point(mL, ave_norm);
01525             mLn2n = ave_norm;
01526             ae_point_mult(mLn2n, 2 * mL_dot_norm);
01527             ae_point_add_point(r, L, mLn2n);
01528 
01529             tri->light_intensity[i] = c_ambi + scene->light_source0.light_intensity * (c_diff *
      fmaxf(mL_dot_norm, 0) + c_spec * powf(fmaxf(ae_point_dot_point(r, v), 0), alpha));
01530         }
01531         break;
01532     case AE_LIGHTING_SMOOTH:
01533         for (int i = 0; i < 3; i++) {
01534             if (scene->light_source0.light_direction_or_pos.w == 0) {
01535                 L = scene->light_source0.light_direction_or_pos;
01536                 L = ae_point_normalize_xyz(L);
01537                 mL = L;
01538                 ae_point_mult(mL, -1);
01539             } else {
01540                 Point l = scene->light_source0.light_direction_or_pos;
01541                 Point p = tri->points[i];
01542                 ae_point_sub_point(pml, p, l);
01543                 pml = ae_point_normalize_xyz(pml);
01544                 L = pml;
01545                 L.w = 0;
01546                 mL = L;
01547                 ae_point_mult(mL, -1);
01548             }
01549             ae_point_sub_point(v, camera_pos, tri->points[i]);
01550             float mL_dot_norm = ae_point_dot_point(mL, tri->normals[i]);
01551             mLn2n = tri->normals[i];
01552             ae_point_mult(mLn2n, 2 * mL_dot_norm);
01553             ae_point_add_point(r, L, mLn2n);
01554 
01555             tri->light_intensity[i] = c_ambi + scene->light_source0.light_intensity * (c_diff *
      fmaxf(mL_dot_norm, 0) + c_spec * powf(fmaxf(ae_point_dot_point(r, v), 0), alpha));
01556         }
01557         break;
01558     default:
01559         for (int i = 0; i < 3; i++) {
01560             tri->light_intensity[i] = 1;
01561         }
01562         break;
01563     }
01564 
01565     for (int i = 0; i < 3; i++) {
01566         tri->light_intensity[i] = fminf(1, fmaxf(0, tri->light_intensity[i]));
01567     }
01568 }
01569 
01580 void ae_quad_calc_light_intensity(Quad *quad, Scene *scene, Lighting_mode lighting_mode)
01581 {
01582     /* based on the lighting model described in: 'Alexandru C. Telea-Data Visualization_ Principles
      and Practice-A K Peters_CRC Press (2014)' Pg.29 */
01583     Point L = {0};
01584     Point r = {0};
01585     Point v = {0};
01586     Point mL = {0};
01587     Point pml = {0};
```

```
01588     Point mLn2n = {0};
01589     Point ave_norm = ae_quad_get_average_normal(*quad);
01590     Point camera_pos = ae_mat2D_to_point(scene->camera.current_position);
01591 
01592     float c_ambi = scene->material0.c_ambi;
01593     float c_diff = scene->material0.c_diff;
01594     float c_spec = scene->material0.c_spec;
01595     float alpha  = scene->material0.specular_power_alpha;
01596 
01597     switch (lighting_mode) {
01598     case AE_LIGHTING_FLAT:
01599         for (int i = 0; i < 4; i++) {
01600             if (scene->light_source0.light_direction_or_pos.w == 0) {
01601                 L = scene->light_source0.light_direction_or_pos;
01602                 L = ae_point_normalize_xyz(L);
01603                 mL = L;
01604                 ae_point_mult(mL, -1);
01605             } else {
01606                 Point l = scene->light_source0.light_direction_or_pos;
01607                 Point p = quad->points[i];
01608                 ae_point_sub_point(pml, p, l);
01609                 pml = ae_point_normalize_xyz(pml);
01610                 L = pml;
01611                 L.w = 0;
01612                 mL = L;
01613                 ae_point_mult(mL, -1);
01614             }
01615 
01616             ae_point_sub_point(v, camera_pos, ae_quad_get_average_point(*quad));
01617             float mL_dot_norm = ae_point_dot_point(mL, ave_norm);
01618             mLn2n = ave_norm;
01619             ae_point_mult(mLn2n, 2 * mL_dot_norm);
01620             ae_point_add_point(r, L, mLn2n);
01621 
01622             quad->light_intensity[i] = c_ambi + scene->light_source0.light_intensity * (c_diff *
      fmaxf(mL_dot_norm, 0) + c_spec * powf(fmaxf(ae_point_dot_point(r, v), 0), alpha));
01623         }
01624         break;
01625     case AE_LIGHTING_SMOOTH:
01626         for (int i = 0; i < 4; i++) {
01627             if (scene->light_source0.light_direction_or_pos.w == 0) {
01628                 L = scene->light_source0.light_direction_or_pos;
01629                 L = ae_point_normalize_xyz(L);
01630                 mL = L;
01631                 ae_point_mult(mL, -1);
01632             } else {
01633                 Point l = scene->light_source0.light_direction_or_pos;
01634                 Point p = quad->points[i];
01635                 ae_point_sub_point(pml, p, l);
01636                 pml = ae_point_normalize_xyz(pml);
01637                 L = pml;
01638                 L.w = 0;
01639                 mL = L;
01640                 ae_point_mult(mL, -1);
01641             }
01642             ae_point_sub_point(v, camera_pos, quad->points[i]);
01643             float mL_dot_norm = ae_point_dot_point(mL, quad->normals[i]);
01644             mLn2n = quad->normals[i];
01645             ae_point_mult(mLn2n, 2 * mL_dot_norm);
01646             ae_point_add_point(r, L, mLn2n);
01647 
01648             quad->light_intensity[i] = c_ambi + scene->light_source0.light_intensity * (c_diff *
      fmaxf(mL_dot_norm, 0) + c_spec * powf(fmaxf(ae_point_dot_point(r, v), 0), alpha));
01649         }
01650         break;
01651     default:
01652         for (int i = 0; i < 4; i++) {
01653             quad->light_intensity[i] = 1;
01654         }
01655         break;
01656     }
01657 
01658     for (int i = 0; i < 4; i++) {
01659         quad->light_intensity[i] = fminf(1, fmaxf(0, quad->light_intensity[i]));
01660     }
01661 }
01662 
01680 Point ae_line_itersect_plane(Mat2D plane_p, Mat2D plane_n, Mat2D line_start, Mat2D line_end, float *t)
01681 {
01682     mat2D_normalize(plane_n);
01683     float plane_d = - mat2D_dot_product(plane_n, plane_p);
01684     float ad = mat2D_dot_product(line_start, plane_n);
01685     float bd = mat2D_dot_product(line_end, plane_n);
01686     *t  = (- plane_d - ad) / (bd - ad);
01687     mat2D_sub(line_end, line_start);
01688     Mat2D line_start_to_end = line_end;
01689     mat2D_mult(line_start_to_end, *t);
```

```
01690     Mat2D line_to_intersection = line_start_to_end;
01691
01692     Mat2D intersection_p = mat2D_alloc(3, 1);
01693     mat2D_fill(intersection_p, 0);
01694     mat2D_add(intersection_p, line_start);
01695     mat2D_add(intersection_p, line_to_intersection);
01696
01697     Point ans_p = ae_mat2D_to_point(intersection_p);
01698
01699     mat2D_free(intersection_p);
01700
01701     return ans_p;
01702 }
01703
01720 int ae_line_clip_with_plane(Point start_in, Point end_in, Mat2D plane_p, Mat2D plane_n, Point
       *start_out, Point *end_out)
01721 {
01722     ae_assert_point_is_valid(start_in);
01723     ae_assert_point_is_valid(end_in);
01724
01725     mat2D_normalize(plane_n);
01726
01727     /* if the signed distance is positive, the point lies on the "inside" of the plane */
01728     Point inside_points[2];
01729     Point outside_points[2];
01730     int inside_points_count = 0;
01731     int outside_points_count = 0;
01732
01733     /* calc signed distance of each point of tri_in */
01734     float d0 = ae_signed_dist_point_and_plane(start_in, plane_p, plane_n);
01735     float d1 = ae_signed_dist_point_and_plane(end_in, plane_p, plane_n);
01736     float t;
01737
01738     // float epsilon = 1e-3;
01739     float epsilon = 0;
01740     if (d0 >= epsilon) {
01741         inside_points[inside_points_count++] = start_in;
01742     } else {
01743         outside_points[outside_points_count++] = start_in;
01744     }
01745     if (d1 >= epsilon) {
01746         inside_points[inside_points_count++] = end_in;
01747     } else {
01748         outside_points[outside_points_count++] = end_in;
01749     }
01750
01751     /* classifying the triangle points */
01752     if (outside_points_count == 2) {
01753         return 0;
01754     } else if (inside_points_count == 2) {
01755         *start_out = start_in;
01756         *end_out = end_in;
01757         return 1;
01758     } else if (d0 >= epsilon && d1 < epsilon) {
01759         Mat2D line_start = mat2D_alloc(3, 1);
01760         Mat2D line_end   = mat2D_alloc(3, 1);
01761
01762         *start_out = inside_points[0];
01763
01764         ae_point_to_mat2D(inside_points[0], line_start);
01765         ae_point_to_mat2D(outside_points[0], line_end);
01766         *end_out = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
01767
01768         mat2D_free(line_start);
01769         mat2D_free(line_end);
01770
01771         ae_assert_point_is_valid(*start_out);
01772         ae_assert_point_is_valid(*end_out);
01773
01774         return 1;
01775     } else if (d1 >= epsilon && d0 < epsilon) {
01776         Mat2D line_start = mat2D_alloc(3, 1);
01777         Mat2D line_end   = mat2D_alloc(3, 1);
01778
01779         *end_out = inside_points[0];
01780
01781         ae_point_to_mat2D(inside_points[0], line_start);
01782         ae_point_to_mat2D(outside_points[0], line_end);
01783         *start_out = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
01784
01785         mat2D_free(line_start);
01786         mat2D_free(line_end);
01787
01788         ae_assert_point_is_valid(*start_out);
01789         ae_assert_point_is_valid(*end_out);
01790
01791         return 1;
```

```
01792     }
01793     return -1;
01794 }
01795
01807 float ae_signed_dist_point_and_plane(Point p, Mat2D plane_p, Mat2D plane_n)
01808 {
01809     ae_assert_point_is_valid(p);
01810
01811     // mat2D_normalize(plane_n);
01812     // Mat2D p_mat2D = mat2D_alloc(3, 1);
01813     // ae_point_to_mat2D(p, p_mat2D);
01814
01815     // float res = mat2D_dot_product(plane_n, p_mat2D) - mat2D_dot_product(plane_n, plane_p);
01816
01817     float res = MAT2D_AT(plane_n, 0, 0) * p.x + MAT2D_AT(plane_n, 1, 0) * p.y + MAT2D_AT(plane_n, 2,
       0) * p.z - (MAT2D_AT(plane_n, 0, 0) * MAT2D_AT(plane_p, 0, 0) + MAT2D_AT(plane_n, 1, 0) *
      MAT2D_AT(plane_p, 1, 0) + MAT2D_AT(plane_n, 2, 0) * MAT2D_AT(plane_p, 2, 0));
01818
01819     // mat2D_free(p_mat2D);
01820
01821     return res;
01822 }
01823
01838 int ae_tri_clip_with_plane(Tri tri_in, Mat2D plane_p, Mat2D plane_n, Tri *tri_out1, Tri *tri_out2)
01839 {
01840     ae_assert_tri_is_valid(tri_in);
01841
01842     mat2D_normalize(plane_n);
01843
01844     /* if the signed distance is positive, the point lies on the "inside" of the plane */
01845     Point inside_points[3];
01846     Point outside_points[3];
01847     int inside_points_count = 0;
01848     int outside_points_count = 0;
01849     Point tex_inside_points[3];
01850     Point tex_outside_points[3];
01851     int tex_inside_points_count = 0;
01852     int tex_outside_points_count = 0;
01853
01854     /* calc signed distance of each point of tri_in */
01855     float d0 = ae_signed_dist_point_and_plane(tri_in.points[0], plane_p, plane_n);
01856     float d1 = ae_signed_dist_point_and_plane(tri_in.points[1], plane_p, plane_n);
01857     float d2 = ae_signed_dist_point_and_plane(tri_in.points[2], plane_p, plane_n);
01858     float t;
01859
01860     // float epsilon = 1e-3;
01861     float epsilon = 0;
01862     if (d0 >= epsilon) {
01863         inside_points[inside_points_count++] = tri_in.points[0];
01864         tex_inside_points[tex_inside_points_count++] = tri_in.tex_points[0];
01865     } else {
01866         outside_points[outside_points_count++] = tri_in.points[0];
01867         tex_outside_points[tex_outside_points_count++] = tri_in.tex_points[0];
01868     }
01869     if (d1 >= epsilon) {
01870         inside_points[inside_points_count++] = tri_in.points[1];
01871         tex_inside_points[tex_inside_points_count++] = tri_in.tex_points[1];
01872     } else {
01873         outside_points[outside_points_count++] = tri_in.points[1];
01874         tex_outside_points[tex_outside_points_count++] = tri_in.tex_points[1];
01875     }
01876     if (d2 >= epsilon) {
01877         inside_points[inside_points_count++] = tri_in.points[2];
01878         tex_inside_points[tex_inside_points_count++] = tri_in.tex_points[2];
01879     } else {
01880         outside_points[outside_points_count++] = tri_in.points[2];
01881         tex_outside_points[tex_outside_points_count++] = tri_in.tex_points[2];
01882     }
01883
01884     /* classifying the triangle points */
01885     if (inside_points_count == 0) {
01886         return 0;
01887     } else if (inside_points_count == 3) {
01888         *tri_out1 = tri_in;
01889         return 1;
01890     } else if (inside_points_count == 1 && outside_points_count == 2 && d2 >= epsilon) {
01891         Mat2D line_start = mat2D_alloc(3, 1);
01892         Mat2D line_end   = mat2D_alloc(3, 1);
01893
01894         *tri_out1 = tri_in;
01895         // tri_out1->colors[0] = 0xFF0000;
01896         // tri_out1->colors[1] = 0xFF0000;
01897         // tri_out1->colors[2] = 0xFF0000;
01898
01899         (*tri_out1).points[0] = inside_points[0];
01900         (*tri_out1).tex_points[0] = tex_inside_points[0];
01901
```

```
01902         ae_point_to_mat2D(inside_points[0], line_start);
01903         ae_point_to_mat2D(outside_points[0], line_end);
01904         (*tri_out1).points[1] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
01905         (*tri_out1).points[1].w = t * (outside_points[0].w - inside_points[0].w) + inside_points[0].w;
01906         (*tri_out1).tex_points[1].x = t * (tex_outside_points[0].x - tex_inside_points[0].x) +
      tex_inside_points[0].x;
01907         (*tri_out1).tex_points[1].y = t * (tex_outside_points[0].y - tex_inside_points[0].y) +
      tex_inside_points[0].y;
01908 
01909         ae_point_to_mat2D(inside_points[0], line_start);
01910         ae_point_to_mat2D(outside_points[1], line_end);
01911         (*tri_out1).points[2] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
01912         (*tri_out1).points[2].w = t * (outside_points[1].w - inside_points[0].w) + inside_points[0].w;
01913         (*tri_out1).tex_points[2].x = t * (tex_outside_points[1].x - tex_inside_points[0].x) +
      tex_inside_points[0].x;
01914         (*tri_out1).tex_points[2].y = t * (tex_outside_points[1].y - tex_inside_points[0].y) +
      tex_inside_points[0].y;
01915 
01916         mat2D_free(line_start);
01917         mat2D_free(line_end);
01918 
01919         /* fixing color ordering */
01920         uint32_t temp_color = tri_out1->colors[2];
01921         tri_out1->colors[2] = tri_out1->colors[1];
01922         tri_out1->colors[1] = tri_out1->colors[0];
01923         tri_out1->colors[0] = temp_color;
01924 
01925         ae_assert_tri_is_valid(*tri_out1);
01926 
01927         return 1;
01928     } else if (inside_points_count == 1 && outside_points_count == 2 && d1 >= epsilon) {
01929         Mat2D line_start = mat2D_alloc(3, 1);
01930         Mat2D line_end   = mat2D_alloc(3, 1);
01931 
01932         *tri_out1 = tri_in;
01933         // tri_out1->colors[0] = 0xFF0000;
01934         // tri_out1->colors[1] = 0xFF0000;
01935         // tri_out1->colors[2] = 0xFF0000;
01936 
01937         (*tri_out1).points[0] = inside_points[0];
01938         (*tri_out1).tex_points[0] = tex_inside_points[0];
01939 
01940         ae_point_to_mat2D(inside_points[0], line_start);
01941         ae_point_to_mat2D(outside_points[0], line_end);
01942         (*tri_out1).points[1] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
01943         (*tri_out1).points[1].w = t * (outside_points[0].w - inside_points[0].w) + inside_points[0].w;
01944         (*tri_out1).tex_points[1].x = t * (tex_outside_points[0].x - tex_inside_points[0].x) +
      tex_inside_points[0].x;
01945         (*tri_out1).tex_points[1].y = t * (tex_outside_points[0].y - tex_inside_points[0].y) +
      tex_inside_points[0].y;
01946 
01947         ae_point_to_mat2D(inside_points[0], line_start);
01948         ae_point_to_mat2D(outside_points[1], line_end);
01949         (*tri_out1).points[2] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
01950         (*tri_out1).points[2].w = t * (outside_points[1].w - inside_points[0].w) + inside_points[0].w;
01951         (*tri_out1).tex_points[2].x = t * (tex_outside_points[1].x - tex_inside_points[0].x) +
      tex_inside_points[0].x;
01952         (*tri_out1).tex_points[2].y = t * (tex_outside_points[1].y - tex_inside_points[0].y) +
      tex_inside_points[0].y;
01953 
01954         mat2D_free(line_start);
01955         mat2D_free(line_end);
01956 
01957         /* fixing color ordering */
01958         uint32_t temp_color = tri_out1->colors[2];
01959         tri_out1->colors[2] = tri_out1->colors[1];
01960         tri_out1->colors[1] = tri_out1->colors[0];
01961         tri_out1->colors[0] = temp_color;
01962 
01963         temp_color = tri_out1->colors[2];
01964         tri_out1->colors[2] = tri_out1->colors[0];
01965         tri_out1->colors[0] = temp_color;
01966 
01967         ae_assert_tri_is_valid(*tri_out1);
01968 
01969         return 1;
01970     } else if (inside_points_count == 1 && outside_points_count == 2 && d0 >= epsilon) {
01971         Mat2D line_start = mat2D_alloc(3, 1);
01972         Mat2D line_end   = mat2D_alloc(3, 1);
01973 
01974         *tri_out1 = tri_in;
01975         // tri_out1->colors[0] = 0xFF0000;
01976         // tri_out1->colors[1] = 0xFF0000;
01977         // tri_out1->colors[2] = 0xFF0000;
01978 
01979         (*tri_out1).points[0] = inside_points[0];
01980         (*tri_out1).tex_points[0] = tex_inside_points[0];
```

```
01981
01982         ae_point_to_mat2D(inside_points[0], line_start);
01983         ae_point_to_mat2D(outside_points[0], line_end);
01984         (*tri_out1).points[1] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
01985         (*tri_out1).points[1].w = t * (outside_points[0].w - inside_points[0].w) + inside_points[0].w;
01986         (*tri_out1).tex_points[1].x = t * (tex_outside_points[0].x - tex_inside_points[0].x) +
      tex_inside_points[0].x;
01987         (*tri_out1).tex_points[1].y = t * (tex_outside_points[0].y - tex_inside_points[0].y) +
      tex_inside_points[0].y;
01988
01989         ae_point_to_mat2D(inside_points[0], line_start);
01990         ae_point_to_mat2D(outside_points[1], line_end);
01991         (*tri_out1).points[2] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
01992         (*tri_out1).points[2].w = t * (outside_points[1].w - inside_points[0].w) + inside_points[0].w;
01993         (*tri_out1).tex_points[2].x = t * (tex_outside_points[1].x - tex_inside_points[0].x) +
      tex_inside_points[0].x;
01994         (*tri_out1).tex_points[2].y = t * (tex_outside_points[1].y - tex_inside_points[0].y) +
      tex_inside_points[0].y;
01995
01996         mat2D_free(line_start);
01997         mat2D_free(line_end);
01998
01999         ae_assert_tri_is_valid(*tri_out1);
02000
02001         return 1;
02002     } else if (inside_points_count == 2 && outside_points_count == 1 && d2 < epsilon) {
02003         Mat2D line_start = mat2D_alloc(3, 1);
02004         Mat2D line_end   = mat2D_alloc(3, 1);
02005
02006         *tri_out1 = tri_in;
02007         // tri_out1->colors[0] = 0x00FF00;
02008         // tri_out1->colors[1] = 0x00FF00;
02009         // tri_out1->colors[2] = 0x00FF00;
02010
02011         *tri_out2 = tri_in;
02012         // tri_out2->colors[0] = 0x0000FF;
02013         // tri_out2->colors[1] = 0x0000FF;
02014         // tri_out2->colors[2] = 0x0000FF;
02015
02016         (*tri_out1).points[0] = inside_points[0];
02017         (*tri_out1).tex_points[0] = tex_inside_points[0];
02018         (*tri_out1).points[1] = inside_points[1];
02019         (*tri_out1).tex_points[1] = tex_inside_points[1];
02020         ae_point_to_mat2D(inside_points[0], line_start);
02021         ae_point_to_mat2D(outside_points[0], line_end);
02022         (*tri_out1).points[2] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
02023         (*tri_out1).points[2].w = t * (outside_points[0].w - inside_points[0].w) + inside_points[0].w;
02024         (*tri_out1).tex_points[2].x = t * (tex_outside_points[0].x - tex_inside_points[0].x) +
      tex_inside_points[0].x;
02025         (*tri_out1).tex_points[2].y = t * (tex_outside_points[0].y - tex_inside_points[0].y) +
      tex_inside_points[0].y;
02026
02027         (*tri_out2).points[0] = inside_points[1];
02028         (*tri_out2).tex_points[0] = tex_inside_points[1];
02029         ae_point_to_mat2D(inside_points[1], line_start);
02030         ae_point_to_mat2D(outside_points[0], line_end);
02031         (*tri_out2).points[1] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
02032         (*tri_out2).points[1].w = t * (outside_points[0].w - inside_points[1].w) + inside_points[1].w;
02033         (*tri_out2).tex_points[1].x = t * (tex_outside_points[0].x - tex_inside_points[1].x) +
      tex_inside_points[1].x;
02034         (*tri_out2).tex_points[1].y = t * (tex_outside_points[0].y - tex_inside_points[1].y) +
      tex_inside_points[1].y;
02035         (*tri_out2).points[2] = (*tri_out1).points[2];
02036         (*tri_out2).tex_points[2] = (*tri_out1).tex_points[2];
02037
02038         mat2D_free(line_start);
02039         mat2D_free(line_end);
02040
02041         /* fixing color ordering */
02042         uint32_t temp_color = tri_out2->colors[2];
02043         tri_out2->colors[2] = tri_out2->colors[0];
02044         tri_out2->colors[0] = tri_out2->colors[1];
02045         tri_out2->colors[1] = temp_color;
02046
02047         ae_assert_tri_is_valid(*tri_out1);
02048         ae_assert_tri_is_valid(*tri_out2);
02049
02050         return 2;
02051     } else if (inside_points_count == 2 && outside_points_count == 1 && d1 < epsilon) {
02052         Mat2D line_start = mat2D_alloc(3, 1);
02053         Mat2D line_end   = mat2D_alloc(3, 1);
02054
02055         *tri_out1 = tri_in;
02056         // tri_out1->colors[0] = 0x00FF00;
02057         // tri_out1->colors[1] = 0x00FF00;
02058         // tri_out1->colors[2] = 0x00FF00;
02059
```

```
02060         *tri_out2 = tri_in;
02061         // tri_out2->colors[0] = 0x0000FF;
02062         // tri_out2->colors[1] = 0x0000FF;
02063         // tri_out2->colors[2] = 0x0000FF;
02064 
02065         (*tri_out1).points[0] = inside_points[0];
02066         (*tri_out1).tex_points[0] = tex_inside_points[0];
02067         (*tri_out1).points[1] = inside_points[1];
02068         (*tri_out1).tex_points[1] = tex_inside_points[1];
02069         ae_point_to_mat2D(inside_points[0], line_start);
02070         ae_point_to_mat2D(outside_points[0], line_end);
02071         (*tri_out1).points[2] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
02072         (*tri_out1).points[2].w = t * (outside_points[0].w - inside_points[0].w) + inside_points[0].w;
02073         (*tri_out1).tex_points[2].x = t * (tex_outside_points[0].x - tex_inside_points[0].x) +
      tex_inside_points[0].x;
02074         (*tri_out1).tex_points[2].y = t * (tex_outside_points[0].y - tex_inside_points[0].y) +
      tex_inside_points[0].y;
02075 
02076         (*tri_out2).points[0] = inside_points[1];
02077         (*tri_out2).tex_points[0] = tex_inside_points[1];
02078         ae_point_to_mat2D(inside_points[1], line_start);
02079         ae_point_to_mat2D(outside_points[0], line_end);
02080         (*tri_out2).points[1] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
02081         (*tri_out2).points[1].w = t * (outside_points[0].w - inside_points[1].w) + inside_points[1].w;
02082         (*tri_out2).tex_points[1].x = t * (tex_outside_points[0].x - tex_inside_points[1].x) +
      tex_inside_points[1].x;
02083         (*tri_out2).tex_points[1].y = t * (tex_outside_points[0].y - tex_inside_points[1].y) +
      tex_inside_points[1].y;
02084         (*tri_out2).points[2] = (*tri_out1).points[2];
02085         (*tri_out2).tex_points[2] = (*tri_out1).tex_points[2];
02086 
02087         mat2D_free(line_start);
02088         mat2D_free(line_end);
02089 
02090         /* fixing color ordering */
02091         uint32_t temp_color = tri_out1->colors[2];
02092         tri_out1->colors[2] = tri_out1->colors[1];
02093         tri_out1->colors[1] = temp_color;
02094 
02095         temp_color = tri_out2->colors[2];
02096         tri_out2->colors[2] = tri_out2->colors[0];
02097         tri_out2->colors[0] = tri_out2->colors[1];
02098         tri_out2->colors[1] = temp_color;
02099         temp_color = tri_out2->colors[1];
02100         tri_out2->colors[1] = tri_out2->colors[0];
02101         tri_out2->colors[0] = temp_color;
02102 
02103         ae_assert_tri_is_valid(*tri_out1);
02104         ae_assert_tri_is_valid(*tri_out2);
02105 
02106         return 2;
02107     } else if (inside_points_count == 2 && outside_points_count == 1 && d0 < epsilon) {
02108         Mat2D line_start = mat2D_alloc(3, 1);
02109         Mat2D line_end   = mat2D_alloc(3, 1);
02110 
02111         *tri_out1 = tri_in;
02112         // tri_out1->colors[0] = 0x00FF00;
02113         // tri_out1->colors[1] = 0x00FF00;
02114         // tri_out1->colors[2] = 0x00FF00;
02115 
02116         *tri_out2 = tri_in;
02117         // tri_out2->colors[0] = 0x0000FF;
02118         // tri_out2->colors[1] = 0x0000FF;
02119         // tri_out2->colors[2] = 0x0000FF;
02120 
02121         (*tri_out1).points[0] = inside_points[0];
02122         (*tri_out1).tex_points[0] = tex_inside_points[0];
02123         (*tri_out1).points[1] = inside_points[1];
02124         (*tri_out1).tex_points[1] = tex_inside_points[1];
02125         ae_point_to_mat2D(inside_points[0], line_start);
02126         ae_point_to_mat2D(outside_points[0], line_end);
02127         (*tri_out1).points[2] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
02128         (*tri_out1).points[2].w = t * (outside_points[0].w - inside_points[0].w) + inside_points[0].w;
02129         (*tri_out1).tex_points[2].x = t * (tex_outside_points[0].x - tex_inside_points[0].x) +
      tex_inside_points[0].x;
02130         (*tri_out1).tex_points[2].y = t * (tex_outside_points[0].y - tex_inside_points[0].y) +
      tex_inside_points[0].y;
02131 
02132         (*tri_out2).points[0] = inside_points[1];
02133         (*tri_out2).tex_points[0] = tex_inside_points[1];
02134         ae_point_to_mat2D(inside_points[1], line_start);
02135         ae_point_to_mat2D(outside_points[0], line_end);
02136         (*tri_out2).points[1] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
02137         (*tri_out2).points[1].w = t * (outside_points[0].w - inside_points[1].w) + inside_points[1].w;
02138         (*tri_out2).tex_points[1].x = t * (tex_outside_points[0].x - tex_inside_points[1].x) +
      tex_inside_points[1].x;
02139         (*tri_out2).tex_points[1].y = t * (tex_outside_points[0].y - tex_inside_points[1].y) +
```

```
    tex_inside_points[1].y;
02140         (*tri_out2).points[2] = (*tri_out1).points[2];
02141         (*tri_out2).tex_points[2] = (*tri_out1).tex_points[2];
02142 
02143         mat2D_free(line_start);
02144         mat2D_free(line_end);
02145 
02146         /* fixing color ordering */
02147         uint32_t temp_color = tri_out1->colors[2];
02148         tri_out1->colors[2] = tri_out1->colors[0];
02149         tri_out1->colors[0] = tri_out1->colors[1];
02150         tri_out1->colors[1] = temp_color;
02151 
02152         temp_color = tri_out2->colors[2];
02153         tri_out2->colors[2] = tri_out2->colors[1];
02154         tri_out2->colors[1] = tri_out2->colors[0];
02155         tri_out2->colors[0] = temp_color;
02156 
02157         ae_assert_tri_is_valid(*tri_out1);
02158         ae_assert_tri_is_valid(*tri_out2);
02159 
02160         return 2;
02161     }
02162     return -1;
02163 }
02164 
02181 int ae_quad_clip_with_plane(Quad quad_in, Mat2D plane_p, Mat2D plane_n, Quad *quad_out1, Quad
     *quad_out2)
02182 {
02183     ae_assert_quad_is_valid(quad_in);
02184 
02185     mat2D_normalize(plane_n);
02186 
02187     /* if the signed distance is positive, the point lies on the "inside" of the plane */
02188     Point inside_points[4];
02189     Point outside_points[4];
02190     int inside_points_count = 0;
02191     int outside_points_count = 0;
02192 
02193     /* calc signed distance of each point of tri_in */
02194     float d0 = ae_signed_dist_point_and_plane(quad_in.points[0], plane_p, plane_n);
02195     float d1 = ae_signed_dist_point_and_plane(quad_in.points[1], plane_p, plane_n);
02196     float d2 = ae_signed_dist_point_and_plane(quad_in.points[2], plane_p, plane_n);
02197     float d3 = ae_signed_dist_point_and_plane(quad_in.points[3], plane_p, plane_n);
02198     float t;
02199 
02200     // float epsilon = 1e-3;
02201     float epsilon = 0;
02202     if (d0 >= epsilon) {
02203         inside_points[inside_points_count++] = quad_in.points[0];
02204     } else {
02205         outside_points[outside_points_count++] = quad_in.points[0];
02206     }
02207     if (d1 >= epsilon) {
02208         inside_points[inside_points_count++] = quad_in.points[1];
02209     } else {
02210         outside_points[outside_points_count++] = quad_in.points[1];
02211     }
02212     if (d2 >= epsilon) {
02213         inside_points[inside_points_count++] = quad_in.points[2];
02214     } else {
02215         outside_points[outside_points_count++] = quad_in.points[2];
02216     }
02217     if (d3 >= epsilon) {
02218         inside_points[inside_points_count++] = quad_in.points[3];
02219     } else {
02220         outside_points[outside_points_count++] = quad_in.points[3];
02221     }
02222 
02223     /* classifying the triangle points */
02224     if (inside_points_count == 0) {
02225         return 0;
02226     } else if (inside_points_count == 4) {
02227         *quad_out1 = quad_in;
02228         return 1;
02229     } else if (inside_points_count == 1 && outside_points_count == 3 && d1 >= epsilon) {
02230         Mat2D line_start = mat2D_alloc(3, 1);
02231         Mat2D line_end   = mat2D_alloc(3, 1);
02232 
02233         *quad_out1 = quad_in;
02234         *quad_out2 = quad_in;
02235 
02236         (*quad_out1).points[1] = quad_in.points[1];
02237 
02238         ae_point_to_mat2D(quad_in.points[1], line_start);
02239         ae_point_to_mat2D(quad_in.points[2], line_end);
02240         (*quad_out1).points[2] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
```

```
02241         (*quad_out1).points[2].w = t * (quad_in.points[2].w - quad_in.points[1].w) +
      quad_in.points[1].w;
02242         (*quad_out1).colors[2] = quad_in.colors[2];
02243 
02244         ae_point_to_mat2D(quad_in.points[1], line_start);
02245         ae_point_to_mat2D(quad_in.points[0], line_end);
02246         (*quad_out1).points[0] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
02247         (*quad_out1).points[0].w = t * (quad_in.points[0].w - quad_in.points[1].w) +
      quad_in.points[1].w;
02248         (*quad_out1).colors[0] = quad_in.colors[0];
02249 
02250         (*quad_out1).points[3].x = ((*quad_out1).points[0].x + (*quad_out1).points[2].x) / 2;
02251         (*quad_out1).points[3].y = ((*quad_out1).points[0].y + (*quad_out1).points[2].y) / 2;
02252         (*quad_out1).points[3].z = ((*quad_out1).points[0].z + (*quad_out1).points[2].z) / 2;
02253         (*quad_out1).points[3].w = ((*quad_out1).points[0].w + (*quad_out1).points[2].w) / 2;
02254         (*quad_out1).colors[3] = quad_in.colors[3];
02255 
02256         mat2D_free(line_start);
02257         mat2D_free(line_end);
02258 
02259         ae_assert_quad_is_valid(*quad_out1);
02260 
02261         return 1;
02262     } else if (inside_points_count == 1 && outside_points_count == 3 && d2 >= epsilon) {
02263         Mat2D line_start = mat2D_alloc(3, 1);
02264         Mat2D line_end   = mat2D_alloc(3, 1);
02265 
02266         *quad_out1 = quad_in;
02267         *quad_out2 = quad_in;
02268 
02269         (*quad_out1).points[2] = quad_in.points[2];
02270 
02271         ae_point_to_mat2D(quad_in.points[2], line_start);
02272         ae_point_to_mat2D(quad_in.points[3], line_end);
02273         (*quad_out1).points[3] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
02274         (*quad_out1).points[3].w = t * (quad_in.points[3].w - quad_in.points[2].w) +
      quad_in.points[2].w;
02275         (*quad_out1).colors[3] = quad_in.colors[3];
02276 
02277         ae_point_to_mat2D(quad_in.points[2], line_start);
02278         ae_point_to_mat2D(quad_in.points[1], line_end);
02279         (*quad_out1).points[1] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
02280         (*quad_out1).points[1].w = t * (quad_in.points[1].w - quad_in.points[2].w) +
      quad_in.points[2].w;
02281         (*quad_out1).colors[1] = quad_in.colors[1];
02282 
02283         (*quad_out1).points[0].x = ((*quad_out1).points[3].x + (*quad_out1).points[1].x) / 2;
02284         (*quad_out1).points[0].y = ((*quad_out1).points[3].y + (*quad_out1).points[1].y) / 2;
02285         (*quad_out1).points[0].z = ((*quad_out1).points[3].z + (*quad_out1).points[1].z) / 2;
02286         (*quad_out1).points[0].w = ((*quad_out1).points[3].w + (*quad_out1).points[1].w) / 2;
02287         (*quad_out1).colors[0] = quad_in.colors[0];
02288 
02289         mat2D_free(line_start);
02290         mat2D_free(line_end);
02291 
02292         ae_assert_quad_is_valid(*quad_out1);
02293 
02294         return 1;
02295     } else if (inside_points_count == 1 && outside_points_count == 3 && d3 >= epsilon) {
02296         Mat2D line_start = mat2D_alloc(3, 1);
02297         Mat2D line_end   = mat2D_alloc(3, 1);
02298 
02299         *quad_out1 = quad_in;
02300         *quad_out2 = quad_in;
02301 
02302         (*quad_out1).points[3] = quad_in.points[3];
02303 
02304         ae_point_to_mat2D(quad_in.points[3], line_start);
02305         ae_point_to_mat2D(quad_in.points[0], line_end);
02306         (*quad_out1).points[0] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
02307         (*quad_out1).points[0].w = t * (quad_in.points[0].w - quad_in.points[3].w) +
      quad_in.points[3].w;
02308         (*quad_out1).colors[0] = quad_in.colors[0];
02309 
02310         ae_point_to_mat2D(quad_in.points[3], line_start);
02311         ae_point_to_mat2D(quad_in.points[2], line_end);
02312         (*quad_out1).points[2] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
02313         (*quad_out1).points[2].w = t * (quad_in.points[2].w - quad_in.points[3].w) +
      quad_in.points[3].w;
02314         (*quad_out1).colors[2] = quad_in.colors[2];
02315 
02316         (*quad_out1).points[1].x = ((*quad_out1).points[2].x + (*quad_out1).points[0].x) / 2;
02317         (*quad_out1).points[1].y = ((*quad_out1).points[2].y + (*quad_out1).points[0].y) / 2;
02318         (*quad_out1).points[1].z = ((*quad_out1).points[2].z + (*quad_out1).points[0].z) / 2;
02319         (*quad_out1).points[1].w = ((*quad_out1).points[2].w + (*quad_out1).points[0].w) / 2;
02320         (*quad_out1).colors[1] = quad_in.colors[1];
02321 
```

```
02322         mat2D_free(line_start);
02323         mat2D_free(line_end);
02324 
02325         ae_assert_quad_is_valid(*quad_out1);
02326 
02327         return 1;
02328     } else if (inside_points_count == 1 && outside_points_count == 3) {
02329         Mat2D line_start = mat2D_alloc(3, 1);
02330         Mat2D line_end   = mat2D_alloc(3, 1);
02331 
02332         *quad_out1 = quad_in;
02333         *quad_out2 = quad_in;
02334 
02335         (*quad_out1).points[0] = inside_points[0];
02336 
02337         ae_point_to_mat2D(inside_points[0], line_start);
02338         ae_point_to_mat2D(outside_points[0], line_end);
02339         (*quad_out1).points[1] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
02340         (*quad_out1).points[1].w = t * (outside_points[0].w - inside_points[0].w) +
    inside_points[0].w;
02341 
02342         ae_point_to_mat2D(inside_points[0], line_start);
02343         ae_point_to_mat2D(outside_points[1], line_end);
02344         (*quad_out1).points[2] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
02345         (*quad_out1).points[2].w = t * (outside_points[1].w - inside_points[0].w) +
    inside_points[0].w;
02346 
02347         ae_point_to_mat2D(inside_points[0], line_start);
02348         ae_point_to_mat2D(outside_points[2], line_end);
02349         (*quad_out1).points[3] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
02350         (*quad_out1).points[3].w = t * (outside_points[2].w - inside_points[0].w) +
    inside_points[0].w;
02351 
02352         mat2D_free(line_start);
02353         mat2D_free(line_end);
02354 
02355         ae_assert_quad_is_valid(*quad_out1);
02356 
02357         return 1;
02358     } else if (inside_points_count == 2 && outside_points_count == 2 && d2 < epsilon && d1 < epsilon)
    {
02359         Mat2D line_start = mat2D_alloc(3, 1);
02360         Mat2D line_end   = mat2D_alloc(3, 1);
02361 
02362         *quad_out1 = quad_in;
02363 
02364         (*quad_out1).points[0] = quad_in.points[3];
02365         (*quad_out1).colors[0] = quad_in.colors[3];
02366         (*quad_out1).points[1] = quad_in.points[0];
02367         (*quad_out1).colors[1] = quad_in.colors[0];
02368 
02369         ae_point_to_mat2D(quad_in.points[0], line_start);
02370         ae_point_to_mat2D(quad_in.points[1], line_end);
02371         (*quad_out1).points[2] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
02372         (*quad_out1).points[2].w = t * (quad_in.points[1].w - quad_in.points[0].w) +
    quad_in.points[0].w;
02373         (*quad_out1).colors[2] = quad_in.colors[1];
02374 
02375         ae_point_to_mat2D(quad_in.points[3], line_start);
02376         ae_point_to_mat2D(quad_in.points[2], line_end);
02377         (*quad_out1).points[3] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
02378         (*quad_out1).points[3].w = t * (quad_in.points[2].w - quad_in.points[3].w) +
    quad_in.points[3].w;
02379         (*quad_out1).colors[3] = quad_in.colors[2];
02380 
02381         mat2D_free(line_start);
02382         mat2D_free(line_end);
02383 
02384         ae_assert_quad_is_valid(*quad_out1);
02385 
02386         return 2;
02387     } else if (inside_points_count == 2 && outside_points_count == 2 && d0 < epsilon && d1 < epsilon)
    {
02388         Mat2D line_start = mat2D_alloc(3, 1);
02389         Mat2D line_end   = mat2D_alloc(3, 1);
02390 
02391         *quad_out1 = quad_in;
02392 
02393         (*quad_out1).points[0] = quad_in.points[2];
02394         (*quad_out1).colors[0] = quad_in.colors[2];
02395         (*quad_out1).points[1] = quad_in.points[3];
02396         (*quad_out1).colors[1] = quad_in.colors[3];
02397 
02398         ae_point_to_mat2D(quad_in.points[2], line_start);
02399         ae_point_to_mat2D(quad_in.points[1], line_end);
02400         (*quad_out1).points[3] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
02401         (*quad_out1).points[3].w = t * (quad_in.points[1].w - quad_in.points[2].w) +
```

```
    quad_in.points[2].w;
02402         (*quad_out1).colors[3] = quad_in.colors[1];
02403
02404         ae_point_to_mat2D(quad_in.points[3], line_start);
02405         ae_point_to_mat2D(quad_in.points[0], line_end);
02406         (*quad_out1).points[2] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
02407         (*quad_out1).points[2].w = t * (quad_in.points[0].w - quad_in.points[3].w) +
    quad_in.points[3].w;
02408         (*quad_out1).colors[2] = quad_in.colors[0];
02409
02410         mat2D_free(line_start);
02411         mat2D_free(line_end);
02412
02413         ae_assert_quad_is_valid(*quad_out1);
02414
02415         return 2;
02416     } else if (inside_points_count == 2 && outside_points_count == 2 && d0 < epsilon && d3 < epsilon)
    {
02417         Mat2D line_start = mat2D_alloc(3, 1);
02418         Mat2D line_end   = mat2D_alloc(3, 1);
02419
02420         *quad_out1 = quad_in;
02421
02422         (*quad_out1).points[0] = quad_in.points[1];
02423         (*quad_out1).colors[0] = quad_in.colors[1];
02424         (*quad_out1).points[1] = quad_in.points[2];
02425         (*quad_out1).colors[1] = quad_in.colors[2];
02426
02427         ae_point_to_mat2D(quad_in.points[2], line_start);
02428         ae_point_to_mat2D(quad_in.points[3], line_end);
02429         (*quad_out1).points[2] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
02430         (*quad_out1).points[2].w = t * (quad_in.points[3].w - quad_in.points[2].w) +
    quad_in.points[2].w;
02431         (*quad_out1).colors[2] = quad_in.colors[3];
02432
02433         ae_point_to_mat2D(quad_in.points[1], line_start);
02434         ae_point_to_mat2D(quad_in.points[0], line_end);
02435         (*quad_out1).points[3] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
02436         (*quad_out1).points[3].w = t * (quad_in.points[1].w - quad_in.points[3].w) +
    quad_in.points[3].w;
02437         (*quad_out1).colors[3] = quad_in.colors[0];
02438
02439         mat2D_free(line_start);
02440         mat2D_free(line_end);
02441
02442         ae_assert_quad_is_valid(*quad_out1);
02443
02444         return 1;
02445     } else if (inside_points_count == 2 && outside_points_count == 2) {
02446         Mat2D line_start = mat2D_alloc(3, 1);
02447         Mat2D line_end   = mat2D_alloc(3, 1);
02448
02449         *quad_out1 = quad_in;
02450
02451         (*quad_out1).points[0] = inside_points[0];
02452         (*quad_out1).points[1] = inside_points[1];
02453         ae_point_to_mat2D(inside_points[1], line_start);
02454         ae_point_to_mat2D(outside_points[0], line_end);
02455         (*quad_out1).points[2] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
02456         (*quad_out1).points[2].w = t * (outside_points[0].w - inside_points[1].w) +
    inside_points[1].w;
02457
02458         ae_point_to_mat2D(inside_points[0], line_start);
02459         ae_point_to_mat2D(outside_points[1], line_end);
02460         (*quad_out1).points[3] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
02461         (*quad_out1).points[3].w = t * (outside_points[1].w - inside_points[0].w) +
    inside_points[0].w;
02462
02463         mat2D_free(line_start);
02464         mat2D_free(line_end);
02465
02466         ae_assert_quad_is_valid(*quad_out1);
02467
02468         return 1;
02469     } else if (inside_points_count == 3 && outside_points_count == 1 && d0 < epsilon) {
02470         Mat2D line_start = mat2D_alloc(3, 1);
02471         Mat2D line_end   = mat2D_alloc(3, 1);
02472
02473         *quad_out1 = quad_in;
02474         *quad_out2 = quad_in;
02475
02476         ae_point_to_mat2D(quad_in.points[3], line_start);
02477         ae_point_to_mat2D(quad_in.points[0], line_end);
02478         (*quad_out1).points[0] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
02479         (*quad_out1).points[0].w = t * (quad_in.points[0].w - quad_in.points[3].w) +
    quad_in.points[3].w;
02480         // adl_interpolate_ARGBcolor_on_RGB((quad_in).colors[3], (quad_in).colors[0], t,
```

```
    &((*quad_out1).colors[0]));
02481
02482         (*quad_out2).points[1] = quad_in.points[1];
02483         // (*quad_out2).colors[1] = quad_in.colors[1];
02484
02485         ae_point_to_mat2D(quad_in.points[1], line_start);
02486         ae_point_to_mat2D(quad_in.points[0], line_end);
02487         (*quad_out2).points[0] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
02488         (*quad_out2).points[0].w = t * (quad_in.points[0].w - quad_in.points[1].w) +
    quad_in.points[1].w;
02489         // adl_interpolate_ARGBcolor_on_RGB((quad_in).colors[1], (quad_in).colors[0], t,
    &((*quad_out2).colors[0]));
02490
02491         (*quad_out2).points[2] = (*quad_out1).points[0];
02492         // (*quad_out2).colors[2] = (*quad_out1).colors[0];
02493
02494         (*quad_out2).points[3].x = ((*quad_out2).points[2].x + (*quad_out2).points[0].x) / 2;
02495         (*quad_out2).points[3].y = ((*quad_out2).points[2].y + (*quad_out2).points[0].y) / 2;
02496         (*quad_out2).points[3].z = ((*quad_out2).points[2].z + (*quad_out2).points[0].z) / 2;
02497         (*quad_out2).points[3].w = ((*quad_out2).points[2].w + (*quad_out2).points[0].w) / 2;
02498         // adl_interpolate_ARGBcolor_on_RGB((*quad_out2).colors[2], (*quad_out2).colors[0], 0.5f,
    &((*quad_out2).colors[3]));
02499
02500
02501         mat2D_free(line_start);
02502         mat2D_free(line_end);
02503
02504         ae_assert_quad_is_valid(*quad_out1);
02505
02506         return 2;
02507     } else if (inside_points_count == 3 && outside_points_count == 1 && d1 < epsilon) {
02508         Mat2D line_start = mat2D_alloc(3, 1);
02509         Mat2D line_end   = mat2D_alloc(3, 1);
02510
02511         *quad_out1 = quad_in;
02512         *quad_out2 = quad_in;
02513
02514         (*quad_out1).points[0] = quad_in.points[0];
02515         (*quad_out1).colors[0] = quad_in.colors[0];
02516         (*quad_out1).points[2] = quad_in.points[2];
02517         (*quad_out1).colors[2] = quad_in.colors[2];
02518         (*quad_out1).points[3] = quad_in.points[3];
02519         (*quad_out1).colors[3] = quad_in.colors[3];
02520
02521         ae_point_to_mat2D(quad_in.points[2], line_start);
02522         ae_point_to_mat2D(quad_in.points[1], line_end);
02523         (*quad_out1).points[1] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
02524         (*quad_out1).points[1].w = t * (quad_in.points[1].w - quad_in.points[2].w) +
    quad_in.points[2].w;
02525         (*quad_out1).colors[1] = (*quad_out1).colors[1];
02526         // adl_interpolate_ARGBcolor_on_RGB((quad_in).colors[2], (quad_in).colors[1], t,
    &((*quad_out1).colors[1]));
02527
02528         (*quad_out2).points[0] = quad_in.points[0];
02529         (*quad_out2).colors[0] = quad_in.colors[0];
02530         (*quad_out2).points[3] = (*quad_out1).points[1];
02531         (*quad_out2).colors[3] = (*quad_out1).colors[3];
02532
02533         ae_point_to_mat2D(quad_in.points[0], line_start);
02534         ae_point_to_mat2D(quad_in.points[1], line_end);
02535         (*quad_out2).points[1] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
02536         (*quad_out2).points[1].w = t * (quad_in.points[1].w - quad_in.points[0].w) +
    quad_in.points[0].w;
02537         (*quad_out2).colors[1] = quad_in.colors[1];
02538         // adl_interpolate_ARGBcolor_on_RGB((quad_in).colors[0], (quad_in).colors[1], t,
    &((*quad_out2).colors[1]));
02539
02540         (*quad_out2).points[2].x = ((*quad_out2).points[1].x + (*quad_out2).points[3].x) / 2;
02541         (*quad_out2).points[2].y = ((*quad_out2).points[1].y + (*quad_out2).points[3].y) / 2;
02542         (*quad_out2).points[2].z = ((*quad_out2).points[1].z + (*quad_out2).points[3].z) / 2;
02543         (*quad_out2).points[2].w = ((*quad_out2).points[1].w + (*quad_out2).points[3].w) / 2;
02544         // adl_interpolate_ARGBcolor_on_RGB((*quad_out2).colors[1], (*quad_out2).colors[3], 0.5f,
    &((*quad_out2).colors[2]));
02545
02546
02547         mat2D_free(line_start);
02548         mat2D_free(line_end);
02549
02550         ae_assert_quad_is_valid(*quad_out1);
02551
02552         return 2;
02553     } else if (inside_points_count == 3 && outside_points_count == 1 && d2 < epsilon) {
02554         Mat2D line_start = mat2D_alloc(3, 1);
02555         Mat2D line_end   = mat2D_alloc(3, 1);
02556
02557         *quad_out1 = quad_in;
02558         *quad_out2 = quad_in;
```

```
02559
02560         (*quad_out1).points[0] = quad_in.points[0];
02561         (*quad_out1).colors[0] = quad_in.colors[0];
02562         (*quad_out1).points[1] = quad_in.points[1];
02563         (*quad_out1).colors[1] = quad_in.colors[1];
02564         (*quad_out1).points[3] = quad_in.points[3];
02565         (*quad_out1).colors[3] = quad_in.colors[3];
02566
02567         ae_point_to_mat2D(quad_in.points[1], line_start);
02568         ae_point_to_mat2D(quad_in.points[2], line_end);
02569         (*quad_out1).points[2] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
02570         (*quad_out1).points[2].w = t * (quad_in.points[2].w - quad_in.points[1].w) +
      quad_in.points[1].w;
02571         (*quad_out1).colors[2] = (*quad_out1).colors[2];
02572         // adl_interpolate_ARGBcolor_on_RGB((quad_in).colors[2], (quad_in).colors[1], t,
      &((*quad_out1).colors[1]));
02573
02574         (*quad_out2).points[3] = quad_in.points[3];
02575         (*quad_out2).colors[3] = quad_in.colors[3];
02576         (*quad_out2).points[0] = (*quad_out1).points[2];
02577         (*quad_out2).colors[0] = (*quad_out1).colors[0];
02578
02579         ae_point_to_mat2D(quad_in.points[3], line_start);
02580         ae_point_to_mat2D(quad_in.points[2], line_end);
02581         (*quad_out2).points[2] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
02582         (*quad_out2).points[2].w = t * (quad_in.points[2].w - quad_in.points[3].w) +
      quad_in.points[3].w;
02583         (*quad_out2).colors[2] = quad_in.colors[2];
02584         // adl_interpolate_ARGBcolor_on_RGB((quad_in).colors[0], (quad_in).colors[1], t,
      &((*quad_out2).colors[1]));
02585
02586         (*quad_out2).points[1].x = ((*quad_out2).points[2].x + (*quad_out2).points[0].x) / 2;
02587         (*quad_out2).points[1].y = ((*quad_out2).points[2].y + (*quad_out2).points[0].y) / 2;
02588         (*quad_out2).points[1].z = ((*quad_out2).points[2].z + (*quad_out2).points[0].z) / 2;
02589         (*quad_out2).points[1].w = ((*quad_out2).points[2].w + (*quad_out2).points[0].w) / 2;
02590         // adl_interpolate_ARGBcolor_on_RGB((*quad_out2).colors[1], (*quad_out2).colors[3], 0.5f,
      &((*quad_out2).colors[2]));
02591
02592
02593         mat2D_free(line_start);
02594         mat2D_free(line_end);
02595
02596         ae_assert_quad_is_valid(*quad_out1);
02597
02598         return 2;
02599     } else if (inside_points_count == 3 && outside_points_count == 1 && d3 < epsilon) {
02600         Mat2D line_start = mat2D_alloc(3, 1);
02601         Mat2D line_end   = mat2D_alloc(3, 1);
02602
02603         *quad_out1 = quad_in;
02604         *quad_out2 = quad_in;
02605
02606         (*quad_out1).points[0] = quad_in.points[0];
02607         (*quad_out1).colors[0] = quad_in.colors[0];
02608         (*quad_out1).points[1] = quad_in.points[1];
02609         (*quad_out1).colors[1] = quad_in.colors[1];
02610         (*quad_out1).points[2] = quad_in.points[2];
02611         (*quad_out1).colors[2] = quad_in.colors[2];
02612
02613         ae_point_to_mat2D(quad_in.points[0], line_start);
02614         ae_point_to_mat2D(quad_in.points[3], line_end);
02615         (*quad_out1).points[3] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
02616         (*quad_out1).points[3].w = t * (quad_in.points[3].w - quad_in.points[0].w) +
      quad_in.points[0].w;
02617         (*quad_out1).colors[3] = (*quad_out1).colors[3];
02618         // adl_interpolate_ARGBcolor_on_RGB((quad_in).colors[2], (quad_in).colors[1], t,
      &((*quad_out1).colors[1]));
02619
02620         (*quad_out2).points[2] = quad_in.points[2];
02621         (*quad_out2).colors[2] = quad_in.colors[2];
02622         (*quad_out2).points[1] = (*quad_out1).points[3];
02623         (*quad_out2).colors[1] = (*quad_out1).colors[1];
02624
02625         ae_point_to_mat2D(quad_in.points[2], line_start);
02626         ae_point_to_mat2D(quad_in.points[3], line_end);
02627         (*quad_out2).points[3] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
02628         (*quad_out2).points[3].w = t * (quad_in.points[3].w - quad_in.points[2].w) +
      quad_in.points[2].w;
02629         (*quad_out2).colors[3] = quad_in.colors[3];
02630         // adl_interpolate_ARGBcolor_on_RGB((quad_in).colors[0], (quad_in).colors[1], t,
      &((*quad_out2).colors[1]));
02631
02632         (*quad_out2).points[0].x = ((*quad_out2).points[3].x + (*quad_out2).points[1].x) / 2;
02633         (*quad_out2).points[0].y = ((*quad_out2).points[3].y + (*quad_out2).points[1].y) / 2;
02634         (*quad_out2).points[0].z = ((*quad_out2).points[3].z + (*quad_out2).points[1].z) / 2;
02635         (*quad_out2).points[0].w = ((*quad_out2).points[3].w + (*quad_out2).points[1].w) / 2;
02636         // adl_interpolate_ARGBcolor_on_RGB((*quad_out2).colors[1], (*quad_out2).colors[3], 0.5f,
```

```
      &((*quad_out2).colors[2]));
02637
02638
02639         mat2D_free(line_start);
02640         mat2D_free(line_end);
02641
02642         ae_assert_quad_is_valid(*quad_out1);
02643
02644         return 2;
02645     } else if (inside_points_count == 3 && outside_points_count == 1) {
02646         Mat2D line_start = mat2D_alloc(3, 1);
02647         Mat2D line_end   = mat2D_alloc(3, 1);
02648
02649         *quad_out1 = quad_in;
02650
02651         (*quad_out1).points[0] = inside_points[0];
02652         (*quad_out1).points[1] = inside_points[1];
02653         (*quad_out1).points[2] = inside_points[2];
02654         ae_point_to_mat2D(inside_points[2], line_start);
02655         ae_point_to_mat2D(outside_points[0], line_end);
02656         (*quad_out1).points[3] = ae_line_itersect_plane(plane_p, plane_n, line_start, line_end, &t);
02657         (*quad_out1).points[3].w = t * (outside_points[0].w - inside_points[2].w) +
      inside_points[2].w;
02658
02659         mat2D_free(line_start);
02660         mat2D_free(line_end);
02661
02662         ae_assert_quad_is_valid(*quad_out1);
02663
02664         return 1;
02665     }
02666     return -1;
02667 }
02668
02682 void ae_projection_mat_set(Mat2D proj_mat,float aspect_ratio, float FOV_deg, float z_near, float
      z_far)
02683 {
02684     AE_ASSERT(4 == proj_mat.cols);
02685     AE_ASSERT(4 == proj_mat.rows);
02686     AE_ASSERT(FOV_deg && "FOV needs to bee bigger then zero");
02687
02688     mat2D_fill(proj_mat, 0);
02689
02690     float field_of_view = 1.0f / tanf(0.5f * FOV_deg * PI / 180);
02691     float z_normalization = z_far / (z_far - z_near);
02692
02693     MAT2D_AT(proj_mat, 0, 0) = aspect_ratio * field_of_view;
02694     MAT2D_AT(proj_mat, 1, 1) = field_of_view;
02695     MAT2D_AT(proj_mat, 2, 2) = z_normalization;
02696     MAT2D_AT(proj_mat, 2, 3) = 1;
02697     MAT2D_AT(proj_mat, 3, 2) = - z_normalization * z_near;
02698 }
02699
02716 void ae_view_mat_set(Mat2D view_mat, Camera camera, Mat2D up)
02717 {
02718     Mat2D DCM = mat2D_alloc(3,3);
02719     Mat2D DCM_trans = mat2D_alloc(3,3);
02720     mat2D_set_DCM_zyx(DCM, camera.yaw_offset_deg, camera.pitch_offset_deg, camera.roll_offset_deg);
02721     mat2D_transpose(DCM_trans, DCM);
02722
02723     Mat2D temp_vec = mat2D_alloc(3, 1);
02724     Mat2D camera_direction = mat2D_alloc(3, 1);
02725
02726     /* rotating camera_direction */
02727     mat2D_dot(camera_direction, DCM_trans, camera.direction);
02728
02729     /* calc new forward direction */
02730     Mat2D new_forward = mat2D_alloc(3, 1);
02731     mat2D_copy(new_forward, camera_direction);
02732     mat2D_mult(new_forward, 1.0 / mat2D_calc_norma(new_forward));
02733
02734     /* calc new up direction */
02735     mat2D_copy(temp_vec, new_forward);
02736     mat2D_mult(temp_vec, mat2D_dot_product(up, new_forward));
02737     Mat2D new_up = mat2D_alloc(3, 1);
02738     mat2D_copy(new_up, up);
02739     mat2D_sub(new_up, temp_vec);
02740     mat2D_mult(new_up, 1.0 / mat2D_calc_norma(new_up));
02741
02742     /* calc new right direction */
02743     Mat2D new_right = mat2D_alloc(3, 1);
02744     mat2D_cross(new_right, new_up, new_forward);
02745     mat2D_mult(new_right, 1.0 / mat2D_calc_norma(new_right));
02746
02747     mat2D_copy(camera.camera_x, new_right);
02748     mat2D_copy(camera.camera_y, new_up);
02749     mat2D_copy(camera.camera_z, new_forward);
```

```
02750
02751     /* adding offset to init_position */
02752     // mat2D_add(camera_pos, camera.offset_position);
02753
02754     mat2D_copy(temp_vec, camera.camera_x);
02755     mat2D_mult(temp_vec, MAT2D_AT(camera.offset_position, 0, 0));
02756     mat2D_add(camera.current_position, temp_vec);
02757     mat2D_copy(temp_vec, camera.camera_y);
02758     mat2D_mult(temp_vec, MAT2D_AT(camera.offset_position, 1, 0));
02759     mat2D_add(camera.current_position, temp_vec);
02760     mat2D_copy(temp_vec, camera.camera_z);
02761     mat2D_mult(temp_vec, MAT2D_AT(camera.offset_position, 2, 0));
02762     mat2D_add(camera.current_position, temp_vec);
02763
02764     mat2D_fill(camera.offset_position, 0);
02765
02766     MAT2D_AT(view_mat, 0, 0) = MAT2D_AT(new_right, 0, 0);
02767     MAT2D_AT(view_mat, 0, 1) = MAT2D_AT(new_up, 0, 0);
02768     MAT2D_AT(view_mat, 0, 2) = MAT2D_AT(new_forward, 0, 0);
02769     MAT2D_AT(view_mat, 0, 3) = 0;
02770     MAT2D_AT(view_mat, 1, 0) = MAT2D_AT(new_right, 1, 0);
02771     MAT2D_AT(view_mat, 1, 1) = MAT2D_AT(new_up, 1, 0);
02772     MAT2D_AT(view_mat, 1, 2) = MAT2D_AT(new_forward, 1, 0);
02773     MAT2D_AT(view_mat, 1, 3) = 0;
02774     MAT2D_AT(view_mat, 2, 0) = MAT2D_AT(new_right, 2, 0);
02775     MAT2D_AT(view_mat, 2, 1) = MAT2D_AT(new_up, 2, 0);
02776     MAT2D_AT(view_mat, 2, 2) = MAT2D_AT(new_forward, 2, 0);
02777     MAT2D_AT(view_mat, 2, 3) = 0;
02778     MAT2D_AT(view_mat, 3, 0) = - mat2D_dot_product(camera.current_position, new_right);
02779     MAT2D_AT(view_mat, 3, 1) = - mat2D_dot_product(camera.current_position, new_up);
02780     MAT2D_AT(view_mat, 3, 2) = - mat2D_dot_product(camera.current_position, new_forward);
02781     MAT2D_AT(view_mat, 3, 3) = 1;
02782
02783
02784     mat2D_free(temp_vec);
02785     mat2D_free(new_forward);
02786     mat2D_free(new_up);
02787     mat2D_free(new_right);
02788     mat2D_free(DCM);
02789     mat2D_free(DCM_trans);
02790     mat2D_free(camera_direction);
02791 }
02792
02806 Point ae_point_project_world2screen(Mat2D view_mat, Mat2D proj_mat, Point src, int window_w, int
       window_h)
02807 {
02808     Point view_point = ae_point_project_world2view(view_mat, src);
02809     Point screen_point = ae_point_project_view2screen(proj_mat, view_point, window_w, window_h);
02810
02811     return screen_point;
02812 }
02813
02824 Point ae_point_project_world2view(Mat2D view_mat, Point src)
02825 {
02826     ae_assert_point_is_valid(src);
02827
02828     Mat2D src_point_mat = mat2D_alloc(1,4);
02829     Mat2D des_point_mat = mat2D_alloc(1,4);
02830
02831     Point des_point = {0};
02832
02833     MAT2D_AT(src_point_mat, 0, 0) = src.x;
02834     MAT2D_AT(src_point_mat, 0, 1) = src.y;
02835     MAT2D_AT(src_point_mat, 0, 2) = src.z;
02836     MAT2D_AT(src_point_mat, 0, 3) = 1;
02837
02838     mat2D_dot(des_point_mat, src_point_mat, view_mat);
02839
02840     double w = MAT2D_AT(des_point_mat, 0, 3);
02841     AE_ASSERT(w == 1);
02842     des_point.x = MAT2D_AT(des_point_mat, 0, 0) / w;
02843     des_point.y = MAT2D_AT(des_point_mat, 0, 1) / w;
02844     des_point.z = MAT2D_AT(des_point_mat, 0, 2) / w;
02845     des_point.w = w;
02846
02847     mat2D_free(src_point_mat);
02848     mat2D_free(des_point_mat);
02849
02850     return des_point;
02851
02852 }
02853
02870 Point ae_point_project_view2screen(Mat2D proj_mat, Point src, int window_w, int window_h)
02871 {
02872     ae_assert_point_is_valid(src);
02873
02874     Mat2D src_point_mat = mat2D_alloc(1,4);
```

```
02875     Mat2D des_point_mat = mat2D_alloc(1,4);
02876     Point des;
02877 
02878     MAT2D_AT(src_point_mat, 0, 0) = src.x;
02879     MAT2D_AT(src_point_mat, 0, 1) = src.y;
02880     MAT2D_AT(src_point_mat, 0, 2) = src.z;
02881     MAT2D_AT(src_point_mat, 0, 3) = 1;
02882 
02883     mat2D_dot(des_point_mat, src_point_mat, proj_mat);
02884 
02885     double w = MAT2D_AT(des_point_mat, 0, 3);
02886     if (fabs(w) > 1e-3) {
02887         des.x = MAT2D_AT(des_point_mat, 0, 0) / w;
02888         des.y = MAT2D_AT(des_point_mat, 0, 1) / w;
02889         des.z = MAT2D_AT(des_point_mat, 0, 2) / w;
02890         des.w = w;
02891     } else {
02892         // des.x = MAT2D_AT(des_point_mat, 0, 0);
02893         // des.y = MAT2D_AT(des_point_mat, 0, 1);
02894         // des.z = MAT2D_AT(des_point_mat, 0, 2);
02895         // des.w = 1;
02896 
02897         des.x = 0;
02898         des.y = 0;
02899         des.z = 0;
02900         des.w = 1;
02901     }
02902 
02903     mat2D_free(src_point_mat);
02904     mat2D_free(des_point_mat);
02905 
02906     /* scale into view */
02907     des.x += 1;
02908     des.y += 1;
02909 
02910     des.x *= 0.5f * window_w;
02911     des.y *= 0.5f * window_h;
02912 
02913     return des;
02914 }
02915 
02933 void ae_line_project_world2screen(Mat2D view_mat, Mat2D proj_mat, Point start_src, Point end_src, int
       window_w, int window_h, Point *start_des, Point *end_des, Scene *scene)
02934 {
02935     Point start_view_point = ae_point_project_world2view(view_mat, start_src);
02936     Point end_view_point = ae_point_project_world2view(view_mat, end_src);
02937 
02938     Mat2D z_p = mat2D_alloc(3, 1);
02939     Mat2D z_n = mat2D_alloc(3, 1);
02940     mat2D_fill(z_p, 0);
02941     mat2D_fill(z_n, 0);
02942     MAT2D_AT(z_p, 2, 0) = scene->camera.z_near+0.01;
02943     MAT2D_AT(z_n, 2, 0) = 1;
02944 
02945     Point clipped_start_view_point = {0}, clipped_end_view_point = {0};
02946     int rc = ae_line_clip_with_plane(start_view_point, end_view_point, z_p, z_n,
       &clipped_start_view_point, &clipped_end_view_point);
02947 
02948     if (rc == -1) {
02949         fprintf(stderr, "%s:%d: [error] problem with clipping lines\n", __FILE__, __LINE__);
02950         exit(1);
02951     } else if (rc == 0) {
02952         clipped_start_view_point = (Point){-1,-1,1,1};
02953         clipped_end_view_point = (Point){-1,-1,1,1};
02954         start_view_point = clipped_start_view_point;
02955         end_view_point = clipped_end_view_point;
02956 
02957         *start_des = start_view_point;
02958         *end_des = end_view_point;
02959         return;
02960 
02961     } else if (rc == 1) {
02962         start_view_point = clipped_start_view_point;
02963         end_view_point = clipped_end_view_point;
02964     }
02965 
02966 
02967     Point start_screen_point = ae_point_project_view2screen(proj_mat, start_view_point, window_w,
       window_h);
02968     Point end_screen_point = ae_point_project_view2screen(proj_mat, end_view_point, window_w,
       window_h);
02969 
02970     mat2D_free(z_p);
02971     mat2D_free(z_n);
02972 
02973     *start_des = start_screen_point;
02974     *end_des = end_screen_point;
```

```
02975
02976 }
02977
02988 Tri ae_tri_transform_to_view(Mat2D view_mat, Tri tri)
02989 {
02990     ae_assert_tri_is_valid(tri);
02991
02992     Mat2D src_point_mat = mat2D_alloc(1,4);
02993     Mat2D des_point_mat = mat2D_alloc(1,4);
02994
02995     Tri des_tri = tri;
02996
02997     for (int i = 0; i < 3; i++) {
02998         MAT2D_AT(src_point_mat, 0, 0) = tri.points[i].x;
02999         MAT2D_AT(src_point_mat, 0, 1) = tri.points[i].y;
03000         MAT2D_AT(src_point_mat, 0, 2) = tri.points[i].z;
03001         MAT2D_AT(src_point_mat, 0, 3) = 1;
03002
03003         mat2D_dot(des_point_mat, src_point_mat, view_mat);
03004
03005         double w = MAT2D_AT(des_point_mat, 0, 3);
03006         AE_ASSERT(w == 1);
03007         des_tri.points[i].x = MAT2D_AT(des_point_mat, 0, 0) / w;
03008         des_tri.points[i].y = MAT2D_AT(des_point_mat, 0, 1) / w;
03009         des_tri.points[i].z = MAT2D_AT(des_point_mat, 0, 2) / w;
03010         des_tri.points[i].w = w;
03011     }
03012
03013     mat2D_free(src_point_mat);
03014     mat2D_free(des_point_mat);
03015
03016     ae_assert_tri_is_valid(des_tri);
03017
03018     return des_tri;
03019 }
03020
03038 Tri_mesh ae_tri_project_world2screen(Mat2D proj_mat, Mat2D view_mat, Tri tri, int window_w, int
       window_h, Scene *scene, Lighting_mode lighting_mode)
03039 {
03040     ae_assert_tri_is_valid(tri);
03041
03042     Mat2D tri_normal = mat2D_alloc(3, 1);
03043     Mat2D temp_camera2tri = mat2D_alloc(3, 1);
03044     Mat2D camera2tri = mat2D_alloc(1, 3);
03045     Mat2D dot_product = mat2D_alloc(1, 1);
03046     Tri des_tri = tri;
03047
03048     ae_point_to_mat2D(tri.points[0], temp_camera2tri);
03049     mat2D_sub(temp_camera2tri, scene->camera.current_position);
03050     mat2D_transpose(camera2tri, temp_camera2tri);
03051
03052     /* calc lighting intensity of tri */
03053     #if 1
03054         ae_tri_calc_light_intensity(&des_tri, scene, lighting_mode);
03055     #else
03056     for (int i = 0; i < 3; i++) {
03057         ae_point_to_mat2D(tri.normals[i], tri_normal);
03058         MAT2D_AT(dot_product, 0, 0) = MAT2D_AT(light_direction, 0, 0) * MAT2D_AT(tri_normal, 0, 0) +
       MAT2D_AT(light_direction, 1, 0) * MAT2D_AT(tri_normal, 1, 0) + MAT2D_AT(light_direction, 2, 0) *
       MAT2D_AT(tri_normal, 2, 0);
03059         des_tri.light_intensity[i] = fmaxf(0.2, fminf(1, MAT2D_AT(dot_product, 0, 0)));
03060     }
03061     #endif
03062
03063     /* calc if tri is visible to the camera */
03064     ae_tri_calc_normal(tri_normal, tri);
03065     // ae_point_to_mat2D(tri.normals[0], tri_normal);
03066     MAT2D_AT(dot_product, 0, 0) = MAT2D_AT(camera2tri, 0, 0) * MAT2D_AT(tri_normal, 0, 0) +
       MAT2D_AT(camera2tri, 0, 1) * MAT2D_AT(tri_normal, 1, 0) + MAT2D_AT(camera2tri, 0, 2) *
       MAT2D_AT(tri_normal, 2, 0);
03067     if (MAT2D_AT(dot_product, 0, 0) < 0) {
03068         des_tri.to_draw = true;
03069     } else {
03070         des_tri.to_draw = false;
03071     }
03072
03073     /* transform tri to camera view */
03074     tri = ae_tri_transform_to_view(view_mat, tri);
03075
03076     // Tri_mesh temp_tri_array;
03077     // ada_init_array(Tri, temp_tri_array);
03078     // ada_append(Tri, temp_tri_array, tri);
03079     /* clip tir */
03080     Tri clipped_tri1 = {0};
03081     Tri clipped_tri2 = {0};
03082     Mat2D z_plane_p = mat2D_alloc(3, 1);
03083     Mat2D z_plane_n = mat2D_alloc(3, 1);
```

```
03084     mat2D_fill(z_plane_p, 0);
03085     mat2D_fill(z_plane_n, 0);
03086     MAT2D_AT(z_plane_p, 2, 0) = scene->camera.z_near+0.01;
03087     MAT2D_AT(z_plane_n, 2, 0) = 1;
03088 
03089     int num_clipped_tri = ae_tri_clip_with_plane(tri, z_plane_p, z_plane_n, &clipped_tri1,
      &clipped_tri2);
03090     Tri_mesh temp_tri_array;
03091     ada_init_array(Tri, temp_tri_array);
03092     if (num_clipped_tri == -1) {
03093         fprintf(stderr, "%s:%d: [error] problem with clipping triangles\n", __FILE__, __LINE__);
03094         exit(1);
03095     } else if (num_clipped_tri == 0) {
03096         ;
03097     } else if (num_clipped_tri == 1) {
03098         ae_assert_tri_is_valid(clipped_tri1);
03099         ada_append(Tri, temp_tri_array, clipped_tri1);
03100     } else if (num_clipped_tri == 2) {
03101         ae_assert_tri_is_valid(clipped_tri1);
03102         ae_assert_tri_is_valid(clipped_tri2);
03103         ada_append(Tri, temp_tri_array, clipped_tri1);
03104         ada_append(Tri, temp_tri_array, clipped_tri2);
03105     }
03106     mat2D_free(z_plane_p);
03107     mat2D_free(z_plane_n);
03108 
03109     for (size_t temp_tri_index = 0; temp_tri_index < temp_tri_array.length; temp_tri_index++) {
03110         /* project tri to screen */
03111         for (int i = 0; i < 3; i++) {
03112             des_tri.points[i] = ae_point_project_view2screen(proj_mat,
      temp_tri_array.elements[temp_tri_index].points[i], window_w, window_h);
03113 
03114             if (des_tri.points[i].w) {
03115                 des_tri.tex_points[i].x /= des_tri.points[i].w;
03116                 des_tri.tex_points[i].y /= des_tri.points[i].w;
03117                 des_tri.tex_points[i].z /= des_tri.points[i].w;
03118                 des_tri.tex_points[i].w  = des_tri.points[i].w;
03119             }
03120 
03121         }
03122         ae_assert_tri_is_valid(des_tri);
03123         temp_tri_array.elements[temp_tri_index] = des_tri;
03124     }
03125 
03126 
03127     mat2D_free(tri_normal);
03128     mat2D_free(temp_camera2tri);
03129     mat2D_free(camera2tri);
03130     mat2D_free(dot_product);
03131 
03132     return temp_tri_array;
03133 }
03134 
03151 void ae_tri_mesh_project_world2screen(Mat2D proj_mat, Mat2D view_mat, Tri_mesh *des, Tri_mesh src, int
      window_w, int window_h, Scene *scene, Lighting_mode lighting_mode)
03152 {
03153     Tri_mesh temp_des = *des;
03154     temp_des.length = 0;
03155 
03156     size_t i;
03157     for (i = 0; i < src.length; i++) {
03158         Tri_mesh temp_tri_array = ae_tri_project_world2screen(proj_mat, view_mat, src.elements[i],
      window_w, window_h, scene, lighting_mode);
03159 
03160         for (size_t tri_index = 0; tri_index < temp_tri_array.length; tri_index++) {
03161             Tri temp_tri = temp_tri_array.elements[tri_index];
03162             ada_append(Tri, temp_des, temp_tri);
03163         }
03164 
03165         free(temp_tri_array.elements);
03166     }
03167 
03168     /* clip tir */
03169     int offset = 0;
03170     Mat2D top_p = mat2D_alloc(3, 1);
03171     Mat2D top_n = mat2D_alloc(3, 1);
03172     mat2D_fill(top_p, 0);
03173     mat2D_fill(top_n, 0);
03174     MAT2D_AT(top_p, 1, 0) = 0 + offset;
03175     MAT2D_AT(top_n, 1, 0) = 1;
03176 
03177     Mat2D bottom_p = mat2D_alloc(3, 1);
03178     Mat2D bottom_n = mat2D_alloc(3, 1);
03179     mat2D_fill(bottom_p, 0);
03180     mat2D_fill(bottom_n, 0);
03181     MAT2D_AT(bottom_p, 1, 0) = window_h - offset;
03182     MAT2D_AT(bottom_n, 1, 0) = -1;
```

```
03183
03184     Mat2D left_p = mat2D_alloc(3, 1);
03185     Mat2D left_n = mat2D_alloc(3, 1);
03186     mat2D_fill(left_p, 0);
03187     mat2D_fill(left_n, 0);
03188     MAT2D_AT(left_p, 0, 0) = 0 + offset;
03189     MAT2D_AT(left_n, 0, 0) = 1;
03190
03191     Mat2D right_p = mat2D_alloc(3, 1);
03192     Mat2D right_n = mat2D_alloc(3, 1);
03193     mat2D_fill(right_p, 0);
03194     mat2D_fill(right_n, 0);
03195     MAT2D_AT(right_p, 0, 0) = window_w - offset;
03196     MAT2D_AT(right_n, 0, 0) = -1;
03197
03198     for (int plane_number = 0; plane_number < 4; plane_number++) {
03199         for (int tri_index = 0; tri_index < (int)(temp_des.length); tri_index++) {
03200             if (temp_des.length == 0) {
03201                 break;
03202             }
03203             // if (temp_des.elements[tri_index].to_draw == false) {
03204             //     ada_remove_unordered(Tri, temp_des, tri_index);
03205             //     tri_index--;
03206             //     tri_index = (int)fmaxf((float)tri_index, 0.0f);
03207             //     continue;
03208             // }
03209             Tri clipped_tri1 = {0};
03210             Tri clipped_tri2 = {0};
03211             int num_clipped_tri;
03212             switch (plane_number) {
03213                 case 0:
03214                     num_clipped_tri = ae_tri_clip_with_plane(temp_des.elements[tri_index], top_p,
      top_n, &clipped_tri1, &clipped_tri2);
03215                 break;
03216                 case 1:
03217                     num_clipped_tri = ae_tri_clip_with_plane(temp_des.elements[tri_index], right_p,
      right_n, &clipped_tri1, &clipped_tri2);
03218                 break;
03219                 case 2:
03220                     num_clipped_tri = ae_tri_clip_with_plane(temp_des.elements[tri_index], bottom_p,
      bottom_n, &clipped_tri1, &clipped_tri2);
03221                 break;
03222                 case 3:
03223                     num_clipped_tri = ae_tri_clip_with_plane(temp_des.elements[tri_index], left_p,
      left_n, &clipped_tri1, &clipped_tri2);
03224                 break;
03225             }
03226             if (num_clipped_tri == -1) {
03227                 fprintf(stderr, "%s:%d: [error] problem with clipping triangles\n", __FILE__,
      __LINE__);
03228                 exit(1);
03229             } else if (num_clipped_tri == 0) {
03230                 ada_remove_unordered(Tri, temp_des, tri_index);
03231                 tri_index--;
03232                 tri_index = (int)fmaxf((float)tri_index, 0.0f);
03233             } else if (num_clipped_tri == 1) {
03234                 ae_assert_tri_is_valid(clipped_tri1);
03235                 temp_des.elements[tri_index] = clipped_tri1;
03236             } else if (num_clipped_tri == 2) {
03237                 ae_assert_tri_is_valid(clipped_tri1);
03238                 ae_assert_tri_is_valid(clipped_tri2);
03239                 temp_des.elements[tri_index] = clipped_tri1;
03240                 ada_insert_unordered(Tri, temp_des, clipped_tri2, tri_index+1);
03241             }
03242         }
03243     }
03244
03245     // if (temp_des.length > 2) {
03246     //     ae_qsort_tri(temp_des.elements, 0, temp_des.length-1);
03247     // }
03248
03249     mat2D_free(top_p);
03250     mat2D_free(top_n);
03251     mat2D_free(bottom_p);
03252     mat2D_free(bottom_n);
03253     mat2D_free(left_p);
03254     mat2D_free(left_n);
03255     mat2D_free(right_p);
03256     mat2D_free(right_n);
03257
03258     *des = temp_des;
03259 }
03260
03271 Quad ae_quad_transform_to_view(Mat2D view_mat, Quad quad)
03272 {
03273     ae_assert_quad_is_valid(quad);
03274
```

```
03275     Mat2D src_point_mat = mat2D_alloc(1,4);
03276     Mat2D des_point_mat = mat2D_alloc(1,4);
03277
03278     Quad des_quad = quad;
03279
03280     for (int i = 0; i < 4; i++) {
03281         MAT2D_AT(src_point_mat, 0, 0) = quad.points[i].x;
03282         MAT2D_AT(src_point_mat, 0, 1) = quad.points[i].y;
03283         MAT2D_AT(src_point_mat, 0, 2) = quad.points[i].z;
03284         MAT2D_AT(src_point_mat, 0, 3) = 1;
03285
03286         mat2D_dot(des_point_mat, src_point_mat, view_mat);
03287
03288         double w = MAT2D_AT(des_point_mat, 0, 3);
03289         AE_ASSERT(w == 1);
03290         des_quad.points[i].x = MAT2D_AT(des_point_mat, 0, 0) / w;
03291         des_quad.points[i].y = MAT2D_AT(des_point_mat, 0, 1) / w;
03292         des_quad.points[i].z = MAT2D_AT(des_point_mat, 0, 2) / w;
03293         des_quad.points[i].w = w;
03294     }
03295
03296     mat2D_free(src_point_mat);
03297     mat2D_free(des_point_mat);
03298
03299     ae_assert_quad_is_valid(des_quad);
03300
03301     return des_quad;
03302 }
03303
03321 Quad_mesh ae_quad_project_world2screen(Mat2D proj_mat, Mat2D view_mat, Quad quad, int window_w, int
       window_h, Scene *scene, Lighting_mode lighting_mode)
03322 {
03323     ae_assert_quad_is_valid(quad);
03324
03325     Mat2D quad_normal = mat2D_alloc(3, 1);
03326     Mat2D camera2quad = mat2D_alloc(3, 1);
03327     Mat2D dot_product = mat2D_alloc(1, 1);
03328     Quad des_quad = quad;
03329
03330     /* calc lighting intensity of tri */
03331     #if 1
03332         ae_quad_calc_light_intensity(&des_quad, scene, lighting_mode);
03333     #else
03334     for (int i = 0; i < 4; i++) {
03335         ae_point_to_mat2D(quad.normals[i], quad_normal);
03336         MAT2D_AT(dot_product, 0, 0) = scene->light_source0.light_direction_or_pos.x *
       MAT2D_AT(quad_normal, 0, 0) + scene->light_source0.light_direction_or_pos.y * MAT2D_AT(quad_normal,
       1, 0) + scene->light_source0.light_direction_or_pos.z * MAT2D_AT(quad_normal, 2, 0);
03337         des_quad.light_intensity[i] = fmaxf(0.2, fminf(1, MAT2D_AT(dot_product, 0, 0)));
03338     }
03339     #endif
03340
03341     /* calc if quad is visible to the camera */
03342     bool visible = 0;
03343     #if 1
03344     for (int i = 0; i < 4; i++) {
03345         ae_point_to_mat2D(quad.points[i], camera2quad);
03346         mat2D_sub(camera2quad, scene->camera.current_position);
03347
03348         ae_point_to_mat2D(quad.normals[i], quad_normal);
03349         MAT2D_AT(dot_product, 0, 0) = MAT2D_AT(camera2quad, 0, 0) * MAT2D_AT(quad_normal, 0, 0) +
       MAT2D_AT(camera2quad, 1, 0) * MAT2D_AT(quad_normal, 1, 0) + MAT2D_AT(camera2quad, 2, 0) *
       MAT2D_AT(quad_normal, 2, 0);
03350         visible = visible || (MAT2D_AT(dot_product, 0, 0) < 0);
03351     }
03352     #else
03353     ae_point_to_mat2D(quad.points[0], camera2quad);
03354     mat2D_sub(camera2quad, scene->camera.current_position);
03355
03356     Point ave_norm = ae_quad_get_average_normal(quad);
03357     ae_point_to_mat2D(ave_norm, quad_normal);
03358     MAT2D_AT(dot_product, 0, 0) = MAT2D_AT(camera2quad, 0, 0) * MAT2D_AT(quad_normal, 0, 0) +
       MAT2D_AT(camera2quad, 1, 0) * MAT2D_AT(quad_normal, 1, 0) + MAT2D_AT(camera2quad, 2, 0) *
       MAT2D_AT(quad_normal, 2, 0);
03359     visible = MAT2D_AT(dot_product, 0, 0) < 0;
03360     #endif
03361
03362     if (visible) {
03363         des_quad.to_draw = true;
03364     } else {
03365         des_quad.to_draw = false;
03366     }
03367
03368     /* transform quad to camera view */
03369     quad = ae_quad_transform_to_view(view_mat, quad);
03370
03371     /* clip quad */
```

```
03372     Quad  clipped_quad1 = {0}, clipped_quad2 = {0};
03373     Mat2D z_plane_p = mat2D_alloc(3, 1);
03374     Mat2D z_plane_n = mat2D_alloc(3, 1);
03375     mat2D_fill(z_plane_p, 0);
03376     mat2D_fill(z_plane_n, 0);
03377     MAT2D_AT(z_plane_p, 2, 0) = scene->camera.z_near+0.01;
03378     MAT2D_AT(z_plane_n, 2, 0) = 1;
03379
03380     int num_clipped_quad = ae_quad_clip_with_plane(quad, z_plane_p, z_plane_n, &clipped_quad1,
      &clipped_quad2);
03381     Quad_mesh temp_quad_array;
03382     ada_init_array(Quad, temp_quad_array);
03383     if (num_clipped_quad == -1) {
03384         fprintf(stderr, "%s:%d: [error] problem with clipping quad\n", __FILE__, __LINE__);
03385         exit(1);
03386     } else if (num_clipped_quad == 0) {
03387         ;
03388     } else if (num_clipped_quad == 1) {
03389         ae_assert_quad_is_valid(clipped_quad1);
03390         ada_append(Quad, temp_quad_array, clipped_quad1);
03391     } else if (num_clipped_quad == 2) {
03392         ae_assert_quad_is_valid(clipped_quad1);
03393         ae_assert_quad_is_valid(clipped_quad2);
03394         ada_append(Quad, temp_quad_array, clipped_quad1);
03395         ada_append(Quad, temp_quad_array, clipped_quad2);
03396     }
03397     mat2D_free(z_plane_p);
03398     mat2D_free(z_plane_n);
03399
03400     for (size_t temp_quad_index = 0; temp_quad_index < temp_quad_array.length; temp_quad_index++) {
03401         /* project quad to screen */
03402         for (int i = 0; i < 4; i++) {
03403             des_quad.points[i] = ae_point_project_view2screen(proj_mat,
      temp_quad_array.elements[temp_quad_index].points[i], window_w, window_h);
03404
03405         }
03406         ae_assert_quad_is_valid(des_quad);
03407         temp_quad_array.elements[temp_quad_index] = des_quad;
03408     }
03409
03410
03411     mat2D_free(quad_normal);
03412     mat2D_free(camera2quad);
03413     mat2D_free(dot_product);
03414
03415     return temp_quad_array;
03416 }
03417
03434 void ae_quad_mesh_project_world2screen(Mat2D proj_mat, Mat2D view_mat, Quad_mesh *des, Quad_mesh src,
       int window_w, int window_h, Scene *scene, Lighting_mode lighting_mode)
03435 {
03436     Quad_mesh temp_des = *des;
03437     temp_des.length = 0;
03438
03439     size_t i;
03440     for (i = 0; i < src.length; i++) {
03441         Quad_mesh temp_quad_array = ae_quad_project_world2screen(proj_mat, view_mat, src.elements[i],
      window_w, window_h, scene, lighting_mode);
03442
03443         for (size_t quad_index = 0; quad_index < temp_quad_array.length; quad_index++) {
03444             Quad temp_quad = temp_quad_array.elements[quad_index];
03445             ada_append(Quad, temp_des, temp_quad);
03446         }
03447
03448         free(temp_quad_array.elements);
03449     }
03450
03451
03452     /* clip quad */
03453     int offset = 0;
03454     Mat2D top_p = mat2D_alloc(3, 1);
03455     Mat2D top_n = mat2D_alloc(3, 1);
03456     mat2D_fill(top_p, 0);
03457     mat2D_fill(top_n, 0);
03458     MAT2D_AT(top_p, 1, 0) = 0 + offset;
03459     MAT2D_AT(top_n, 1, 0) = 1;
03460
03461     Mat2D bottom_p = mat2D_alloc(3, 1);
03462     Mat2D bottom_n = mat2D_alloc(3, 1);
03463     mat2D_fill(bottom_p, 0);
03464     mat2D_fill(bottom_n, 0);
03465     MAT2D_AT(bottom_p, 1, 0) = window_h - offset;
03466     MAT2D_AT(bottom_n, 1, 0) = -1;
03467
03468     Mat2D left_p = mat2D_alloc(3, 1);
03469     Mat2D left_n = mat2D_alloc(3, 1);
03470     mat2D_fill(left_p, 0);
```

```
03471     mat2D_fill(left_n, 0);
03472     MAT2D_AT(left_p, 0, 0) = 0 + offset;
03473     MAT2D_AT(left_n, 0, 0) = 1;
03474 
03475     Mat2D right_p = mat2D_alloc(3, 1);
03476     Mat2D right_n = mat2D_alloc(3, 1);
03477     mat2D_fill(right_p, 0);
03478     mat2D_fill(right_n, 0);
03479     MAT2D_AT(right_p, 0, 0) = window_w - offset;
03480     MAT2D_AT(right_n, 0, 0) = -1;
03481 
03482     for (int plane_number = 0; plane_number < 4; plane_number++) {
03483         for (int quad_index = 0; quad_index < (int)(temp_des.length); quad_index++) {
03484             if (temp_des.length == 0) {
03485                 break;
03486             }
03487             // if (temp_des.elements[quad_index].to_draw == false) {
03488             //     ada_remove_unordered(Quad, temp_des, quad_index);
03489             //     quad_index--;
03490             //     quad_index = (int)fmaxf((float)quad_index, 0.0f);
03491             //     continue;
03492             // }
03493             Quad clipped_quad1 = {0}, clipped_quad2 = {0};
03494             int num_clipped_quad;
03495             switch (plane_number) {
03496                 case 0:
03497                     num_clipped_quad = ae_quad_clip_with_plane(temp_des.elements[quad_index], top_p,
    top_n, &clipped_quad1, &clipped_quad2);
03498                 break;
03499                 case 1:
03500                     num_clipped_quad = ae_quad_clip_with_plane(temp_des.elements[quad_index], right_p,
    right_n, &clipped_quad1, &clipped_quad2);
03501                 break;
03502                 case 2:
03503                     num_clipped_quad = ae_quad_clip_with_plane(temp_des.elements[quad_index],
    bottom_p, bottom_n, &clipped_quad1, &clipped_quad2);
03504                 break;
03505                 case 3:
03506                     num_clipped_quad = ae_quad_clip_with_plane(temp_des.elements[quad_index], left_p,
    left_n, &clipped_quad1, &clipped_quad2);
03507                 break;
03508             }
03509             if (num_clipped_quad == -1) {
03510                 fprintf(stderr, "%s:%d: [error] problem with clipping quads\n", __FILE__, __LINE__);
03511                 exit(1);
03512             } else if (num_clipped_quad == 0) {
03513                 ada_remove_unordered(Quad, temp_des, quad_index);
03514                 quad_index--;
03515                 quad_index = (int)fmaxf((float)quad_index, 0.0f);
03516             } else if (num_clipped_quad == 1) {
03517                 ae_assert_quad_is_valid(clipped_quad1);
03518                 temp_des.elements[quad_index] = clipped_quad1;
03519             } else if (num_clipped_quad == 2) {
03520                 ae_assert_quad_is_valid(clipped_quad1);
03521                 ae_assert_quad_is_valid(clipped_quad2);
03522                 temp_des.elements[quad_index] = clipped_quad1;
03523                 ada_insert_unordered(Quad, temp_des, clipped_quad2, quad_index+1);
03524                 quad_index++;
03525             }
03526         }
03527     }
03528 
03529     mat2D_free(top_p);
03530     mat2D_free(top_n);
03531     mat2D_free(bottom_p);
03532     mat2D_free(bottom_n);
03533     mat2D_free(left_p);
03534     mat2D_free(left_n);
03535     mat2D_free(right_p);
03536     mat2D_free(right_n);
03537 
03538     *des = temp_des;
03539 }
03540 
03541 
03558 void ae_curve_project_world2screen(Mat2D proj_mat, Mat2D view_mat, Curve *des, Curve src, int
     window_w, int window_h, Scene *scene)
03559 {
03560     ae_curve_copy(des, src);
03561     Curve temp_des = *des;
03562     /* set planes */
03563     int offset = 50;
03564     Mat2D top_p = mat2D_alloc(3, 1);
03565     Mat2D top_n = mat2D_alloc(3, 1);
03566     mat2D_fill(top_p, 0);
03567     mat2D_fill(top_n, 0);
03568     MAT2D_AT(top_p, 1, 0) = 0 + offset;
```

```
03569     MAT2D_AT(top_n, 1, 0) = 1;
03570     Mat2D bottom_p = mat2D_alloc(3, 1);
03571     Mat2D bottom_n = mat2D_alloc(3, 1);
03572     mat2D_fill(bottom_p, 0);
03573     mat2D_fill(bottom_n, 0);
03574     MAT2D_AT(bottom_p, 1, 0) = window_h - offset;
03575     MAT2D_AT(bottom_n, 1, 0) = -1;
03576     Mat2D left_p = mat2D_alloc(3, 1);
03577     Mat2D left_n = mat2D_alloc(3, 1);
03578     mat2D_fill(left_p, 0);
03579     mat2D_fill(left_n, 0);
03580     MAT2D_AT(left_p, 0, 0) = 0 + offset;
03581     MAT2D_AT(left_n, 0, 0) = 1;
03582     Mat2D right_p = mat2D_alloc(3, 1);
03583     Mat2D right_n = mat2D_alloc(3, 1);
03584     mat2D_fill(right_p, 0);
03585     mat2D_fill(right_n, 0);
03586     MAT2D_AT(right_p, 0, 0) = window_w - offset;
03587     MAT2D_AT(right_n, 0, 0) = -1;
03588
03589     for (size_t point_index = 0; point_index < temp_des.length-1; point_index++) {
03590         Point start_src_point = src.elements[point_index];
03591         Point end_src_point = src.elements[point_index+1];
03592
03593         Point start_des_point = {0}, end_des_point = {0};
03594
03595         ae_line_project_world2screen(view_mat, proj_mat, start_src_point, end_src_point, window_w,
    window_h, &start_des_point, &end_des_point, scene);
03596
03597
03598         Point clipped_start_des_point = {0}, clipped_end_des_point = {0};
03599
03600         for (int plane_number = 0; plane_number < 4; plane_number++) {
03601             int rc;
03602             switch (plane_number) {
03603                 case 0:
03604                     rc = ae_line_clip_with_plane(start_des_point, end_des_point, top_p, top_n,
    &clipped_start_des_point, &clipped_end_des_point);
03605                 break;
03606                 case 1:
03607                     rc = ae_line_clip_with_plane(start_des_point, end_des_point, right_p, right_n,
    &clipped_start_des_point, &clipped_end_des_point);
03608                 break;
03609                 case 2:
03610                     rc = ae_line_clip_with_plane(start_des_point, end_des_point, bottom_p, bottom_n,
    &clipped_start_des_point, &clipped_end_des_point);
03611                 break;
03612                 case 3:
03613                     rc = ae_line_clip_with_plane(start_des_point, end_des_point, left_p, left_n,
    &clipped_start_des_point, &clipped_end_des_point);
03614                 break;
03615             }
03616             if (rc == -1) {
03617                 fprintf(stderr, "%s:%d: [error] problem with clipping lines\n", __FILE__, __LINE__);
03618                 exit(1);
03619             } else if (rc == 0) {
03620                 clipped_start_des_point = (Point){-1,-1,1,1};
03621                 clipped_end_des_point = (Point){-1,-1,1,1};
03622                 start_des_point = clipped_start_des_point;
03623                 end_des_point = clipped_end_des_point;
03624                 temp_des.elements[point_index] = start_des_point;
03625                 temp_des.elements[point_index+1] = end_des_point;
03626             } else if (rc == 1) {
03627                 start_des_point = clipped_start_des_point;
03628                 end_des_point = clipped_end_des_point;
03629                 temp_des.elements[point_index] = start_des_point;
03630                 temp_des.elements[point_index+1] = end_des_point;
03631             }
03632         }
03633
03634     }
03635
03636     Point default_point = (Point){-1,-1,1,1};
03637     for (int i = 0; i < (int)temp_des.length; i++) {
03638         if (ae_points_equal(temp_des.elements[i], default_point)) {
03639             ada_remove(Point, temp_des, i);
03640             i--;
03641         }
03642     }
03643
03644     *des = temp_des;
03645
03646     mat2D_free(top_p);
03647     mat2D_free(top_n);
03648     mat2D_free(bottom_p);
03649     mat2D_free(bottom_n);
03650     mat2D_free(left_p);
```

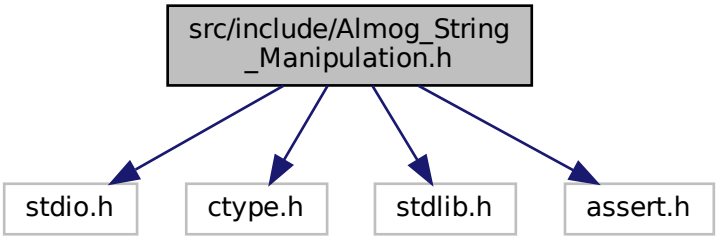
```
03651     mat2D_free(left_n);
03652     mat2D_free(right_p);
03653     mat2D_free(right_n);
03654 }
03655
03670 void ae_curve_ada_project_world2screen(Mat2D proj_mat, Mat2D view_mat, Curve_ada *des, Curve_ada src,
       int window_w, int window_h, Scene *scene)
03671 {
03672     if (src.length == 0) return;
03673     for (size_t curve_index = 0; curve_index < src.length; curve_index++) {
03674         ae_curve_project_world2screen(proj_mat, view_mat, &(des->elements[curve_index]),
       src.elements[curve_index], window_w, window_h, scene);
03675     }
03676 }
03677
03691 void ae_grid_project_world2screen(Mat2D proj_mat, Mat2D view_mat, Grid des, Grid src, int window_w,
       int window_h, Scene *scene)
03692 {
03693     if (src.curves.length == 0) return;
03694     for (size_t curve_index = 0; curve_index < src.curves.length; curve_index++) {
03695         ae_curve_project_world2screen(proj_mat, view_mat, &(des.curves.elements[curve_index]),
       src.curves.elements[curve_index], window_w, window_h, scene);
03696     }
03697 }
03698
03706 void ae_tri_swap(Tri *v, int i, int j)
03707 {
03708     Tri temp;
03709
03710     temp = v[i];
03711     v[i] = v[j];
03712     v[j] = temp;
03713 }
03714
03725 bool ae_tri_compare(Tri t1, Tri t2)
03726 {
03727     float t1_z_max = fmaxf(t1.points[0].z, fmaxf(t1.points[1].z, t1.points[2].z));
03728     float t2_z_max = fmaxf(t2.points[0].z, fmaxf(t2.points[1].z, t2.points[2].z));
03729
03730     return t1_z_max > t2_z_max;
03731 }
03732
03742 void ae_tri_qsort(Tri *v, int left, int right)
03743 {
03744     int i, last;
03745
03746     if (left >= right)                  /* do nothing if array contains */
03747         return;                         /* fewer than two elements */
03748     ae_tri_swap(v, left, (left + right) / 2);  /* move partition elem */
03749     last = left;                        /* to v[0] */
03750     for (i = left + 1; i <= right; i++) /* partition */
03751         if (ae_tri_compare(v[i], v[left]))
03752             ae_tri_swap(v, ++last, i);
03753     ae_tri_swap(v, left, last); /* restore partition elem */
03754     ae_tri_qsort(v, left, last - 1);
03755     ae_tri_qsort(v, last + 1, right);
03756 }
03757
03770 double ae_linear_map(double s, double min_in, double max_in, double min_out, double max_out)
03771 {
03772     return (min_out + ((s-min_in)*(max_out-min_out))/(max_in-min_in));
03773 }
03774
03785 void ae_z_buffer_copy_to_screen(Mat2D_uint32 screen_mat, Mat2D inv_z_buffer)
03786 {
03787     double max_inv_z = 0;
03788     double min_inv_z = DBL_MAX;
03789     for (size_t i = 0; i < inv_z_buffer.rows; i++) {
03790         for (size_t j = 0; j < inv_z_buffer.cols; j++) {
03791             if (MAT2D_AT(inv_z_buffer, i, j) > max_inv_z) {
03792                 max_inv_z = MAT2D_AT(inv_z_buffer, i, j);
03793             }
03794             if (MAT2D_AT(inv_z_buffer, i, j) < min_inv_z && MAT2D_AT(inv_z_buffer, i, j) > 0) {
03795                 min_inv_z = MAT2D_AT(inv_z_buffer, i, j);
03796             }
03797         }
03798     }
03799     for (size_t i = 0; i < inv_z_buffer.rows; i++) {
03800         for (size_t j = 0; j < inv_z_buffer.cols; j++) {
03801             double z_fraq = MAT2D_AT(inv_z_buffer, i, j);
03802             z_fraq = fmax(z_fraq, min_inv_z);
03803             z_fraq = ae_linear_map(z_fraq, min_inv_z, max_inv_z, 0.1, 1);
03804             uint32_t color = RGB_hexRGB(0xFF*z_fraq, 0xFF*z_fraq, 0xFF*z_fraq);
03805             MAT2D_AT_UINT32(screen_mat, i, j) = color;
03806         }
03807     }
03808 }
```

```
03809
03810 #endif /* ALMOG_ENGINE_IMPLEMENTATION */ //
```

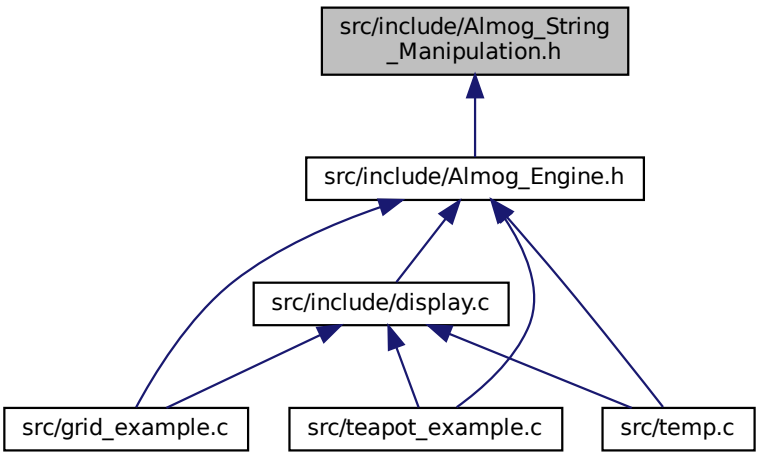
4.9 src/include/Almog_String_Manipulation.h File Reference

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

Include dependency graph for Almog_String_Manipulation.h:



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



Macros

- #define MAXDIR 100

- #define MAX_LEN_LINE (int)1e3
- #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 dprintSIZE_T(expr) printf(#expr " = %zu\n", expr)

Functions

- int asm_get_line (FILE *fp, char *dst)
- int asm_length (char *str)
- int asm_get_next_word_from_line (char *dst, char *src, char seperator)
- void asm_copy_arry_by_indesies (char *target, int start, int end, char *src)
- int asm_get_word_and_cut (char *dst, char *src, char seperator)
- int asm_str_in_str (char *src, char *word2search)
- int asm_strncmp (const char *s1, const char *s2, const int N)

4.9.1 Macro Definition Documentation

4.9.1.1 dprintCHAR

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

Definition at line 12 of file Almog_String_Manipulation.h.

4.9.1.2 dprintINT

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

Definition at line 13 of file Almog_String_Manipulation.h.

4.9.1.3 dprintSIZE_T

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

Definition at line 14 of file Almog_String_Manipulation.h.

4.9.1.4 dprintSTRING

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

Definition at line 11 of file Almog_String_Manipulation.h.

4.9.1.5 MAX_LEN_LINE

```
#define MAX_LEN_LINE (int)1e3
```

Definition at line 10 of file Almog_String_Manipulation.h.

4.9.1.6 MAXDIR

```
#define MAXDIR 100
```

Definition at line 9 of file Almog_String_Manipulation.h.

4.9.2 Function Documentation

4.9.2.1 asm_copy_arry_by_indesies()

```
void asm_copy_arry_by_indesies (
             char * target,
             int start,
             int end,
             char * src )
```

4.9.2.2 asm_get_line()

```
int asm_get_line (
             FILE * fp,
             char * dst )
```

Referenced by ae_tri_mesh_get_from_obj_file().

4.9.2.3 asm_get_next_word_from_line()

```
int asm_get_next_word_from_line (
            char * dst,
            char * src,
            char seperator )
```

Referenced by ae_tri_mesh_get_from_obj_file().

4.9.2.4 asm_get_word_and_cut()

```
int asm_get_word_and_cut (
            char * dst,
            char * src,
            char seperator )
```

Referenced by ae_tri_mesh_get_from_file(), and ae_tri_mesh_get_from_obj_file().

4.9.2.5 asm_length()

```
int asm_length (
            char * str )
```

Referenced by ae_tri_mesh_get_from_obj_file().

4.9.2.6 asm_str_in_str()

```
int asm_str_in_str (
            char * src,
            char * word2search )
```

Referenced by ae_tri_mesh_get_from_file(), and ae_tri_mesh_get_from_obj_file().

4.9.2.7 asm_strncmp()

```
int asm_strncmp (
            const char * s1,
            const char * s2,
            const int N )
```

4.10 Almog_String_Manipulation.h

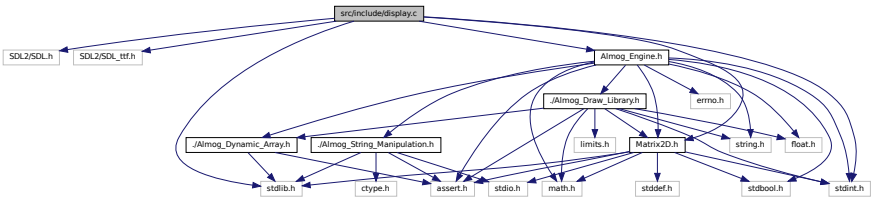
```
00001 #ifndef ALMOG_STRING_MANIPULATION_H_
00002 #define ALMOG_STRING_MANIPULATION_H_
00003
00004 #include <stdio.h>
00005 #include <ctype.h>
00006 #include <stdlib.h>
00007 #include <assert.h>
00008
00009 #define MAXDIR 100
00010 #define MAX_LEN_LINE (int)1e3
00011 #define dprintSTRING(expr) printf(#expr " = %s\n", expr)
00012 #define dprintCHAR(expr) printf(#expr " = %c\n", expr)
00013 #define dprintINT(expr) printf(#expr " = %d\n", expr)
00014 #define dprintSIZE_T(expr) printf(#expr " = %zu\n", expr)
00015
00016
00017 int asm_get_line(FILE *fp, char *dst);
00018 int asm_length(char *str);
00019 int asm_get_next_word_from_line(char *dst, char *src, char seperator);
00020 void asm_copy_arry_by_indesies(char *target, int start, int end, char *src);
00021 int asm_get_word_and_cut(char *dst, char *src, char seperator);
00022 int asm_str_in_str(char *src, char *word2search);
00023 int asm_strncmp(const char *s1, const char *s2, const int N);
00024
00025 #endif /*ALMOG_STRING_MANIPULATION_H_*/
00026
00027 #ifdef ALMOG_STRING_MANIPULATION_IMPLEMENTATION
00028 #undef ALMOG_STRING_MANIPULATION_IMPLEMENTATION
00029
00030 int asm_get_line(FILE *fp, char *dst)
00031 {
00032     int i = 0;
00033     char c;
00034
00035     while ((c = fgetc(fp)) != '\n' && c != EOF) {
00036         dst[i] = c;
00037         i++;
00038         if (i >= MAX_LEN_LINE) {
00039             fprintf(stderr, "ERROR: line too long\n");
00040             exit(1);
00041         }
00042     }
00043     dst[i] = '\0';
00044     if (c == EOF && i == 0) {
00045         return -1;
00046     }
00047     return i;
00048 }
00049
00050 int asm_length(char *str)
00051 {
00052     char c;
00053     int i = 0;
00054
00055     while ((c = str[i]) != '\0') {
00056         i++;
00057     }
00058     return i++;
00059 }
00060
00061 int asm_get_next_word_from_line(char *dst, char *src, char seperator)
00062 {
00063     int i = 0, j = 0;
00064     char c;
00065
00066     while (isspace((c = src[i]))) {
00067         i++;
00068     }
00069
00070     while ((c = src[i]) != seperator &&
00071                       c != '\n'&&
00072                       c != '\0') {
00073                         dst[j] = src[i];
00074                         i++;
00075                         j++;
00076     }
00077
00078     if ((c == seperator ||
00079          c == '\n'||
00080          c == '\0') && i == 0) {
00081             dst[j++] = c;
00082             i++;
00083     }
00084
00085     dst[j] = '\0';
```

```
00086
00087     if (j == 0) {
00088         return -1;
00089     }
00090     return i;
00091
00092 }
00093
00094 void asm_copy_arry_by_indesies(char *target, int start, int end, char *src)
00095 {
00096     int j = 0;
00097     for (int i = start; i < end; i++) {
00098         target[j] = src[i];
00099         j++;
00100     }
00101     target[j] = '\0';
00102 }
00103
00104 int asm_get_word_and_cut(char *dst, char *src, char seperator)
00105 {
00106     int last_pos;
00107
00108     if (src[0] == '\0') {
00109         return 0;
00110     }
00111     last_pos = asm_get_next_word_from_line(dst, src, seperator);
00112     if (last_pos == -1) {
00113         return 0;
00114     }
00115     asm_copy_arry_by_indesies(src, last_pos, asm_length(src), src);
00116     return 1;
00117 }
00118
00119 int asm_str_in_str(char *src, char *word2search)
00120 {
00121     int i = 0, num_of_accur = 0;
00122     while (src[i] != '\0') {
00123         if (asm_strncmp(src+i, word2search, asm_length(word2search))) {
00124             num_of_accur++;
00125         }
00126         i++;
00127     }
00128     return num_of_accur;
00129 }
00130
00131 /* return 1 if equal, 0 if different */
00132 int asm_strncmp(const char *s1, const char *s2, const int N)
00133 {
00134     int i = 0;
00135     while (i < N) {
00136         if (s1[i] == '\0' && s2[i] == '\0') {
00137             break;
00138         }
00139         if (s1[i] != s2[i] || (s1[i] == '\0') || (s2[i] == '\0')) {
00140             return 0;
00141         }
00142         i++;
00143     }
00144     return 1;
00145 }
00146
00147
00148 #endif /*ALMOG_STRING_MANIPULATION_IMPLEMENTATION*/
00149
```

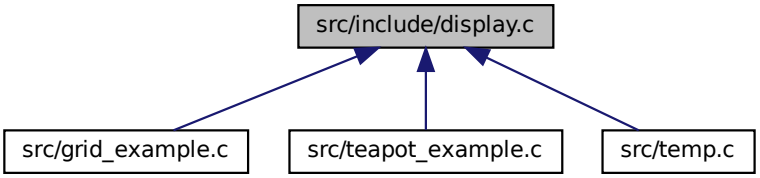
4.11 src/include/display.c File Reference

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

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 ()

4.11.1 Macro Definition Documentation

4.11.1.1 dprintCHAR

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

Definition at line 25 of file display.c.

4.11.1.2 dprintD

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

Definition at line 27 of file display.c.

4.11.1.3 dprintINT

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

Definition at line 26 of file display.c.

4.11.1.4 dprintSIZE_T

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

Definition at line 28 of file display.c.

4.11.1.5 dprintSTRING

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

Definition at line 24 of file display.c.

4.11.1.6 FPS

```
#define FPS 100
```

Definition at line 17 of file display.c.

4.11.1.7 FRAME_TARGET_TIME

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

Definition at line 21 of file display.c.

4.11.1.8 WINDOW_HEIGHT

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

Definition at line 13 of file display.c.

4.11.1.9 WINDOW_WIDTH

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

Definition at line 9 of file display.c.

4.11.2 Function Documentation

4.11.2.1 check_window_mat_size()

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

Definition at line 361 of file display.c.

References Camera::aspect_ratio, Scene::camera, 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::scene, 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().

4.11.2.2 copy_mat_to_surface_RGB()

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

Definition at line 376 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().

4.11.2.3 destroy_window()

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

Definition at line 316 of file display.c.

References ae_scene_free(), game_state_t::inv_z_buffer_mat, mat2D_free(), mat2D_free_uint32(), game_state_t::renderer, game_state_t::scene, game_state_t::window, game_state_t::window_pixels_mat, game_state_t::window_surface, and game_state_t::window_texture.

Referenced by main().

4.11.2.4 fix_framerate()

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

Definition at line 333 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().

4.11.2.5 initialize_window()

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

Definition at line 137 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().

4.11.2.6 main()

```
int main ( )
```

Definition at line 88 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, 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::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, and WINDOW_WIDTH.

4.11.2.7 process_input_window()

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

Definition at line 186 of file display.c.

References ae_camera_reset_pos(), Scene::camera, game_state_t::game_is_running, game_state_t::left_button_pressed, MAT2D_AT, Camera::offset_position, Camera::pitch_offset_deg, game_state_t::previous_frame_time, Camera::roll_offset_deg, game_state_t::scene, game_state_t::space_bar_was_pressed, game_state_t::to_render, and game_state_t::to_update.

Referenced by main().

4.11.2.8 render()

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

Definition at line 32 of file grid_example.c.

References ADL_DEFAULT_OFFSET_ZOOM, adl_grid_draw(), adl_tri_mesh_fill_Pinedas_rasterizer_interpolate_normal(), Tri_mesh_array::elements, grid_proj, Scene::in_world_tri_meshes, game_state_t::inv_z_buffer_mat, Tri_mesh::length, Tri_mesh_array::length, Scene::projected_tri_meshes, game_state_t::scene, and game_state_t::window_pixels_mat.

Referenced by render_window().

4.11.2.9 render_window()

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

Definition at line 295 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().

4.11.2.10 setup()

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

Definition at line 14 of file grid_example.c.

References ada_append, ada_init_array, adl_cartesian_grid_create(), ae_tri_mesh_append_copy(), ae_tri_mesh_get_from_file(), ae_tri_mesh_normalize(), ae_tri_mesh_rotate_Euler_xyz(), game_state_t::const_fps, Tri_mesh_array::elements, grid, grid_proj, Scene::in_world_tri_meshes, Tri_mesh::length, Tri_mesh_array::length, MAX_LEN_LINE, Scene::original_tri_meshes, Scene::projected_tri_meshes, game_state_t::scene, and game_state_t::to_limit_fps.

Referenced by setup_window().

4.11.2.11 setup_window()

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

Definition at line 170 of file display.c.

References ae_scene_init(), game_state_t::inv_z_buffer_mat, mat2D_alloc(), mat2D_alloc_uint32(), game_state_t::scene, 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().

4.11.2.12 update()

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

Definition at line 23 of file grid_example.c.

References ae_grid_project_world2screen(), AE_LIGHTING_FLAT, ae_projection_mat_set(), ae_tri_mesh_project_world2screen(), ae_view_mat_set(), Camera::aspect_ratio, Scene::camera, Tri_mesh_array::elements, Camera::fov_deg, grid, grid_proj, Scene::in_world_tri_meshes, Tri_mesh_array::length, Scene::proj_mat, Scene::projected_tri_meshes, game_state_t::scene, Scene::up_direction, Scene::view_mat, game_state_t::window_h, game_state_t::window_w, Camera::z_far, and Camera::z_near.

Referenced by update_window().

4.11.2.13 update_window()

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

Definition at line 267 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().

4.12 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_Engine.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
00065     SDL_Surface *window_surface;
00066     SDL_Texture *window_texture;
00067
00068     Mat2D_uint32 window_pixels_mat;
00069     Mat2D inv_z_buffer_mat;
00070
00071     Scene scene;
00072 } game_state_t;
00073
00074 int initialize_window(game_state_t *game_state);
00075 void setup_window(game_state_t *game_state);
00076 void process_input_window(game_state_t *game_state);
00077 void update_window(game_state_t *game_state);
00078 void render_window(game_state_t *game_state);
00079 void destroy_window(game_state_t *game_state);
00080 void fix_framerate(game_state_t *game_state);
00081 void setup(game_state_t *game_state);
00082 void update(game_state_t *game_state);
00083 void render(game_state_t *game_state);
00084
00085 void check_window_mat_size(game_state_t *game_state);
00086 void copy_mat_to_surface_RGB(game_state_t *game_state);
00087
00088 int main()
00089 {
00090     game_state_t game_state = {0};
00091
00092     game_state.game_is_running = 0;
00093     game_state.delta_time = 0;
00094     game_state.elapsed_time = 0;
00095     game_state.const_fps = FPS;
00096     game_state.fps = 0;
00097     game_state.frame_target_time = FRAME_TARGET_TIME;
00098
00099     game_state.space_bar_was_pressed = 0;
00100     game_state.w_was_pressed = 0;
00101     game_state.s_was_pressed = 0;
00102     game_state.a_was_pressed = 0;
00103     game_state.d_was_pressed = 0;
00104     game_state.e_was_pressed = 0;
00105     game_state.q_was_pressed = 0;
00106
00107     game_state.to_render = 1;
00108     game_state.to_update = 1;
00109     game_state.previous_frame_time = 0;
00110     game_state.left_button_pressed = 0;
00111     game_state.to_limit_fps = 1;
00112     game_state.to_clear_renderer = 1;
00113     game_state.window = NULL;
00114     game_state.window_w = WINDOW_WIDTH;
00115     game_state.window_h = WINDOW_HEIGHT;
00116     game_state.renderer = NULL;
00117
00118     game_state.game_is_running = !initialize_window(&game_state);
00119
00120     setup_window(&game_state);
00121
```

```
00122     while (game_state.game_is_running) {
00123         process_input_window(&game_state);
00124         if (game_state.to_update) {
00125             update_window(&game_state);
00126         }
00127         if (game_state.to_render) {
00128             render_window(&game_state);
00129         }
00130 
00131     }
00132     destroy_window(&game_state);
00133 
00134     return 0;
00135 }
00136 
00137 int initialize_window(game_state_t *game_state)
00138 {
00139     if (SDL_Init(SDL_INIT_EVERYTHING) != 0) {
00140         fprintf(stderr, "%s:%d: [Error] initializing SDL.\n", __FILE__, __LINE__);
00141         return -1;
00142     }
00143 
00144     game_state->window = SDL_CreateWindow(NULL,
00145                                 SDL_WINDOWPOS_CENTERED,
00146                                 SDL_WINDOWPOS_CENTERED,
00147                                 game_state->window_w,
00148                                 game_state->window_h,
00149                                 SDL_WINDOW_RESIZABLE
00150                                 );
00151     if (!game_state->window) {
00152         fprintf(stderr, "%s:%d: [Error] creating SDL window.\n", __FILE__, __LINE__);
00153         return -1;
00154     }
00155 
00156     game_state->renderer = SDL_CreateRenderer(game_state->window, -1, 0);
00157     if (!game_state->renderer) {
00158         fprintf(stderr, "%s:%d: [Error] creating SDL renderer.\n", __FILE__, __LINE__);
00159         return -1;
00160     }
00161 
00162     if (TTF_Init() == -1) {
00163         fprintf(stderr, "%s:%d: [Error] initializing SDL_ttf.\n", __FILE__, __LINE__);
00164         return -1;
00165     }
00166 
00167     return 0;
00168 }
00169 
00170 void setup_window(game_state_t *game_state)
00171 {
00172 
00173     game_state->window_surface = SDL_GetWindowSurface(game_state->window);
00174 
00175     game_state->window_pixels_mat = mat2D_alloc_uint32(game_state->window_h, game_state->window_w);
00176     game_state->inv_z_buffer_mat = mat2D_alloc(game_state->window_h, game_state->window_w);
00177 
00178     game_state->scene = ae_scene_init(game_state->window_h, game_state->window_w);
00179 
00180     /*-----------------------------------*/
00181 
00182     setup(game_state);
00183 
00184 }
00185 
00186 void process_input_window(game_state_t *game_state)
00187 {
00188     SDL_Event event;
00189     while (SDL_PollEvent(&event)) {
00190         switch (event.type) {
00191             case SDL_QUIT:
00192                 game_state->game_is_running = 0;
00193                 break;
00194             case SDL_KEYDOWN:
00195                 if (event.key.keysym.sym == SDLK_ESCAPE) {
00196                     game_state->game_is_running = 0;
00197                 }
00198                 if (event.key.keysym.sym == SDLK_SPACE) {
00199                     if (!game_state->space_bar_was_pressed) {
00200                         game_state->to_render = 0;
00201                         game_state->to_update = 0;
00202                         game_state->space_bar_was_pressed = 1;
00203                         break;
00204                     }
00205                     if (game_state->space_bar_was_pressed) {
00206                         game_state->to_render = 1;
00207                         game_state->to_update = 1;
00208                         game_state->previous_frame_time = SDL_GetTicks();
```

```
00209                         game_state->space_bar_was_pressed = 0;
00210                         break;
00211                     }
00212                 }
00213                 if (event.key.keysym.sym == SDLK_w) {
00214                     MAT2D_AT(game_state->scene.camera.offset_position, 1, 0) -= 0.05;
00215                 }
00216                 if (event.key.keysym.sym == SDLK_s) {
00217                     MAT2D_AT(game_state->scene.camera.offset_position, 1, 0) += 0.05;
00218                 }
00219                 if (event.key.keysym.sym == SDLK_d) {
00220                     MAT2D_AT(game_state->scene.camera.offset_position, 0, 0) += 0.05;
00221                 }
00222                 if (event.key.keysym.sym == SDLK_a) {
00223                     MAT2D_AT(game_state->scene.camera.offset_position, 0, 0) -= 0.05;
00224                 }
00225                 if (event.key.keysym.sym == SDLK_e) {
00226                     MAT2D_AT(game_state->scene.camera.offset_position, 2, 0) += 0.05;
00227                 }
00228                 if (event.key.keysym.sym == SDLK_q) {
00229                     MAT2D_AT(game_state->scene.camera.offset_position, 2, 0) -= 0.05;
00230                 }
00231                 if (event.key.keysym.sym == SDLK_LEFT) {
00232                     game_state->scene.camera.pitch_offset_deg -= 1;
00233                 }
00234                 if (event.key.keysym.sym == SDLK_RIGHT) {
00235                     game_state->scene.camera.pitch_offset_deg += 1;
00236                 }
00237                 if (event.key.keysym.sym == SDLK_UP) {
00238                     game_state->scene.camera.roll_offset_deg += 1;
00239                     if (game_state->scene.camera.roll_offset_deg > 89) {
00240                         game_state->scene.camera.roll_offset_deg = 89;
00241                     }
00242                 }
00243                 if (event.key.keysym.sym == SDLK_DOWN) {
00244                     game_state->scene.camera.roll_offset_deg -= 1;
00245                     if (game_state->scene.camera.roll_offset_deg < -89) {
00246                         game_state->scene.camera.roll_offset_deg = -89;
00247                     }
00248                 }
00249                 if (event.key.keysym.sym == SDLK_r) {
00250                     ae_camera_reset_pos(&(game_state->scene));
00251                 }
00252                 break;
00253             case SDL_MOUSEBUTTONDOWN:
00254                 if (event.button.button == SDL_BUTTON_LEFT) {
00255                     game_state->left_button_pressed = 1;
00256                 }
00257                 break;
00258             case SDL_MOUSEBUTTONUP:
00259                 if (event.button.button == SDL_BUTTON_LEFT) {
00260                     game_state->left_button_pressed = 0;
00261                 }
00262                 break;
00263         }
00264     }
00265 }
00266
00267 void update_window(game_state_t *game_state)
00268 {
00269     SDL_GetWindowSize(game_state->window, &(game_state->window_w), &(game_state->window_h));
00270
00271     fix_framerate(game_state);
00272     game_state->elapsed_time += game_state->delta_time;
00273     game_state->fps = 1.0f / game_state->delta_time;
00274     game_state->frame_target_time = 1000/game_state->const_fps;
00275
00276     char fps_count[100];
00277     if (!game_state->to_limit_fps) {
00278         sprintf(fps_count, "dt = %5.02f [ms]", game_state->delta_time*1000);
00279     } else {
00280         sprintf(fps_count, "FPS = %5.2f", game_state->fps);
00281     }
00282
00283     if (game_state->elapsed_time*10-(int)(game_state->elapsed_time*10) < 0.1) {
00284         SDL_SetWindowTitle(game_state->window, fps_count);
00285     }
00286
00287     check_window_mat_size(game_state);
00288
00289     /*-------------------------------------------------------------------------*/
00290
00291     update(game_state);
00292
00293 }
00294
00295 void render_window(game_state_t *game_state)
```

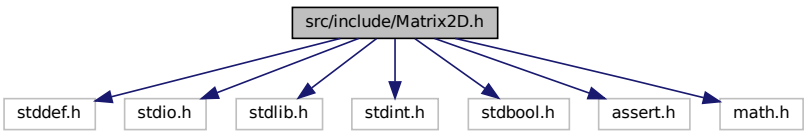
```
00296 {
00297     if (game_state->to_clear_renderer) {
00298         // SDL_SetRenderDrawColor(game_state->renderer, HexARGB_RGBA(0xFF181818));
00299         // SDL_RenderClear(game_state->renderer);
00300         // mat2D_fill(game_state->window_pixels_mat, 0x181818);
00301         memset(game_state->window_pixels_mat.elements, 0x20, sizeof(uint32_t) *
      game_state->window_pixels_mat.rows * game_state->window_pixels_mat.cols);
00302         /* not using mat2D_fill but using memset because it is way faster, so the buffer needs to be
      of 1/z */
00303         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);
00304     }
00305     /*-------------------------------------------------------------------------*/
00306
00307     render(game_state);
00308
00309     /*-------------------------------------------------------------------------*/
00310
00311     copy_mat_to_surface_RGB(game_state);
00312     SDL_UpdateWindowSurface(game_state->window);
00313
00314 }
00315
00316 void destroy_window(game_state_t *game_state)
00317 {
00318     mat2D_free_uint32(game_state->window_pixels_mat);
00319     mat2D_free(game_state->inv_z_buffer_mat);
00320     ae_scene_free(&(game_state->scene));
00321
00322     if (game_state->window_surface) SDL_FreeSurface(game_state->window_surface);
00323     if (game_state->window_texture) SDL_DestroyTexture(game_state->window_texture);
00324
00325     SDL_DestroyRenderer(game_state->renderer);
00326     SDL_DestroyWindow(game_state->window);
00327
00328     SDL_Quit();
00329
00330     (void)game_state;
00331 }
00332
00333 void fix_framerate(game_state_t *game_state)
00334 {
00335     int time_ellapsed = SDL_GetTicks() - game_state->previous_frame_time;
00336     int time_to_wait = game_state->frame_target_time - time_ellapsed;
00337     if (time_to_wait > 0 && time_to_wait < game_state->frame_target_time) {
00338         if (game_state->to_limit_fps) {
00339             SDL_Delay(time_to_wait);
00340         }
00341     }
00342     game_state->delta_time = (SDL_GetTicks() - game_state->previous_frame_time) / 1000.0f;
00343     game_state->previous_frame_time = SDL_GetTicks();
00344 }
00345
00346 #ifndef SETUP
00347 #define SETUP
00348 void setup(game_state_t *game_state) { (void)game_state; }
00349 #endif
00350
00351 #ifndef UPDATE
00352 #define UPDATE
00353 void update(game_state_t *game_state) { (void)game_state; }
00354 #endif
00355
00356 #ifndef RENDER
00357 #define RENDER
00358 void render(game_state_t *game_state) { (void)game_state; }
00359 #endif
00360
00361 void check_window_mat_size(game_state_t *game_state)
00362 {
00363     if (game_state->window_h != (int)game_state->window_pixels_mat.rows || game_state->window_w !=
      (int)game_state->window_pixels_mat.cols) {
00364         mat2D_free_uint32(game_state->window_pixels_mat);
00365         mat2D_free(game_state->inv_z_buffer_mat);
00366         SDL_FreeSurface(game_state->window_surface);
00367
00368         game_state->window_pixels_mat = mat2D_alloc_uint32(game_state->window_h,
      game_state->window_w);
00369         game_state->inv_z_buffer_mat = mat2D_alloc(game_state->window_h, game_state->window_w);
00370         game_state->scene.camera.aspect_ratio = (float)(game_state->window_h) /
      (float)(game_state->window_w);
00371
00372         game_state->window_surface = SDL_GetWindowSurface(game_state->window);
00373     }
00374 }
00375
00376 void copy_mat_to_surface_RGB(game_state_t *game_state)
```

```
00377 {
00378     SDL_LockSurface(game_state->window_surface);
00379
00380     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);
00381
00382     SDL_UnlockSurface(game_state->window_surface);
00383 }
00384
00385
```

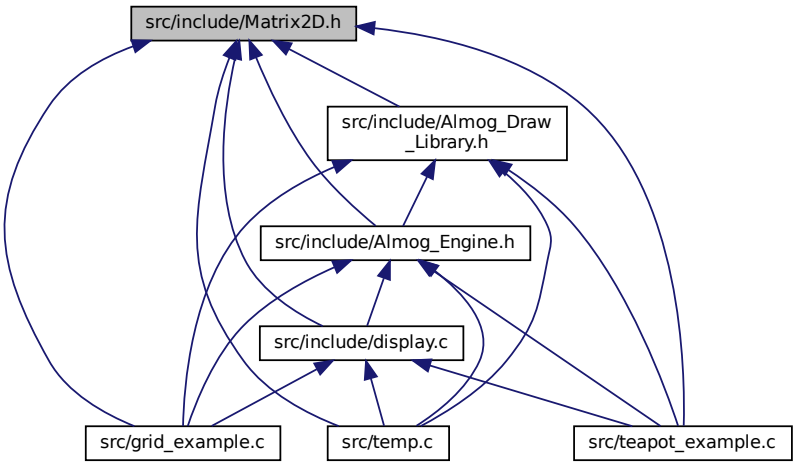
4.13 src/include/Matrix2D.h File Reference

```
#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
- struct Mat2D_uint32
- struct Mat2D_Minor

Macros

- #define MATRIX2D_MALLOC malloc
- #define MATRIX2D_ASSERT assert
- #define MAT2D_AT(m, i, j) (m).elements[mat2D_offset2d((m), (i), (j))]
- #define MAT2D_AT_UINT32(m, i, j) (m).elements[mat2D_offset2d_uint32((m), (i), (j))]
- #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])
- #define MAT2D_PRINT(m) mat2D_print(m, #m, 0)
- #define MAT2D_PRINT_AS_COL(m) mat2D_print_as_col(m, #m, 0)
- #define MAT2D_MINOR_PRINT(mm) mat2D_minor_print(mm, #mm, 0)
- #define mat2D_normalize(m) mat2D_mult((m), 1.0 / mat2D_calc_norma((m)))

Functions

- double rand_double (void)
- Mat2D mat2D_alloc (size_t rows, size_t cols)
- Mat2D_uint32 mat2D_alloc_uint32 (size_t rows, size_t cols)
- void mat2D_free (Mat2D m)
- void mat2D_free_uint32 (Mat2D_uint32 m)
- size_t mat2D_offset2d (Mat2D m, size_t i, size_t j)
- size_t mat2D_offset2d_uint32 (Mat2D_uint32 m, size_t i, size_t j)
- void mat2D_fill (Mat2D m, double x)
- void mat2D_fill_sequence (Mat2D m, double start, double step)
- void mat2D_fill_uint32 (Mat2D_uint32 m, uint32_t x)
- void mat2D_rand (Mat2D m, double low, double high)
- void mat2D_dot (Mat2D dst, Mat2D a, Mat2D b)
- double mat2D_dot_product (Mat2D a, Mat2D b)
- void mat2D_cross (Mat2D dst, Mat2D a, Mat2D b)
- void mat2D_add (Mat2D dst, Mat2D a)
- void mat2D_add_row_time_factor_to_row (Mat2D m, size_t des_r, size_t src_r, double factor)
- void mat2D_sub (Mat2D dst, Mat2D a)
- void mat2D_sub_row_time_factor_to_row (Mat2D m, size_t des_r, size_t src_r, double factor)
- void mat2D_mult (Mat2D m, double factor)
- void mat2D_mult_row (Mat2D m, size_t r, double factor)
- void mat2D_print (Mat2D m, const char *name, size_t padding)
- void mat2D_print_as_col (Mat2D m, const char *name, size_t padding)
- void mat2D_set_identity (Mat2D m)
- double mat2D_make_identity (Mat2D m)
- void mat2D_set_rot_mat_x (Mat2D m, float angle_deg)
- void mat2D_set_rot_mat_y (Mat2D m, float angle_deg)
- void mat2D_set_rot_mat_z (Mat2D m, float angle_deg)
- void mat2D_set_DCM_zyx (Mat2D DCM, float yaw_deg, float pitch_deg, float roll_deg)
- void mat2D_copy (Mat2D des, Mat2D src)
- void mat2D_copy_mat_to_mat_at_window (Mat2D des, Mat2D src, size_t is, size_t js, size_t ie, size_t je)
- void mat2D_get_col (Mat2D des, size_t des_col, Mat2D src, size_t src_col)
- void mat2D_add_col_to_col (Mat2D des, size_t des_col, Mat2D src, size_t src_col)
- void mat2D_sub_col_to_col (Mat2D des, size_t des_col, Mat2D src, size_t src_col)
- void mat2D_swap_rows (Mat2D m, size_t r1, size_t r2)
- void mat2D_get_row (Mat2D des, size_t des_row, Mat2D src, size_t src_row)
- void mat2D_add_row_to_row (Mat2D des, size_t des_row, Mat2D src, size_t src_row)
- void mat2D_sub_row_to_row (Mat2D des, size_t des_row, Mat2D src, size_t src_row)
- double mat2D_calc_norma (Mat2D m)

- bool mat2D_mat_is_all_digit (Mat2D m, double digit)
- bool mat2D_row_is_all_digit (Mat2D m, double digit, size_t r)
- bool mat2D_col_is_all_digit (Mat2D m, double digit, size_t c)
- double mat2D_det_2x2_mat (Mat2D m)
- double mat2D_triangulate (Mat2D m)
- double mat2D_det (Mat2D m)
- void mat2D_LUP_decomposition_with_swap (Mat2D src, Mat2D l, Mat2D p, Mat2D u)
- void mat2D_transpose (Mat2D des, Mat2D src)
- void mat2D_invert (Mat2D des, Mat2D src)
- void mat2D_solve_linear_sys_LUP_decomposition (Mat2D A, Mat2D x, Mat2D B)
- Mat2D_Minor mat2D_minor_alloc_fill_from_mat (Mat2D ref_mat, size_t i, size_t j)
- Mat2D_Minor mat2D_minor_alloc_fill_from_mat_minor (Mat2D_Minor ref_mm, size_t i, size_t j)
- void mat2D_minor_free (Mat2D_Minor mm)
- void mat2D_minor_print (Mat2D_Minor mm, const char *name, size_t padding)
- double mat2D_det_2x2_mat_minor (Mat2D_Minor mm)
- double mat2D_minor_det (Mat2D_Minor mm)

4.13.1 Macro Definition Documentation

4.13.1.1 __USE_MISC

```
#define __USE_MISC
```

Definition at line 62 of file Matrix2D.h.

4.13.1.2 MAT2D_AT

```
#define MAT2D_AT(
                m,
                i,
                j ) (m).elements[mat2D_offset2d((m), (i), (j))]
```

Definition at line 53 of file Matrix2D.h.

4.13.1.3 MAT2D_AT_UINT32

```
#define MAT2D_AT_UINT32(
                m,
                i,
                j ) (m).elements[mat2D_offset2d_uint32((m), (i), (j))]
```

Definition at line 54 of file Matrix2D.h.

4.13.1.4 MAT2D_MINOR_AT

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

Definition at line 68 of file Matrix2D.h.

4.13.1.5 MAT2D_MINOR_PRINT

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

Definition at line 71 of file Matrix2D.h.

4.13.1.6 mat2D_normalize

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

Definition at line 72 of file Matrix2D.h.

4.13.1.7 MAT2D_PRINT

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

Definition at line 69 of file Matrix2D.h.

4.13.1.8 MAT2D_PRINT_AS_COL

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

Definition at line 70 of file Matrix2D.h.

4.13.1.9 MATRIX2D_ASSERT

```
#define MATRIX2D_ASSERT assert
```

Definition at line 26 of file Matrix2D.h.

4.13.1.10 MATRIX2D_MALLOC

```
#define MATRIX2D_MALLOC malloc
```

Definition at line 21 of file Matrix2D.h.

4.13.1.11 PI

```
#define PI M_PI
```

Definition at line 65 of file Matrix2D.h.

4.13.2 Function Documentation

4.13.2.1 mat2D_add()

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

Definition at line 288 of file Matrix2D.h.

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

Referenced by adl_arrow_draw(), ae_line_itersect_plane(), and ae_view_mat_set().

4.13.2.2 mat2D_add_col_to_col()

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

Definition at line 512 of file Matrix2D.h.

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

4.13.2.3 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 )
```

Definition at line 299 of file Matrix2D.h.

References Mat2D::cols, and MAT2D_AT.

4.13.2.4 mat2D_add_row_to_row()

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

Definition at line 554 of file Matrix2D.h.

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

4.13.2.5 mat2D_alloc()

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

Definition at line 154 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(), ae_camera_init(), ae_curve_project_world2screen(), ae_line_clip_with_plane(), ae_line_itersect_plane(), ae_line_project_world2screen(), ae_point_project_view2screen(), ae_point_project_world2view(), ae_quad_calc_normal(), ae_quad_clip_with_plane(), ae_quad_mesh_project_world2screen(), ae_quad_project_world2screen(), ae_quad_set_normals(), ae_quad_transform_to_view(), ae_scene_init(), ae_tri_calc_normal(), ae_tri_clip_with_plane(), ae_tri_mesh_project_world2screen(), ae_tri_mesh_rotate_Euler_xyz(), ae_tri_project_world2screen(), ae_tri_set_normals(), ae_tri_transform_to_view(), ae_view_mat_set(), check_window_mat_size(), mat2D_det(), mat2D_invert(), mat2D_set_DCM_zyx(), mat2D_solve_linear_sys_LUP_decomposition(), and setup_window().

4.13.2.6 mat2D_alloc_uint32()

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

Definition at line 166 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().

4.13.2.7 mat2D_calc_norma()

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

Definition at line 576 of file Matrix2D.h.

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

Referenced by ae_quad_calc_normal(), ae_tri_calc_normal(), and ae_view_mat_set().

4.13.2.8 mat2D_col_is_all_digit()

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

Definition at line 610 of file Matrix2D.h.

References Mat2D::cols, and MAT2D_AT.

Referenced by mat2D_det().

4.13.2.9 mat2D_copy()

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

Definition at line 476 of file Matrix2D.h.

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

Referenced by adl_arrow_draw(), ae_camera_init(), ae_camera_reset_pos(), ae_quad_set_normals(), ae_tri_set_normals(), ae_view_mat_set(), mat2D_det(), mat2D_invert(), and mat2D_LUP_decomposition_with_swap().

4.13.2.10 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 )
```

Definition at line 488 of file Matrix2D.h.

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

4.13.2.11 mat2D_cross()

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

Definition at line 277 of file Matrix2D.h.

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

Referenced by ae_quad_calc_normal(), ae_quad_set_normals(), ae_tri_calc_normal(), ae_tri_set_normals(), and ae_view_mat_set().

4.13.2.12 mat2D_det()

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

Definition at line 658 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().

4.13.2.13 mat2D_det_2x2_mat()

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

Definition at line 620 of file Matrix2D.h.

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

4.13.2.14 mat2D_det_2x2_mat_minor()

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

Definition at line 926 of file Matrix2D.h.

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

Referenced by mat2D_minor_det().

4.13.2.15 mat2D_dot()

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

Definition at line 235 of file Matrix2D.h.

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

Referenced by adl_arrow_draw(), ae_point_project_view2screen(), ae_point_project_world2view(), ae_quad_transform_to_view(), ae_tri_mesh_rotate_Euler_xyz(), ae_tri_transform_to_view(), ae_view_mat_set(), mat2D_set_DCM_zyx(), and mat2D_solve_linear_sys_LUP_decomposition().

4.13.2.16 mat2D_dot_product()

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

Definition at line 255 of file Matrix2D.h.

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

Referenced by ae_line_itersect_plane(), and ae_view_mat_set().

4.13.2.17 mat2D_fill()

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

Definition at line 200 of file Matrix2D.h.

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

Referenced by adl_arrow_draw(), ae_camera_init(), ae_camera_reset_pos(), ae_curve_project_world2screen(), ae_line_itersect_plane(), ae_line_project_world2screen(), ae_projection_mat_set(), ae_quad_mesh_project_world2screen(), ae_quad_project_world2screen(), ae_scene_init(), ae_tri_mesh_project_world2screen(), ae_tri_project_world2screen(), ae_view_mat_set(), mat2D_invert(), mat2D_LUP_decomposition_with_swap(), and mat2D_solve_linear_sys_LUP_decomposition().

4.13.2.18 mat2D_fill_sequence()

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

Definition at line 209 of file Matrix2D.h.

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

4.13.2.19 mat2D_fill_uint32()

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

Definition at line 217 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().

4.13.2.20 mat2D_free()

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

Definition at line 178 of file Matrix2D.h.

References Mat2D::elements.

Referenced by adl_arrow_draw(), ae_camera_free(), ae_curve_project_world2screen(), ae_line_clip_with_plane(), ae_line_itersect_plane(), ae_line_project_world2screen(), ae_point_project_view2screen(), ae_point_project_world2view(), ae_quad_calc_normal(), ae_quad_clip_with_plane(), ae_quad_mesh_project_world2screen(), ae_quad_project_world2screen(), ae_quad_set_normals(), ae_quad_transform_to_view(), ae_scene_free(), ae_tri_calc_normal(), ae_tri_clip_with_plane(), ae_tri_mesh_project_world2screen(), ae_tri_mesh_rotate_Euler_xyz(), ae_tri_project_world2screen(), ae_tri_set_normals(), ae_tri_transform_to_view(), ae_view_mat_set(), check_window_mat_size(), destroy_window(), mat2D_det(), mat2D_invert(), mat2D_set_DCM_zyx(), and mat2D_solve_linear_sys_LUP_decomposition().

4.13.2.21 mat2D_free_uint32()

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

Definition at line 183 of file Matrix2D.h.

References Mat2D_uint32::elements.

Referenced by check_window_mat_size(), and destroy_window().

4.13.2.22 mat2D_get_col()

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

Definition at line 501 of file Matrix2D.h.

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

4.13.2.23 mat2D_get_row()

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

Definition at line 543 of file Matrix2D.h.

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

4.13.2.24 mat2D_invert()

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

Definition at line 754 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().

4.13.2.25 mat2D_LUP_decomposition_with_swap()

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

Definition at line 705 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().

4.13.2.26 mat2D_make_identity()

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

Definition at line 379 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.

4.13.2.27 mat2D_mat_is_all_digit()

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

Definition at line 588 of file Matrix2D.h.

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

4.13.2.28 mat2D_minor_alloc_fill_from_mat()

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

Definition at line 847 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.

4.13.2.29 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 )
```

Definition at line 877 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().

4.13.2.30 mat2D_minor_det()

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

Definition at line 932 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.

4.13.2.31 mat2D_minor_free()

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

Definition at line 907 of file Matrix2D.h.

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

Referenced by mat2D_minor_det().

4.13.2.32 mat2D_minor_print()

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

Definition at line 913 of file Matrix2D.h.

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

4.13.2.33 mat2D_mult()

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

Definition at line 324 of file Matrix2D.h.

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

Referenced by ae_line_itersect_plane(), ae_quad_calc_normal(), ae_tri_calc_normal(), and ae_view_mat_set().

4.13.2.34 mat2D_mult_row()

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

Definition at line 333 of file Matrix2D.h.

References Mat2D::cols, and MAT2D_AT.

Referenced by mat2D_invert(), and mat2D_make_identity().

4.13.2.35 mat2D_offset2d()

```
size_t mat2D_offset2d (
            Mat2D m,
            size_t i,
            size_t j )
```

Definition at line 188 of file Matrix2D.h.

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

Referenced by mat2D_fill_sequence().

4.13.2.36 mat2D_offset2d_uint32()

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

Definition at line 194 of file Matrix2D.h.

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

4.13.2.37 mat2D_print()

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

Definition at line 340 of file Matrix2D.h.

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

4.13.2.38 mat2D_print_as_col()

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

Definition at line 353 of file Matrix2D.h.

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

4.13.2.39 mat2D_rand()

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

Definition at line 226 of file Matrix2D.h.

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

4.13.2.40 mat2D_row_is_all_digit()

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

Definition at line 600 of file Matrix2D.h.

References Mat2D::cols, and MAT2D_AT.

Referenced by mat2D_det().

4.13.2.41 mat2D_set_DCM_zyx()

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

Definition at line 456 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().

Referenced by ae_view_mat_set().

4.13.2.42 mat2D_set_identity()

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

Definition at line 363 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().

4.13.2.43 mat2D_set_rot_mat_x()

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

Definition at line 420 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, mat2D_set_identity(), MATRIX2D_ASSERT, PI, and Mat2D::rows.

Referenced by ae_tri_mesh_rotate_Euler_xyz(), and mat2D_set_DCM_zyx().

4.13.2.44 mat2D_set_rot_mat_y()

```
void mat2D_set_rot_mat_y (
            Mat2D m,
            float angle_deg )
```

Definition at line 432 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, mat2D_set_identity(), MATRIX2D_ASSERT, PI, and Mat2D::rows.

Referenced by ae_tri_mesh_rotate_Euler_xyz(), and mat2D_set_DCM_zyx().

4.13.2.45 mat2D_set_rot_mat_z()

```
void mat2D_set_rot_mat_z (
            Mat2D m,
            float angle_deg )
```

Definition at line 444 of file Matrix2D.h.

References Mat2D::cols, MAT2D_AT, mat2D_set_identity(), MATRIX2D_ASSERT, PI, and Mat2D::rows.

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

4.13.2.46 mat2D_solve_linear_sys_LUP_decomposition()

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

Definition at line 812 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.

4.13.2.47 mat2D_sub()

```
void mat2D_sub (
            Mat2D dst,
            Mat2D a )
```

Definition at line 306 of file Matrix2D.h.

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

Referenced by adl_arrow_draw(), ae_line_itersect_plane(), ae_quad_calc_normal(), ae_quad_project_world2screen(), ae_quad_set_normals(), ae_tri_calc_normal(), ae_tri_project_world2screen(), ae_tri_set_normals(), and ae_view_mat_set().

4.13.2.48 mat2D_sub_col_to_col()

```
void mat2D_sub_col_to_col (
            Mat2D des,
            size_t des_col,
            Mat2D src,
            size_t src_col )
```

Definition at line 523 of file Matrix2D.h.

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

4.13.2.49 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 )
```

Definition at line 317 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().

4.13.2.50 mat2D_sub_row_to_row()

```
void mat2D_sub_row_to_row (
            Mat2D des,
            size_t des_row,
            Mat2D src,
            size_t src_row )
```

Definition at line 565 of file Matrix2D.h.

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

4.13.2.51 mat2D_swap_rows()

```
void mat2D_swap_rows (
            Mat2D m,
            size_t r1,
            size_t r2 )
```

Definition at line 534 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().

4.13.2.52 mat2D_transpose()

```
void mat2D_transpose (
            Mat2D des,
            Mat2D src )
```

Definition at line 742 of file Matrix2D.h.

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

Referenced by ae_tri_project_world2screen(), and ae_view_mat_set().

4.13.2.53 mat2D_triangulate()

```
double mat2D_triangulate (
            Mat2D m )
```

Definition at line 626 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().

4.13.2.54 rand_double()

```
double rand_double (
            void  )
```

Definition at line 149 of file Matrix2D.h.

Referenced by mat2D_rand().

4.14 Matrix2D.h

```
00001 /* This one-file library is heavily inspired by Tsoding's nn.h implementation of matrix
00002 creation and operation. you can find the source code in:
00003 https://github.com/tsoding/nn.h .
00004 featured in this video of his:
00005 https://youtu.be/L1TbWe8bVOc?list=PLpM-Dvs8t0VZPZKggcql-MmjaBdZKeDMw .*/
00006
00007 /* NOTES:
00008  * There is a hole set of function for deling with the minors of a matrix because I tried to calculate
       the determinant of a matrix with them but it terns out to be TOO SLOW. Insted I use Gauss
       elimination.
00009  * There are some stability problems in the inversion function. When the values of the matrix becomes
       too small, the inversion fails. Currently the only fix I can think of is to use pre-conditioners.
       Which means using a function to solve the hole problem 'Ax=B' */
00010
00011 #ifndef MATRIX2D_H_
00012 #define MATRIX2D_H_
00013
00014 #include <stddef.h>
00015 #include <stdio.h>
00016 #include <stdlib.h>
00017 #include <stdint.h>
00018 #include <stdbool.h>
00019
00020 #ifndef MATRIX2D_MALLOC
00021 #define MATRIX2D_MALLOC malloc
00022 #endif //MATRIX2D_MALLOC
00023
00024 #ifndef MATRIX2D_ASSERT
00025 #include <assert.h>
00026 #define MATRIX2D_ASSERT assert
00027 #endif //MATRIX2D_ASSERT
00028
00029 typedef struct {
00030     size_t rows;
00031     size_t cols;
00032     size_t stride_r; /* how many element you need to traves to get to the element underneath */
00033     double *elements;
00034 } Mat2D;
00035
00036 typedef struct {
00037     size_t rows;
00038     size_t cols;
00039     size_t stride_r; /* how many element you need to traves to get to the element underneath */
00040     uint32_t *elements;
00041 } Mat2D_uint32;
00042
00043 typedef struct {
00044     size_t rows;
00045     size_t cols;
00046     size_t stride_r; /* how many element you need to traves to get to the element underneath */
00047     size_t *rows_list;
00048     size_t *cols_list;
00049     Mat2D ref_mat;
00050 } Mat2D_Minor;
00051
00052 #if 1
00053 #define MAT2D_AT(m, i, j) (m).elements[mat2D_offset2d((m), (i), (j))]
00054 #define MAT2D_AT_UINT32(m, i, j) (m).elements[mat2D_offset2d_uint32((m), (i), (j))]
00055 #else /* use this macro for batter performance but no assertion */
00056 #define MAT2D_AT(m, i, j) (m).elements[i * m.stride_r + j]
00057 #define MAT2D_AT_UINT32(m, i, j) (m).elements[i * m.stride_r + j]
00058 #endif
00059
00060 #ifndef PI
00061     #ifndef __USE_MISC
00062     #define __USE_MISC
00063     #endif
00064     #include <math.h>
```

```
00065     #define PI M_PI
00066 #endif
00067
00068 #define MAT2D_MINOR_AT(mm, i, j) MAT2D_AT(mm.ref_mat, mm.rows_list[i], mm.cols_list[j])
00069 #define MAT2D_PRINT(m) mat2D_print(m, #m, 0)
00070 #define MAT2D_PRINT_AS_COL(m) mat2D_print_as_col(m, #m, 0)
00071 #define MAT2D_MINOR_PRINT(mm) mat2D_minor_print(mm, #mm, 0)
00072 #define mat2D_normalize(m) mat2D_mult((m), 1.0 / mat2D_calc_norma((m)))
00073
00074 double rand_double(void);
00075
00076 Mat2D mat2D_alloc(size_t rows, size_t cols);
00077 Mat2D_uint32 mat2D_alloc_uint32(size_t rows, size_t cols);
00078 void mat2D_free(Mat2D m);
00079 void mat2D_free_uint32(Mat2D_uint32 m);
00080 size_t mat2D_offset2d(Mat2D m, size_t i, size_t j);
00081 size_t mat2D_offset2d_uint32(Mat2D_uint32 m, size_t i, size_t j);
00082
00083 void mat2D_fill(Mat2D m, double x);
00084 void mat2D_fill_sequence(Mat2D m, double start, double step);
00085 void mat2D_fill_uint32(Mat2D_uint32 m, uint32_t x);
00086 void mat2D_rand(Mat2D m, double low, double high);
00087
00088 void mat2D_dot(Mat2D dst, Mat2D a, Mat2D b);
00089 double mat2D_dot_product(Mat2D a, Mat2D b);
00090 void mat2D_cross(Mat2D dst, Mat2D a, Mat2D b);
00091
00092 void mat2D_add(Mat2D dst, Mat2D a);
00093 void mat2D_add_row_time_factor_to_row(Mat2D m, size_t des_r, size_t src_r, double factor);
00094
00095 void mat2D_sub(Mat2D dst, Mat2D a);
00096 void mat2D_sub_row_time_factor_to_row(Mat2D m, size_t des_r, size_t src_r, double factor);
00097
00098 void mat2D_mult(Mat2D m, double factor);
00099 void mat2D_mult_row(Mat2D m, size_t r, double factor);
00100
00101 void mat2D_print(Mat2D m, const char *name, size_t padding);
00102 void mat2D_print_as_col(Mat2D m, const char *name, size_t padding);
00103
00104 void mat2D_set_identity(Mat2D m);
00105 double mat2D_make_identity(Mat2D m);
00106 void mat2D_set_rot_mat_x(Mat2D m, float angle_deg);
00107 void mat2D_set_rot_mat_y(Mat2D m, float angle_deg);
00108 void mat2D_set_rot_mat_z(Mat2D m, float angle_deg);
00109 void mat2D_set_DCM_zyx(Mat2D DCM, float yaw_deg, float pitch_deg, float roll_deg);
00110
00111 void mat2D_copy(Mat2D des, Mat2D src);
00112 void mat2D_copy_mat_to_mat_at_window(Mat2D des, Mat2D src, size_t is, size_t js, size_t ie, size_t
      je);
00113
00114 void mat2D_get_col(Mat2D des, size_t des_col, Mat2D src, size_t src_col);
00115 void mat2D_add_col_to_col(Mat2D des, size_t des_col, Mat2D src, size_t src_col);
00116 void mat2D_sub_col_to_col(Mat2D des, size_t des_col, Mat2D src, size_t src_col);
00117
00118 void mat2D_swap_rows(Mat2D m, size_t r1, size_t r2);
00119 void mat2D_get_row(Mat2D des, size_t des_row, Mat2D src, size_t src_row);
00120 void mat2D_add_row_to_row(Mat2D des, size_t des_row, Mat2D src, size_t src_row);
00121 void mat2D_sub_row_to_row(Mat2D des, size_t des_row, Mat2D src, size_t src_row);
00122
00123 double mat2D_calc_norma(Mat2D m);
00124
00125 bool mat2D_mat_is_all_digit(Mat2D m, double digit);
00126 bool mat2D_row_is_all_digit(Mat2D m, double digit, size_t r);
00127 bool mat2D_col_is_all_digit(Mat2D m, double digit, size_t c);
00128
00129 double mat2D_det_2x2_mat(Mat2D m);
00130 double mat2D_triangulate(Mat2D m);
00131 double mat2D_det(Mat2D m);
00132 void mat2D_LUP_decomposition_with_swap(Mat2D src, Mat2D l, Mat2D p, Mat2D u);
00133 void mat2D_transpose(Mat2D des, Mat2D src);
00134 void mat2D_invert(Mat2D des, Mat2D src);
00135 void mat2D_solve_linear_sys_LUP_decomposition(Mat2D A, Mat2D x, Mat2D B);
00136
00137 Mat2D_Minor mat2D_minor_alloc_fill_from_mat(Mat2D ref_mat, size_t i, size_t j);
00138 Mat2D_Minor mat2D_minor_alloc_fill_from_mat_minor(Mat2D_Minor ref_mm, size_t i, size_t j);
00139 void mat2D_minor_free(Mat2D_Minor mm);
00140 void mat2D_minor_print(Mat2D_Minor mm, const char *name, size_t padding);
00141 double mat2D_det_2x2_mat_minor(Mat2D_Minor mm);
00142 double mat2D_minor_det(Mat2D_Minor mm);
00143
00144 #endif // MATRIX2D_H_
00145
00146 #ifdef MATRIX2D_IMPLEMENTATION
00147 #undef MATRIX2D_IMPLEMENTATION
00148
00149 double rand_double(void)
00150 {
```

```
00151     return (double) rand() / (double) RAND_MAX;
00152 }
00153
00154 Mat2D mat2D_alloc(size_t rows, size_t cols)
00155 {
00156     Mat2D m;
00157     m.rows = rows;
00158     m.cols = cols;
00159     m.stride_r = cols;
00160     m.elements = (double*)MATRIX2D_MALLOC(sizeof(double)*rows*cols);
00161     MATRIX2D_ASSERT(m.elements != NULL);
00162
00163     return m;
00164 }
00165
00166 Mat2D_uint32 mat2D_alloc_uint32(size_t rows, size_t cols)
00167 {
00168     Mat2D_uint32 m;
00169     m.rows = rows;
00170     m.cols = cols;
00171     m.stride_r = cols;
00172     m.elements = (uint32_t*)MATRIX2D_MALLOC(sizeof(uint32_t)*rows*cols);
00173     MATRIX2D_ASSERT(m.elements != NULL);
00174
00175     return m;
00176 }
00177
00178 void mat2D_free(Mat2D m)
00179 {
00180     free(m.elements);
00181 }
00182
00183 void mat2D_free_uint32(Mat2D_uint32 m)
00184 {
00185     free(m.elements);
00186 }
00187
00188 size_t mat2D_offset2d(Mat2D m, size_t i, size_t j)
00189 {
00190     MATRIX2D_ASSERT(i < m.rows && j < m.cols);
00191     return i * m.stride_r + j;
00192 }
00193
00194 size_t mat2D_offset2d_uint32(Mat2D_uint32 m, size_t i, size_t j)
00195 {
00196     MATRIX2D_ASSERT(i < m.rows && j < m.cols);
00197     return i * m.stride_r + j;
00198 }
00199
00200 void mat2D_fill(Mat2D m, double x)
00201 {
00202     for (size_t i = 0; i < m.rows; ++i) {
00203         for (size_t j = 0; j < m.cols; ++j) {
00204             MAT2D_AT(m, i, j) = x;
00205         }
00206     }
00207 }
00208
00209 void mat2D_fill_sequence(Mat2D m, double start, double step) {
00210     for (size_t i = 0; i < m.rows; i++) {
00211         for (size_t j = 0; j < m.cols; j++) {
00212             MAT2D_AT(m, i, j) = start + step * mat2D_offset2d(m, i, j);
00213         }
00214     }
00215 }
00216
00217 void mat2D_fill_uint32(Mat2D_uint32 m, uint32_t x)
00218 {
00219     for (size_t i = 0; i < m.rows; ++i) {
00220         for (size_t j = 0; j < m.cols; ++j) {
00221             MAT2D_AT_UINT32(m, i, j) = x;
00222         }
00223     }
00224 }
00225
00226 void mat2D_rand(Mat2D m, double low, double high)
00227 {
00228     for (size_t i = 0; i < m.rows; ++i) {
00229         for (size_t j = 0; j < m.cols; ++j) {
00230             MAT2D_AT(m, i, j) = rand_double()*(high - low) + low;
00231         }
00232     }
00233 }
00234
00235 void mat2D_dot(Mat2D dst, Mat2D a, Mat2D b)
00236 {
00237     MATRIX2D_ASSERT(a.cols == b.rows);
```

```
00238     MATRIX2D_ASSERT(a.rows == dst.rows);
00239     MATRIX2D_ASSERT(b.cols == dst.cols);
00240
00241     size_t i, j, k;
00242
00243     for (i = 0; i < dst.rows; i++) {
00244         for (j = 0; j < dst.cols; j++) {
00245             MAT2D_AT(dst, i, j) = 0;
00246             for (k = 0; k < a.cols; k++) {
00247                 MAT2D_AT(dst, i, j) += MAT2D_AT(a, i, k)*MAT2D_AT(b, k, j);
00248             }
00249         }
00250     }
00251
00252 }
00253
00254 /* calculating the dot product of two vectors. a: nx1, b: nx1 */
00255 double mat2D_dot_product(Mat2D a, Mat2D b)
00256 {
00257     MATRIX2D_ASSERT(a.rows == b.rows);
00258     MATRIX2D_ASSERT(a.cols == b.cols);
00259     MATRIX2D_ASSERT((1 == a.cols && 1 == b.cols) || (1 == a.rows && 1 == b.rows));
00260
00261     double dot_product = 0;
00262
00263     if (1 == a.cols) {
00264         for (size_t i = 0; i < a.rows; i++) {
00265             dot_product += MAT2D_AT(a, i, 0) * MAT2D_AT(b, i, 0);
00266         }
00267     } else {
00268         for (size_t j = 0; j < a.cols; j++) {
00269             dot_product += MAT2D_AT(a, 0, j) * MAT2D_AT(b, 0, j);
00270         }
00271     }
00272
00273     return dot_product;
00274
00275 }
00276
00277 void mat2D_cross(Mat2D dst, Mat2D a, Mat2D b)
00278 {
00279     MATRIX2D_ASSERT(3 == dst.rows && 1 == dst.cols);
00280     MATRIX2D_ASSERT(3 == a.rows && 1 == a.cols);
00281     MATRIX2D_ASSERT(3 == b.rows && 1 == b.cols);
00282
00283     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);
00284     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);
00285     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);
00286 }
00287
00288 void mat2D_add(Mat2D dst, Mat2D a)
00289 {
00290     MATRIX2D_ASSERT(dst.rows == a.rows);
00291     MATRIX2D_ASSERT(dst.cols == a.cols);
00292     for (size_t i = 0; i < dst.rows; ++i) {
00293         for (size_t j = 0; j < dst.cols; ++j) {
00294             MAT2D_AT(dst, i, j) += MAT2D_AT(a, i, j);
00295         }
00296     }
00297 }
00298
00299 void mat2D_add_row_time_factor_to_row(Mat2D m, size_t des_r, size_t src_r, double factor)
00300 {
00301     for (size_t j = 0; j < m.cols; ++j) {
00302         MAT2D_AT(m, des_r, j) += factor * MAT2D_AT(m, src_r, j);
00303     }
00304 }
00305
00306 void mat2D_sub(Mat2D dst, Mat2D a)
00307 {
00308     MATRIX2D_ASSERT(dst.rows == a.rows);
00309     MATRIX2D_ASSERT(dst.cols == a.cols);
00310     for (size_t i = 0; i < dst.rows; ++i) {
00311         for (size_t j = 0; j < dst.cols; ++j) {
00312             MAT2D_AT(dst, i, j) -= MAT2D_AT(a, i, j);
00313         }
00314     }
00315 }
00316
00317 void mat2D_sub_row_time_factor_to_row(Mat2D m, size_t des_r, size_t src_r, double factor)
00318 {
00319     for (size_t j = 0; j < m.cols; ++j) {
00320         MAT2D_AT(m, des_r, j) -= factor * MAT2D_AT(m, src_r, j);
00321     }
```

```
00322 }
00323
00324 void mat2D_mult(Mat2D m, double factor)
00325 {
00326     for (size_t i = 0; i < m.rows; ++i) {
00327         for (size_t j = 0; j < m.cols; ++j) {
00328             MAT2D_AT(m, i, j) *= factor;
00329         }
00330     }
00331 }
00332
00333 void mat2D_mult_row(Mat2D m, size_t r, double factor)
00334 {
00335     for (size_t j = 0; j < m.cols; ++j) {
00336         MAT2D_AT(m, r, j) *= factor;
00337     }
00338 }
00339
00340 void mat2D_print(Mat2D m, const char *name, size_t padding)
00341 {
00342     printf("%*s%s = [\n", (int) padding, "", name);
00343     for (size_t i = 0; i < m.rows; ++i) {
00344         printf("%*s    ", (int) padding, "");
00345         for (size_t j = 0; j < m.cols; ++j) {
00346             printf("%9.6f ", MAT2D_AT(m, i, j));
00347         }
00348         printf("\n");
00349     }
00350     printf("%*s]\n", (int) padding, "");
00351 }
00352
00353 void mat2D_print_as_col(Mat2D m, const char *name, size_t padding)
00354 {
00355     printf("%*s%s = [\n", (int) padding, "", name);
00356     for (size_t i = 0; i < m.rows*m.cols; ++i) {
00357             printf("%*s    ", (int) padding, "");
00358             printf("%f\n", m.elements[i]);
00359     }
00360     printf("%*s]\n", (int) padding, "");
00361 }
00362
00363 void mat2D_set_identity(Mat2D m)
00364 {
00365     MATRIX2D_ASSERT(m.cols == m.rows);
00366     for (size_t i = 0; i < m.rows; ++i) {
00367         for (size_t j = 0; j < m.cols; ++j) {
00368             MAT2D_AT(m, i, j) = i == j ? 1 : 0;
00369             // if (i == j) {
00370             //     MAT2D_AT(m, i, j) = 1;
00371             // }
00372             // else {
00373             //     MAT2D_AT(m, i, j) = 0;
00374             // }
00375         }
00376     }
00377 }
00378
00379 double mat2D_make_identity(Mat2D m)
00380 {
00381     /* make identity matrix using Gauss elimination */
00382     /* preforming Gauss elimination: https://en.wikipedia.org/wiki/Gaussian_elimination */
00383     /* returns the factor multiplying the determinant */
00384
00385     double factor_to_return = 1;
00386
00387     for (size_t i = 0; i < (size_t)fmin(m.rows-1, m.cols); i++) {
00388         /* check if it is the biggest first number (absolute value) */
00389         size_t biggest_r = i;
00390         for (size_t index = i; index < m.rows; index++) {
00391             if (fabs(MAT2D_AT(m, index, index)) > fabs(MAT2D_AT(m, biggest_r, 0))) {
00392                 biggest_r = index;
00393             }
00394         }
00395         if (i != biggest_r) {
00396             mat2D_swap_rows(m, i, biggest_r);
00397             factor_to_return *= -1;
00398         }
00399         for (size_t j = i+1; j < m.cols; j++) {
00400             double factor = 1 / MAT2D_AT(m, i, i);
00401             mat2D_sub_row_time_factor_to_row(m, j, i, MAT2D_AT(m, j, i) * factor);
00402             mat2D_mult_row(m, i, factor);
00403             factor_to_return *= factor;
00404         }
00405     }
00406     double factor = 1 / MAT2D_AT(m, m.rows-1, m.cols-1);
00407     mat2D_mult_row(m, m.rows-1, factor);
00408     factor_to_return *= factor;
```

```
00409     for (size_t c = m.cols-1; c > 0; c--) {
00410         for (int r = c-1; r >= 0; r--) {
00411             double factor = 1 / MAT2D_AT(m, c, c);
00412             mat2D_sub_row_time_factor_to_row(m, r, c, MAT2D_AT(m, r, c) * factor);
00413         }
00414     }
00415 
00416 
00417     return factor_to_return;
00418 }
00419 
00420 void mat2D_set_rot_mat_x(Mat2D m, float angle_deg)
00421 {
00422     MATRIX2D_ASSERT(3 == m.cols && 3 == m.rows);
00423 
00424     float angle_rad = angle_deg * PI / 180;
00425     mat2D_set_identity(m);
00426     MAT2D_AT(m, 1, 1) =  cos(angle_rad);
00427     MAT2D_AT(m, 1, 2) =  sin(angle_rad);
00428     MAT2D_AT(m, 2, 1) = -sin(angle_rad);
00429     MAT2D_AT(m, 2, 2) =  cos(angle_rad);
00430 }
00431 
00432 void mat2D_set_rot_mat_y(Mat2D m, float angle_deg)
00433 {
00434     MATRIX2D_ASSERT(3 == m.cols && 3 == m.rows);
00435 
00436     float angle_rad = angle_deg * PI / 180;
00437     mat2D_set_identity(m);
00438     MAT2D_AT(m, 0, 0) =  cos(angle_rad);
00439     MAT2D_AT(m, 0, 2) = -sin(angle_rad);
00440     MAT2D_AT(m, 2, 0) =  sin(angle_rad);
00441     MAT2D_AT(m, 2, 2) =  cos(angle_rad);
00442 }
00443 
00444 void mat2D_set_rot_mat_z(Mat2D m, float angle_deg)
00445 {
00446     MATRIX2D_ASSERT(3 == m.cols && 3 == m.rows);
00447 
00448     float angle_rad = angle_deg * PI / 180;
00449     mat2D_set_identity(m);
00450     MAT2D_AT(m, 0, 0) =  cos(angle_rad);
00451     MAT2D_AT(m, 0, 1) =  sin(angle_rad);
00452     MAT2D_AT(m, 1, 0) = -sin(angle_rad);
00453     MAT2D_AT(m, 1, 1) =  cos(angle_rad);
00454 }
00455 
00456 void mat2D_set_DCM_zyx(Mat2D DCM, float yaw_deg, float pitch_deg, float roll_deg)
00457 {
00458     Mat2D RotZ = mat2D_alloc(3,3);
00459     mat2D_set_rot_mat_z(RotZ, yaw_deg);
00460     Mat2D RotY = mat2D_alloc(3,3);
00461     mat2D_set_rot_mat_y(RotY, pitch_deg);
00462     Mat2D RotX = mat2D_alloc(3,3);
00463     mat2D_set_rot_mat_x(RotX, roll_deg);
00464     Mat2D temp = mat2D_alloc(3,3);
00465 
00466     mat2D_dot(temp, RotY, RotZ);
00467     mat2D_dot(DCM, RotX, temp); /* I have a DCM */
00468 
00469 
00470     mat2D_free(RotZ);
00471     mat2D_free(RotY);
00472     mat2D_free(RotX);
00473     mat2D_free(temp);
00474 }
00475 
00476 void mat2D_copy(Mat2D des, Mat2D src)
00477 {
00478     MATRIX2D_ASSERT(des.cols == src.cols);
00479     MATRIX2D_ASSERT(des.rows == src.rows);
00480 
00481     for (size_t i = 0; i < des.rows; ++i) {
00482         for (size_t j = 0; j < des.cols; ++j) {
00483             MAT2D_AT(des, i, j) = MAT2D_AT(src, i, j);
00484         }
00485     }
00486 }
00487 
00488 void mat2D_copy_mat_to_mat_at_window(Mat2D des, Mat2D src, size_t is, size_t js, size_t ie, size_t je)
00489 {
00490     MATRIX2D_ASSERT(je > js && ie > is);
00491     MATRIX2D_ASSERT(je-js+1 == des.cols);
00492     MATRIX2D_ASSERT(ie-is+1 == des.rows);
00493 
00494     for (size_t index = 0; index < des.rows; ++index) {
00495         for (size_t jndex = 0; jndex < des.cols; ++jndex) {
```

```
00496             MAT2D_AT(des, index, jndex) = MAT2D_AT(src, is+index, js+jndex);
00497         }
00498     }
00499 }
00500
00501 void mat2D_get_col(Mat2D des, size_t des_col, Mat2D src, size_t src_col)
00502 {
00503     MATRIX2D_ASSERT(src_col < src.cols);
00504     MATRIX2D_ASSERT(des.rows == src.rows);
00505     MATRIX2D_ASSERT(des_col < des.cols);
00506
00507     for (size_t i = 0; i < des.rows; i++) {
00508         MAT2D_AT(des, i, des_col) = MAT2D_AT(src, i, src_col);
00509     }
00510 }
00511
00512 void mat2D_add_col_to_col(Mat2D des, size_t des_col, Mat2D src, size_t src_col)
00513 {
00514     MATRIX2D_ASSERT(src_col < src.cols);
00515     MATRIX2D_ASSERT(des.rows == src.rows);
00516     MATRIX2D_ASSERT(des_col < des.cols);
00517
00518     for (size_t i = 0; i < des.rows; i++) {
00519         MAT2D_AT(des, i, des_col) += MAT2D_AT(src, i, src_col);
00520     }
00521 }
00522
00523 void mat2D_sub_col_to_col(Mat2D des, size_t des_col, Mat2D src, size_t src_col)
00524 {
00525     MATRIX2D_ASSERT(src_col < src.cols);
00526     MATRIX2D_ASSERT(des.rows == src.rows);
00527     MATRIX2D_ASSERT(des_col < des.cols);
00528
00529     for (size_t i = 0; i < des.rows; i++) {
00530         MAT2D_AT(des, i, des_col) -= MAT2D_AT(src, i, src_col);
00531     }
00532 }
00533
00534 void mat2D_swap_rows(Mat2D m, size_t r1, size_t r2)
00535 {
00536     for (size_t j = 0; j < m.cols; j++) {
00537         double temp = MAT2D_AT(m, r1, j);
00538         MAT2D_AT(m, r1, j) = MAT2D_AT(m, r2, j);
00539         MAT2D_AT(m, r2, j) = temp;
00540     }
00541 }
00542
00543 void mat2D_get_row(Mat2D des, size_t des_row, Mat2D src, size_t src_row)
00544 {
00545     MATRIX2D_ASSERT(src_row < src.rows);
00546     MATRIX2D_ASSERT(des.cols == src.cols);
00547     MATRIX2D_ASSERT(des_row < des.rows);
00548
00549     for (size_t j = 0; j < des.cols; j++) {
00550         MAT2D_AT(des, des_row, j) = MAT2D_AT(src, src_row, j);
00551     }
00552 }
00553
00554 void mat2D_add_row_to_row(Mat2D des, size_t des_row, Mat2D src, size_t src_row)
00555 {
00556     MATRIX2D_ASSERT(src_row < src.rows);
00557     MATRIX2D_ASSERT(des.cols == src.cols);
00558     MATRIX2D_ASSERT(des_row < des.rows);
00559
00560     for (size_t j = 0; j < des.cols; j++) {
00561         MAT2D_AT(des, des_row, j) += MAT2D_AT(src, src_row, j);
00562     }
00563 }
00564
00565 void mat2D_sub_row_to_row(Mat2D des, size_t des_row, Mat2D src, size_t src_row)
00566 {
00567     MATRIX2D_ASSERT(src_row < src.rows);
00568     MATRIX2D_ASSERT(des.cols == src.cols);
00569     MATRIX2D_ASSERT(des_row < des.rows);
00570
00571     for (size_t j = 0; j < des.cols; j++) {
00572         MAT2D_AT(des, des_row, j) -= MAT2D_AT(src, src_row, j);
00573     }
00574 }
00575
00576 double mat2D_calc_norma(Mat2D m)
00577 {
00578     double sum = 0;
00579
00580     for (size_t i = 0; i < m.rows; ++i) {
00581         for (size_t j = 0; j < m.cols; ++j) {
00582             sum += MAT2D_AT(m, i, j) * MAT2D_AT(m, i, j);
```

```
00583         }
00584     }
00585     return sqrt(sum);
00586 }
00587
00588 bool mat2D_mat_is_all_digit(Mat2D m, double digit)
00589 {
00590     for (size_t i = 0; i < m.rows; ++i) {
00591         for (size_t j = 0; j < m.cols; ++j) {
00592             if (MAT2D_AT(m, i, j) != digit) {
00593                 return false;
00594             }
00595         }
00596     }
00597     return true;
00598 }
00599
00600 bool mat2D_row_is_all_digit(Mat2D m, double digit, size_t r)
00601 {
00602     for (size_t j = 0; j < m.cols; ++j) {
00603         if (MAT2D_AT(m, r, j) != digit) {
00604             return false;
00605         }
00606     }
00607     return true;
00608 }
00609
00610 bool mat2D_col_is_all_digit(Mat2D m, double digit, size_t c)
00611 {
00612     for (size_t i = 0; i < m.cols; ++i) {
00613         if (MAT2D_AT(m, i, c) != digit) {
00614             return false;
00615         }
00616     }
00617     return true;
00618 }
00619
00620 double mat2D_det_2x2_mat(Mat2D m)
00621 {
00622     MATRIX2D_ASSERT(2 == m.cols && 2 == m.rows && "Not a 2x2 matrix");
00623     return MAT2D_AT(m, 0, 0) * MAT2D_AT(m, 1, 1) - MAT2D_AT(m, 0, 1) * MAT2D_AT(m, 1, 0);
00624 }
00625
00626 double mat2D_triangulate(Mat2D m)
00627 {
00628     /* preforming Gauss elimination: https://en.wikipedia.org/wiki/Gaussian_elimination */
00629     /* returns the factor multiplying the determinant */
00630
00631     double factor_to_return = 1;
00632
00633     for (size_t i = 0; i < (size_t)fmin(m.rows-1, m.cols); i++) {
00634         if (!MAT2D_AT(m, i, i)) {   /* swapping only if it is zero */
00635             /* finding biggest first number (absolute value) */
00636             size_t biggest_r = i;
00637             for (size_t index = i; index < m.rows; index++) {
00638                 if (fabs(MAT2D_AT(m, index, i)) > fabs(MAT2D_AT(m, biggest_r, i))) {
00639                     biggest_r = index;
00640                 }
00641             }
00642             if (i != biggest_r) {
00643                 mat2D_swap_rows(m, i, biggest_r);
00644             }
00645         }
00646         for (size_t j = i+1; j < m.cols; j++) {
00647             double factor = 1 / MAT2D_AT(m, i, i);
00648             if (!isfinite(factor)) {
00649                 printf("%s:%d: [Error] unable to transfrom into uperr triangular matrix. Probably some
       of the rows are not independent.\n", __FILE__, __LINE__);
00650             }
00651             double mat_value = MAT2D_AT(m, j, i);
00652             mat2D_sub_row_time_factor_to_row(m, j, i, mat_value * factor);
00653         }
00654     }
00655     return factor_to_return;
00656 }
00657
00658 double mat2D_det(Mat2D m)
00659 {
00660     MATRIX2D_ASSERT(m.cols == m.rows && "should be a square matrix");
00661
00662     /* checking if there is a row or column with all zeros */
00663     /* checking rows */
00664     for (size_t i = 0; i < m.rows; i++) {
00665         if (mat2D_row_is_all_digit(m, 0, i)) {
00666             return 0;
00667         }
00668     }
```

```
00669     /* checking cols */
00670     for (size_t j = 0; j < m.rows; j++) {
00671         if (mat2D_col_is_all_digit(m, 0, j)) {
00672             return 0;
00673         }
00674     }
00675
00676     /* This is an implementation of naive determinant calculation using minors. This is too slow */
00677
00678     // double det = 0;
00679     // /* TODO: finding beast row or col? */
00680     // for (size_t i = 0, j = 0; i < m.rows; i++) { /* first column */
00681     //     if (MAT2D_AT(m, i, j) < 1e-10) continue;
00682     //     Mat2D_Minor sub_mm = mat2D_minor_alloc_fill_from_mat(m, i, j);
00683     //     int factor = (i+j)%2 ? -1 : 1;
00684     //     if (sub_mm.cols != 2) {
00685     //         MATRIX2D_ASSERT(sub_mm.cols == sub_mm.rows && "should be a square matrix");
00686     //         det += MAT2D_AT(m, i, j) * (factor) * mat2D_minor_det(sub_mm);
00687     //     } else if (sub_mm.cols == 2 && sub_mm.rows == 2) {
00688     //         det += MAT2D_AT(m, i, j) * (factor) * mat2D_det_2x2_mat_minor(sub_mm);;
00689     //     }
00690     //     mat2D_minor_free(sub_mm);
00691     // }
00692
00693     Mat2D temp_m = mat2D_alloc(m.rows, m.cols);
00694     mat2D_copy(temp_m, m);
00695     double factor = mat2D_triangulate(temp_m);
00696     double diag_mul = 1;
00697     for (size_t i = 0; i < temp_m.rows; i++) {
00698         diag_mul *= MAT2D_AT(temp_m, i, i);
00699     }
00700     mat2D_free(temp_m);
00701
00702     return diag_mul / factor;
00703 }
00704
00705 void mat2D_LUP_decomposition_with_swap(Mat2D src, Mat2D l, Mat2D p, Mat2D u)
00706 {
00707     /* performing LU decomposition Following the Wikipedia page:
      https://en.wikipedia.org/wiki/LU_decomposition */
00708
00709     mat2D_copy(u, src);
00710     mat2D_set_identity(p);
00711     mat2D_fill(l, 0);
00712
00713     for (size_t i = 0; i < (size_t)fmin(u.rows-1, u.cols); i++) {
00714         if (!MAT2D_AT(u, i, i)) {   /* swapping only if it is zero */
00715             /* finding biggest first number (absolute value) */
00716             size_t biggest_r = i;
00717             for (size_t index = i; index < u.rows; index++) {
00718                 if (fabs(MAT2D_AT(u, index, i)) > fabs(MAT2D_AT(u, biggest_r, i))) {
00719                     biggest_r = index;
00720                 }
00721             }
00722             if (i != biggest_r) {
00723                 mat2D_swap_rows(u, i, biggest_r);
00724                 mat2D_swap_rows(p, i, biggest_r);
00725                 mat2D_swap_rows(l, i, biggest_r);
00726             }
00727         }
00728         for (size_t j = i+1; j < u.cols; j++) {
00729             double factor = 1 / MAT2D_AT(u, i, i);
00730             if (!isfinite(factor)) {
00731                 printf("%s:%d: [Error] unable to transfrom into uper triangular matrix. Probably some
      of the rows are not independent.\n", __FILE__, __LINE__);
00732             }
00733             double mat_value = MAT2D_AT(u, j, i);
00734             mat2D_sub_row_time_factor_to_row(u, j, i, mat_value * factor);
00735             MAT2D_AT(l, j, i) = mat_value * factor;
00736         }
00737         MAT2D_AT(l, i, i) = 1;
00738     }
00739     MAT2D_AT(l, l.rows-1, l.cols-1) = 1;
00740 }
00741
00742 void mat2D_transpose(Mat2D des, Mat2D src)
00743 {
00744     MATRIX2D_ASSERT(des.cols == src.rows);
00745     MATRIX2D_ASSERT(des.rows == src.cols);
00746
00747     for (size_t index = 0; index < des.rows; ++index) {
00748         for (size_t jndex = 0; jndex < des.cols; ++jndex) {
00749             MAT2D_AT(des, index, jndex) = MAT2D_AT(src, jndex, index);
00750         }
00751     }
00752 }
00753
```

```
00754 void mat2D_invert(Mat2D des, Mat2D src)
00755 {
00756     MATRIX2D_ASSERT(src.cols == src.rows && "should be an NxN matrix");
00757     MATRIX2D_ASSERT(des.cols == src.cols && des.rows == des.cols);
00758
00759     Mat2D m = mat2D_alloc(src.rows, src.cols);
00760     mat2D_copy(m, src);
00761
00762     mat2D_set_identity(des);
00763
00764     if (!mat2D_det(m)) {
00765         mat2D_fill(des, 0);
00766         printf("%s:%d: [Error] Can't invert the matrix. Determinant is zero! Set the inverse matrix to
      all zeros\n", __FILE__, __LINE__);
00767         return;
00768     }
00769
00770     for (size_t i = 0; i < (size_t)fmin(m.rows-1, m.cols); i++) {
00771         if (!MAT2D_AT(m, i, i)) {   /* swapping only if it is zero */
00772             /* finding biggest first number (absolute value) */
00773             size_t biggest_r = i;
00774             for (size_t index = i; index < m.rows; index++) {
00775                 if (fabs(MAT2D_AT(m, index, i)) > fabs(MAT2D_AT(m, biggest_r, i))) {
00776                     biggest_r = index;
00777                 }
00778             }
00779             if (i != biggest_r) {
00780                 mat2D_swap_rows(m, i, biggest_r);
00781                 mat2D_swap_rows(des, i, biggest_r);
00782                 printf("%s:%d: [INFO] swapping row %zu with row %zu.\n", __FILE__, __LINE__, i,
      biggest_r);
00783             } else {
00784                 MATRIX2D_ASSERT(0 && "can't inverse");
00785             }
00786         }
00787         for (size_t j = i+1; j < m.cols; j++) {
00788             double factor = 1 / MAT2D_AT(m, i, i);
00789             double mat_value = MAT2D_AT(m, j, i);
00790             mat2D_sub_row_time_factor_to_row(m, j, i, mat_value * factor);
00791             mat2D_mult_row(m, i, factor);
00792
00793             mat2D_sub_row_time_factor_to_row(des, j, i, mat_value * factor);
00794             mat2D_mult_row(des, i, factor);
00795         }
00796     }
00797     double factor = 1 / MAT2D_AT(m, m.rows-1, m.cols-1);
00798     mat2D_mult_row(m, m.rows-1, factor);
00799     mat2D_mult_row(des, des.rows-1, factor);
00800     for (size_t c = m.cols-1; c > 0; c--) {
00801         for (int r = c-1; r >= 0; r--) {
00802             double factor = 1 / MAT2D_AT(m, c, c);
00803             double mat_value = MAT2D_AT(m, r, c);
00804             mat2D_sub_row_time_factor_to_row(m, r, c, mat_value * factor);
00805             mat2D_sub_row_time_factor_to_row(des, r, c, mat_value * factor);
00806         }
00807     }
00808
00809     mat2D_free(m);
00810 }
00811
00812 void mat2D_solve_linear_sys_LUP_decomposition(Mat2D A, Mat2D x, Mat2D B)
00813 {
00814     MATRIX2D_ASSERT(A.cols == x.rows);
00815     MATRIX2D_ASSERT(1 == x.cols);
00816     MATRIX2D_ASSERT(A.rows == B.rows);
00817     MATRIX2D_ASSERT(1 == B.cols);
00818
00819     Mat2D y     = mat2D_alloc(x.rows, x.cols);
00820     Mat2D l     = mat2D_alloc(A.rows, A.cols);
00821     Mat2D p     = mat2D_alloc(A.rows, A.cols);
00822     Mat2D u     = mat2D_alloc(A.rows, A.cols);
00823     Mat2D inv_l = mat2D_alloc(l.rows, l.cols);
00824     Mat2D inv_u = mat2D_alloc(u.rows, u.cols);
00825
00826     mat2D_LUP_decomposition_with_swap(A, l, p, u);
00827
00828     mat2D_invert(inv_l, l);
00829     mat2D_invert(inv_u, u);
00830
00831     mat2D_fill(x, 0);   /* x here is only a temp mat*/
00832     mat2D_fill(y, 0);
00833     mat2D_dot(x, p, B);
00834     mat2D_dot(y, inv_l, x);
00835
00836     mat2D_fill(x, 0);
00837     mat2D_dot(x, inv_u, y);
00838
```

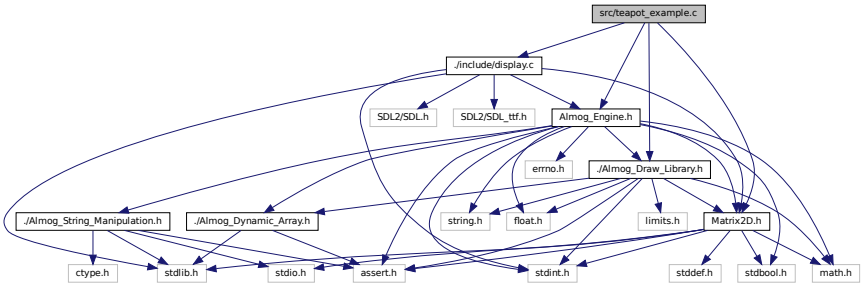
```
00839     mat2D_free(y);
00840     mat2D_free(l);
00841     mat2D_free(p);
00842     mat2D_free(u);
00843     mat2D_free(inv_l);
00844     mat2D_free(inv_u);
00845 }
00846
00847 Mat2D_Minor mat2D_minor_alloc_fill_from_mat(Mat2D ref_mat, size_t i, size_t j)
00848 {
00849     MATRIX2D_ASSERT(ref_mat.cols == ref_mat.rows && "minor is defined only for square matrix");
00850
00851     Mat2D_Minor mm;
00852     mm.cols = ref_mat.cols-1;
00853     mm.rows = ref_mat.rows-1;
00854     mm.stride_r = ref_mat.cols-1;
00855     mm.cols_list = (size_t*)MATRIX2D_MALLOC(sizeof(double)*(ref_mat.cols-1));
00856     mm.rows_list = (size_t*)MATRIX2D_MALLOC(sizeof(double)*(ref_mat.rows-1));
00857     mm.ref_mat = ref_mat;
00858
00859     MATRIX2D_ASSERT(mm.cols_list != NULL && mm.rows_list != NULL);
00860
00861     for (size_t index = 0, temp_index = 0; index < ref_mat.rows; index++) {
00862         if (index != i) {
00863             mm.rows_list[temp_index] = index;
00864             temp_index++;
00865         }
00866     }
00867     for (size_t jndex = 0, temp_jndex = 0; jndex < ref_mat.rows; jndex++) {
00868         if (jndex != j) {
00869             mm.cols_list[temp_jndex] = jndex;
00870             temp_jndex++;
00871         }
00872     }
00873
00874     return mm;
00875 }
00876
00877 Mat2D_Minor mat2D_minor_alloc_fill_from_mat_minor(Mat2D_Minor ref_mm, size_t i, size_t j)
00878 {
00879     MATRIX2D_ASSERT(ref_mm.cols == ref_mm.rows && "minor is defined only for square matrix");
00880
00881     Mat2D_Minor mm;
00882     mm.cols = ref_mm.cols-1;
00883     mm.rows = ref_mm.rows-1;
00884     mm.stride_r = ref_mm.cols-1;
00885     mm.cols_list = (size_t*)MATRIX2D_MALLOC(sizeof(double)*(ref_mm.cols-1));
00886     mm.rows_list = (size_t*)MATRIX2D_MALLOC(sizeof(double)*(ref_mm.rows-1));
00887     mm.ref_mat = ref_mm.ref_mat;
00888
00889     MATRIX2D_ASSERT(mm.cols_list != NULL && mm.rows_list != NULL);
00890
00891     for (size_t index = 0, temp_index = 0; index < ref_mm.rows; index++) {
00892         if (index != i) {
00893             mm.rows_list[temp_index] = ref_mm.rows_list[index];
00894             temp_index++;
00895         }
00896     }
00897     for (size_t jndex = 0, temp_jndex = 0; jndex < ref_mm.rows; jndex++) {
00898         if (jndex != j) {
00899             mm.cols_list[temp_jndex] = ref_mm.cols_list[jndex];
00900             temp_jndex++;
00901         }
00902     }
00903
00904     return mm;
00905 }
00906
00907 void mat2D_minor_free(Mat2D_Minor mm)
00908 {
00909     free(mm.cols_list);
00910     free(mm.rows_list);
00911 }
00912
00913 void mat2D_minor_print(Mat2D_Minor mm, const char *name, size_t padding)
00914 {
00915     printf("%*s%s = [\n", (int) padding, "", name);
00916     for (size_t i = 0; i < mm.rows; ++i) {
00917         printf("%*s    ", (int) padding, "");
00918         for (size_t j = 0; j < mm.cols; ++j) {
00919             printf("%f ", MAT2D_MINOR_AT(mm, i, j));
00920         }
00921         printf("\n");
00922     }
00923     printf("%*s]\n", (int) padding, "");
00924 }
00925
```

```
00926 double mat2D_det_2x2_mat_minor(Mat2D_Minor mm)
00927 {
00928     MATRIX2D_ASSERT(2 == mm.cols && 2 == mm.rows && "Not a 2x2 matrix");
00929     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);
00930 }
00931
00932 double mat2D_minor_det(Mat2D_Minor mm)
00933 {
00934     MATRIX2D_ASSERT(mm.cols == mm.rows && "should be a square matrix");
00935
00936     double det = 0;
00937     /* TODO: finding beast row or col? */
00938     for (size_t i = 0, j = 0; i < mm.rows; i++) { /* first column */
00939         if (MAT2D_MINOR_AT(mm, i, j) < 1e-10) continue;
00940         Mat2D_Minor sub_mm = mat2D_minor_alloc_fill_from_mat_minor(mm, i, j);
00941         int factor = (i+j)%2 ? -1 : 1;
00942         if (sub_mm.cols != 2) {
00943             MATRIX2D_ASSERT(sub_mm.cols == sub_mm.rows && "should be a square matrix");
00944             det += MAT2D_MINOR_AT(mm, i, j) * (factor) * mat2D_minor_det(sub_mm);
00945         } else if (sub_mm.cols == 2 && sub_mm.rows == 2) {
00946             det += MAT2D_MINOR_AT(mm, i, j) * (factor) * mat2D_det_2x2_mat_minor(sub_mm);;
00947         }
00948         mat2D_minor_free(sub_mm);
00949     }
00950     return det;
00951 }
00952
00953
00954 #endif // MATRIX2D_IMPLEMENTATION
```

4.15 src/teapot_example.c File Reference

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

Include dependency graph for teapot_example.c:



Macros

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

Functions

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

4.15.1 Macro Definition Documentation

4.15.1.1 ALMOG_DRAW_LIBRARY_IMPLEMENTATION

```
#define ALMOG_DRAW_LIBRARY_IMPLEMENTATION
```

Definition at line 7 of file teapot_example.c.

4.15.1.2 ALMOG_ENGINE_IMPLEMENTATION

```
#define ALMOG_ENGINE_IMPLEMENTATION
```

Definition at line 9 of file teapot_example.c.

4.15.1.3 MATRIX2D_IMPLEMENTATION

```
#define MATRIX2D_IMPLEMENTATION
```

Definition at line 5 of file teapot_example.c.

4.15.1.4 RENDER

```
#define RENDER
```

Definition at line 3 of file teapot_example.c.

4.15.1.5 SETUP

```
#define SETUP
```

Definition at line 1 of file teapot_example.c.

4.15.1.6 UPDATE

```
#define UPDATE
```

Definition at line 2 of file teapot_example.c.

4.15.2 Function Documentation

4.15.2.1 render()

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

Definition at line 61 of file teapot_example.c.

References ADL_DEFAULT_OFFSET_ZOOM, adl_tri_mesh_fill_Pinedas_rasterizer_interpolate_normal(), Tri_mesh_array::elements, Scene::in_world_tri_meshes, game_state_t::inv_z_buffer_mat, Tri_mesh::length, Tri_mesh_array::length, Scene::projected_tri_meshes, game_state_t::scene, and game_state_t::window_pixels_mat.

4.15.2.2 setup()

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

Definition at line 12 of file teapot_example.c.

References ada_append, ada_init_array, ae_tri_mesh_append_copy(), ae_tri_mesh_get_from_file(), ae_tri_mesh_normalize(), ae_tri_mesh_rotate_Euler_xyz(), Tri_mesh_array::elements, Scene::in_world_tri_meshes, Tri_mesh::length, Tri_mesh_array::length, MAX_LEN_LINE, Scene::original_tri_meshes, Scene::projected_tri_meshes, game_state_t::scene, and game_state_t::to_limit_fps.

4.15.2.3 update()

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

Definition at line 50 of file teapot_example.c.

References AE_LIGHTING_FLAT, ae_projection_mat_set(), ae_tri_mesh_project_world2screen(), ae_view_mat_set(), Camera::aspect_ratio, Scene::camera, Tri_mesh_array::elements, Camera::fov_deg, Scene::in_world_tri_meshes, Tri_mesh_array::length, Scene::proj_mat, Scene::projected_tri_meshes, game_state_t::scene, Scene::up_direction, Scene::view_mat, game_state_t::window_h, game_state_t::window_w, Camera::z_far, and Camera::z_near.

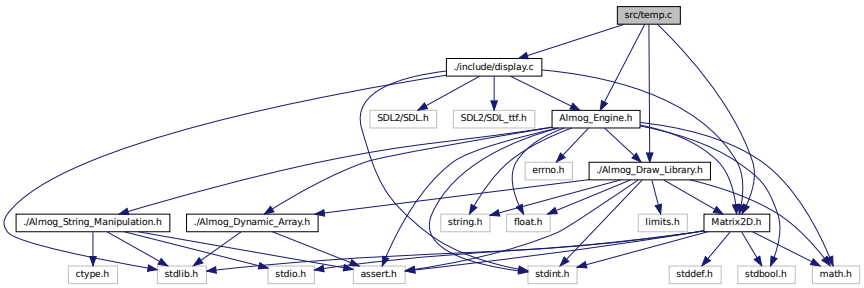
4.16 teapot_example.c

```
00001 #define SETUP
00002 #define UPDATE
00003 #define RENDER
00004 #include "./include/display.c"
00005 #define MATRIX2D_IMPLEMENTATION
00006 #include "./include/Matrix2D.h"
00007 #define ALMOG_DRAW_LIBRARY_IMPLEMENTATION
00008 #include "./include/Almog_Draw_Library.h"
00009 #define ALMOG_ENGINE_IMPLEMENTATION
00010 #include "./include/Almog_Engine.h"
00011
00012 void setup(game_state_t *game_state)
00013 {
00014     game_state->to_limit_fps = 0;
00015
00016     ada_init_array(Tri_mesh, game_state->scene.original_tri_meshes);
00017     ada_init_array(Tri_mesh, game_state->scene.in_world_tri_meshes);
00018     ada_init_array(Tri_mesh, game_state->scene.projected_tri_meshes);
00019
00020     char file_path[MAX_LEN_LINE];
00021     strncpy(file_path, "./teapot.stl", MAX_LEN_LINE);
00022
00023     Tri_mesh teapot_mesh = ae_tri_mesh_get_from_file(file_path);
00024     // ae_tri_mesh_flip_normals(teapot_mesh);
00025     ada_append(Tri_mesh, game_state->scene.original_tri_meshes, teapot_mesh);
00026
00027     printf("[INFO] number of meshes: %zu\n", game_state->scene.original_tri_meshes.length);
00028     size_t sum = 0;
00029     for (size_t i = 0; i < game_state->scene.original_tri_meshes.length; i++) {
00030         printf("[INFO] mesh number %zu: %zu\n", i,
      game_state->scene.original_tri_meshes.elements[i].length);
00031         sum += game_state->scene.original_tri_meshes.elements[i].length;
00032     }
00033     printf("[INFO] total number of triangles: %zu\n", sum);
00034
00035
00036     for (size_t i = 0; i < game_state->scene.original_tri_meshes.length; i++) {
00037         ae_tri_mesh_normalize(game_state->scene.original_tri_meshes.elements[i]);
00038     }
00039     for (size_t i = 0; i < game_state->scene.original_tri_meshes.length; i++) {
00040         ae_tri_mesh_append_copy(&(game_state->scene.in_world_tri_meshes),
      game_state->scene.original_tri_meshes.elements[i]);
00041         ae_tri_mesh_append_copy(&(game_state->scene.projected_tri_meshes),
      game_state->scene.original_tri_meshes.elements[i]);
00042         game_state->scene.projected_tri_meshes.elements[i].length = 0;
00043     }
00044
00045     ae_tri_mesh_rotate_Euler_xyz(game_state->scene.in_world_tri_meshes.elements[0], -90, 0, 180);
00046
00047     // ae_translate_mesh(game_state->scene.in_world_tri_meshes.elements[0], 0, 0, 2);
00048 }
00049
00050 void update(game_state_t *game_state)
00051 {
00052     ae_projection_mat_set(game_state->scene.proj_mat, game_state->scene.camera.aspect_ratio,
      game_state->scene.camera.fov_deg, game_state->scene.camera.z_near, game_state->scene.camera.z_far);
00053     ae_view_mat_set(game_state->scene.view_mat, game_state->scene.camera,
      game_state->scene.up_direction);
00054
00055     for (size_t i = 0; i < game_state->scene.in_world_tri_meshes.length; i++) {
00056         ae_tri_mesh_project_world2screen(game_state->scene.proj_mat, game_state->scene.view_mat,
      &(game_state->scene.projected_tri_meshes.elements[i]),
      game_state->scene.in_world_tri_meshes.elements[i], game_state->window_w, game_state->window_h,
      &(game_state->scene), AE_LIGHTING_FLAT);
00057     }
00058
00059 }
00060
00061 void render(game_state_t *game_state)
00062 {
00063     for (size_t i = 0; i < game_state->scene.projected_tri_meshes.length; i++) {
00064         adl_tri_mesh_fill_Pinedas_rasterizer_interpolate_normal(game_state->window_pixels_mat,
      game_state->inv_z_buffer_mat, game_state->scene.projected_tri_meshes.elements[i], 0xffffffff,
      ADL_DEFAULT_OFFSET_ZOOM);
00065     }
00066
00067     for (size_t i = 0; i < game_state->scene.in_world_tri_meshes.length; i++) {
00068         game_state->scene.projected_tri_meshes.elements[i].length = 0;
00069     }
00070 }
```

4.17 src/temp.c File Reference

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

Include dependency graph for temp.c:



Macros

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

Functions

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

4.17.1 Macro Definition Documentation

4.17.1.1 ALMOG_DRAW_LIBRARY_IMPLEMENTATION

```
#define ALMOG_DRAW_LIBRARY_IMPLEMENTATION
```

Definition at line 7 of file temp.c.

4.17.1.2 ALMOG_ENGINE_IMPLEMENTATION

```
#define ALMOG_ENGINE_IMPLEMENTATION
```

Definition at line 9 of file temp.c.

4.17.1.3 MATRIX2D_IMPLEMENTATION

```
#define MATRIX2D_IMPLEMENTATION
```

Definition at line 5 of file temp.c.

4.17.1.4 RENDER

```
#define RENDER
```

Definition at line 3 of file temp.c.

4.17.1.5 SETUP

```
#define SETUP
```

Definition at line 1 of file temp.c.

4.17.1.6 UPDATE

```
#define UPDATE
```

Definition at line 2 of file temp.c.

4.17.2 Function Documentation

4.17.2.1 render()

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

Definition at line 63 of file temp.c.

References ADL_DEFAULT_OFFSET_ZOOM, adl_tri_mesh_fill_Pinedas_rasterizer_interpolate_normal(), Tri_mesh_array::elements, game_state_t::inv_z_buffer_mat, Tri_mesh_array::length, Scene::projected_tri_meshes, game_state_t::scene, and game_state_t::window_pixels_mat.

Referenced by render_window().

4.17.2.2 setup()

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

Definition at line 12 of file temp.c.

References ada_append, ada_init_array, ae_tri_mesh_append_copy(), ae_tri_mesh_get_from_file(), ae_tri_mesh_normalize(), ae_tri_mesh_rotate_Euler_xyz(), Tri_mesh_array::elements, Scene::in_world_tri_meshes, Tri_mesh::length, Tri_mesh_array::length, MAX_LEN_LINE, Scene::original_tri_meshes, Scene::projected_tri_meshes, game_state_t::scene, and game_state_t::to_limit_fps.

Referenced by setup_window().

4.17.2.3 update()

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

Definition at line 49 of file temp.c.

References AE_LIGHTING_FLAT, ae_projection_mat_set(), ae_tri_mesh_project_world2screen(), ae_view_mat_set(), Camera::aspect_ratio, Scene::camera, Tri_mesh_array::elements, Camera::fov_deg, Scene::in_world_tri_meshes, Tri_mesh_array::length, Scene::proj_mat, Scene::projected_tri_meshes, game_state_t::scene, Scene::up_direction, Scene::view_mat, game_state_t::window_h, game_state_t::window_w, Camera::z_far, and Camera::z_near.

Referenced by update_window().

4.18 temp.c

```
00001 #define SETUP
00002 #define UPDATE
00003 #define RENDER
00004 #include "./include/display.c"
00005 #define MATRIX2D_IMPLEMENTATION
00006 #include "./include/Matrix2D.h"
00007 #define ALMOG_DRAW_LIBRARY_IMPLEMENTATION
00008 #include "./include/Almog_Draw_Library.h"
00009 #define ALMOG_ENGINE_IMPLEMENTATION
00010 #include "./include/Almog_Engine.h"
00011
00012 void setup(game_state_t *game_state)
00013 {
00014     game_state->to_limit_fps = 0;
00015
00016     ada_init_array(Tri_mesh, game_state->scene.original_tri_meshes);
00017     ada_init_array(Tri_mesh, game_state->scene.in_world_tri_meshes);
00018     ada_init_array(Tri_mesh, game_state->scene.projected_tri_meshes);
00019
00020     char file_path[MAX_LEN_LINE];
00021     strncpy(file_path, "./teapot.stl", MAX_LEN_LINE);
00022
00023     Tri_mesh tri_mesh = ae_tri_mesh_get_from_file(file_path);
00024
00025     ada_append(Tri_mesh, game_state->scene.original_tri_meshes, tri_mesh);
00026
00027     printf("[INFO] number of meshes: %zu\n", game_state->scene.original_tri_meshes.length);
00028     size_t sum = 0;
00029     for (size_t i = 0; i < game_state->scene.original_tri_meshes.length; i++) {
00030         printf("[INFO] mesh number %zu: %zu\n", i,
      game_state->scene.original_tri_meshes.elements[i].length);
00031         sum += game_state->scene.original_tri_meshes.elements[i].length;
00032     }
00033     printf("[INFO] total number of triangles: %zu\n", sum);
00034
00035
00036     for (size_t i = 0; i < game_state->scene.original_tri_meshes.length; i++) {
00037         ae_tri_mesh_normalize(game_state->scene.original_tri_meshes.elements[i]);
00038     }
00039     for (size_t i = 0; i < game_state->scene.original_tri_meshes.length; i++) {
00040         ae_tri_mesh_append_copy(&(game_state->scene.in_world_tri_meshes),
      game_state->scene.original_tri_meshes.elements[i]);
00041         ae_tri_mesh_append_copy(&(game_state->scene.projected_tri_meshes),
      game_state->scene.original_tri_meshes.elements[i]);
00042         game_state->scene.projected_tri_meshes.elements[i].length = 0;
00043     }
00044
00045     ae_tri_mesh_rotate_Euler_xyz(game_state->scene.in_world_tri_meshes.elements[0], -90, 0, 180);
00046
00047 }
00048
00049 void update(game_state_t *game_state)
00050 {
00051     // MAT2D_PRINT(game_state->scene.camera.current_position);
00052     // MAT2D_PRINT(game_state->scene.light_direction);
00053
00054     ae_projection_mat_set(game_state->scene.proj_mat, game_state->scene.camera.aspect_ratio,
      game_state->scene.camera.fov_deg, game_state->scene.camera.z_near, game_state->scene.camera.z_far);
00055     ae_view_mat_set(game_state->scene.view_mat, game_state->scene.camera,
      game_state->scene.up_direction);
00056
00057     for (size_t i = 0; i < game_state->scene.in_world_tri_meshes.length; i++) {
00058         ae_tri_mesh_project_world2screen(game_state->scene.proj_mat, game_state->scene.view_mat,
      &(game_state->scene.projected_tri_meshes.elements[i]),
      game_state->scene.in_world_tri_meshes.elements[i], game_state->window_w, game_state->window_h,
      &(game_state->scene), AE_LIGHTING_FLAT);
00059     }
00060
00061 }
00062
00063 void render(game_state_t *game_state)
00064 {
00065     for (size_t i = 0; i < game_state->scene.projected_tri_meshes.length; i++) {
00066         adl_tri_mesh_fill_Pinedas_rasterizer_interpolate_normal(game_state->window_pixels_mat,
      game_state->inv_z_buffer_mat, game_state->scene.projected_tri_meshes.elements[i], 0xffffffff,
      ADL_DEFAULT_OFFSET_ZOOM);
00067     }
00068 }
```

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