HologramDepthmap Library

Generated by Doxygen 1.8.13

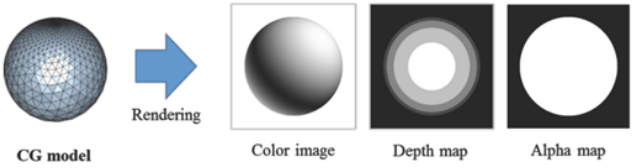
Contents

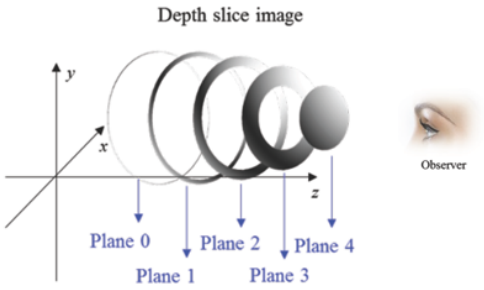
Chapter 1

Main Page

1.1 Introduction

This library implements the hologram generation method using depth map data.
It is implemented on the CPU and the GPU to improve the performance of the hologram generation method. Thus, user can compare the performance between the CPU and GPU implementation.





1.2 Algorithm Reference

The original algorithm is modified in the way that can be easily implemented in parallel.
Back propagate each depth plane to the hologram plane and accumulate the results of each propagation.

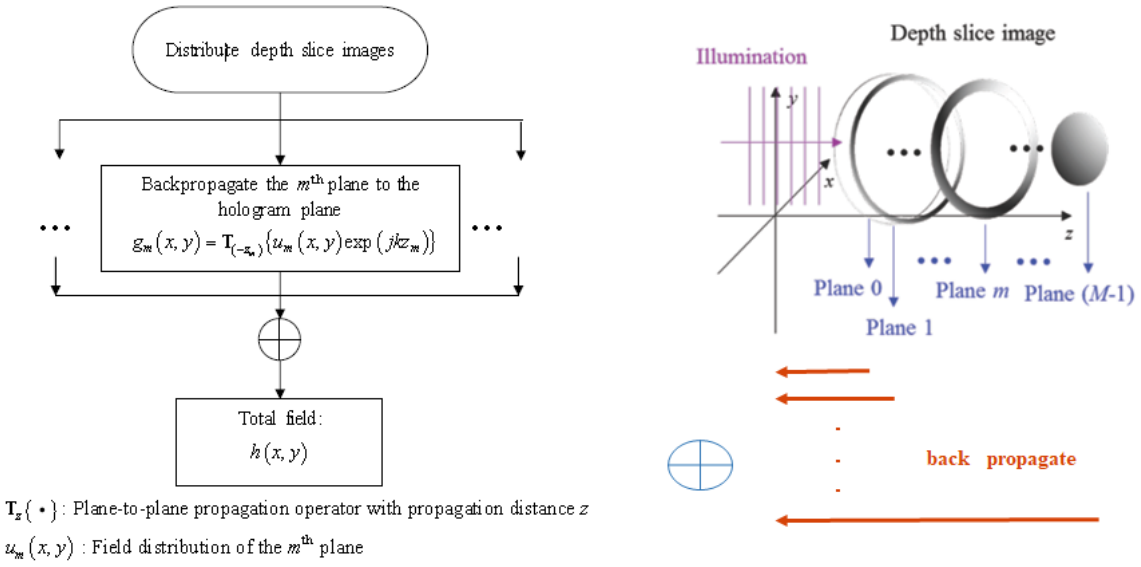
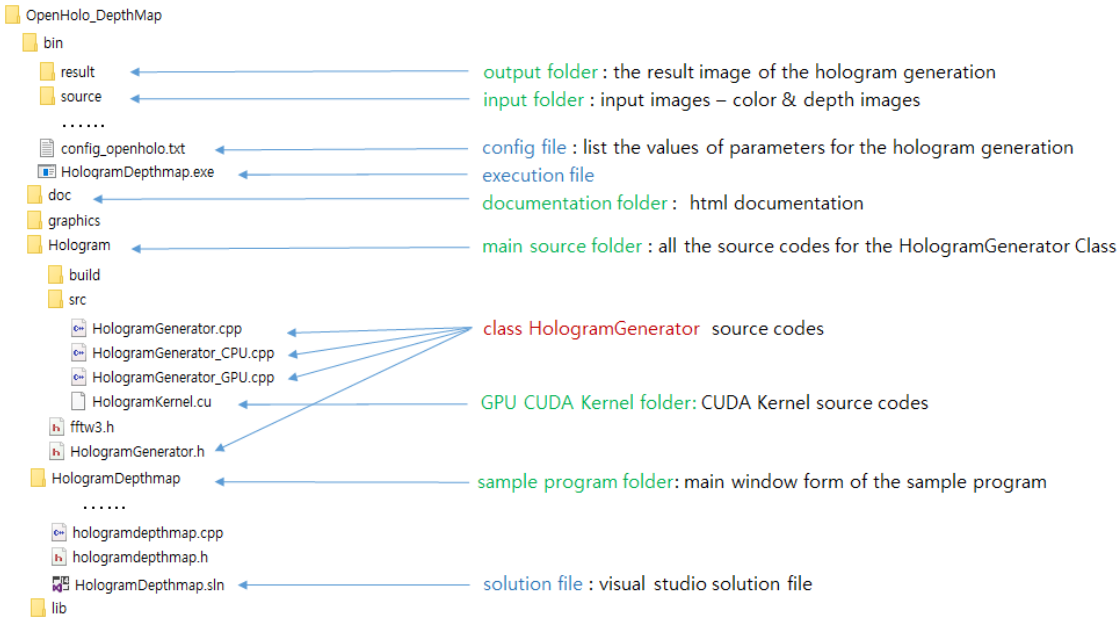


Figure 1.1 Depth Map Hologram Generation Algorithm

1.3 Software Components

The library consists a main hologram generation module(Hologram folder) and its sample program(Hologram↩ Depthmap folder).
The following shows the list of files with the directory structure.



1.4 Main Procedure

The main function of the library is a **`GenerateHologram()`** of `HologramGenerator` class. The following is the procedure of it and functions called form it..

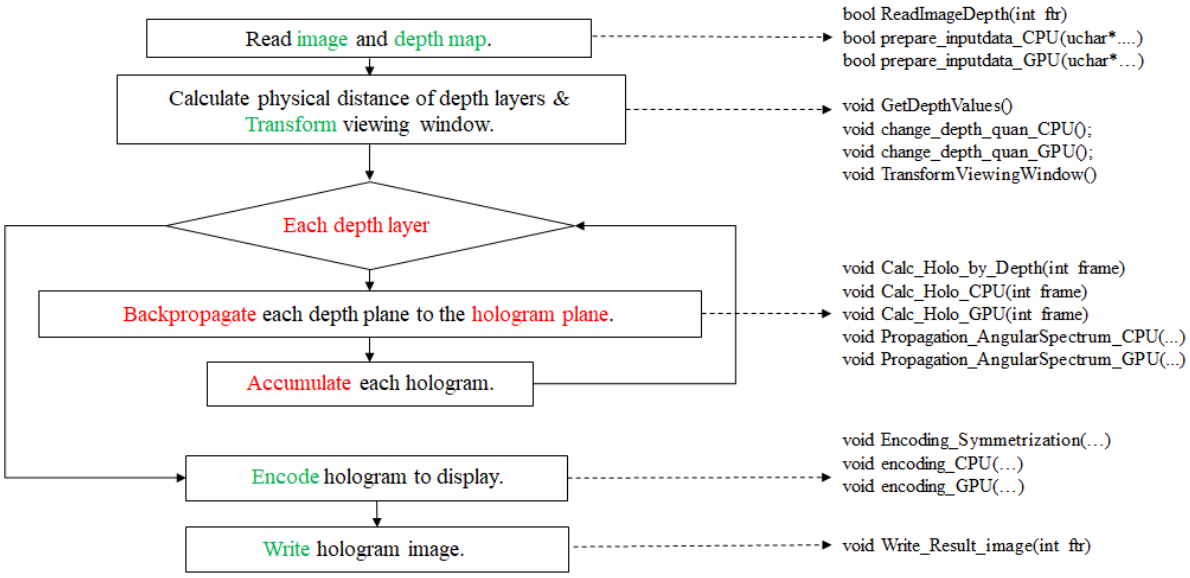


Figure 1.2 GenerateHologram Function Procedure

1.5 Environment

- Microsoft Visual Studio 2015 C++
- Qt 5.6.2
- CUDA 8.0
- FFTW 3.3.5

1.6 How to Build Source Codes

Before building an execution file, you need to install MS Visual Studio 2015 C++ and Qt, also CUDA for the GPU execution.

1. Download the source code from `here`.
2. Go to the directory 'HologramDepthmap'.
3. Open the Visual Studio soulution file, 'HologramDepthmap.sln'.
4. Check the configuation of the Qt & CUDA to work with the Visual Studio.
5. For Qt, you may need to set QTDIR environment variable -> System Properties->Advanced->Environment Variable.

6. To use FFTW, copy 'libfftw3-3.dll' into the 'bin' directory and copy 'libfftw3-3.lib' into the 'lib' directory.
7. Visual Studio Build Menu -> Configuration Menu, set "Release" for the Active solution configuration, "x64" for the Active solution platform.
8. Set 'HologramDepthmap' as a StartUp Project.
9. Build a Solution.
10. After building, you can find the execution file, 'HologramDepthmap.exe' under the 'bin' directory.
11. Execute 'HologramDepthmap.exe', then you can see the following GUI of the sample program.

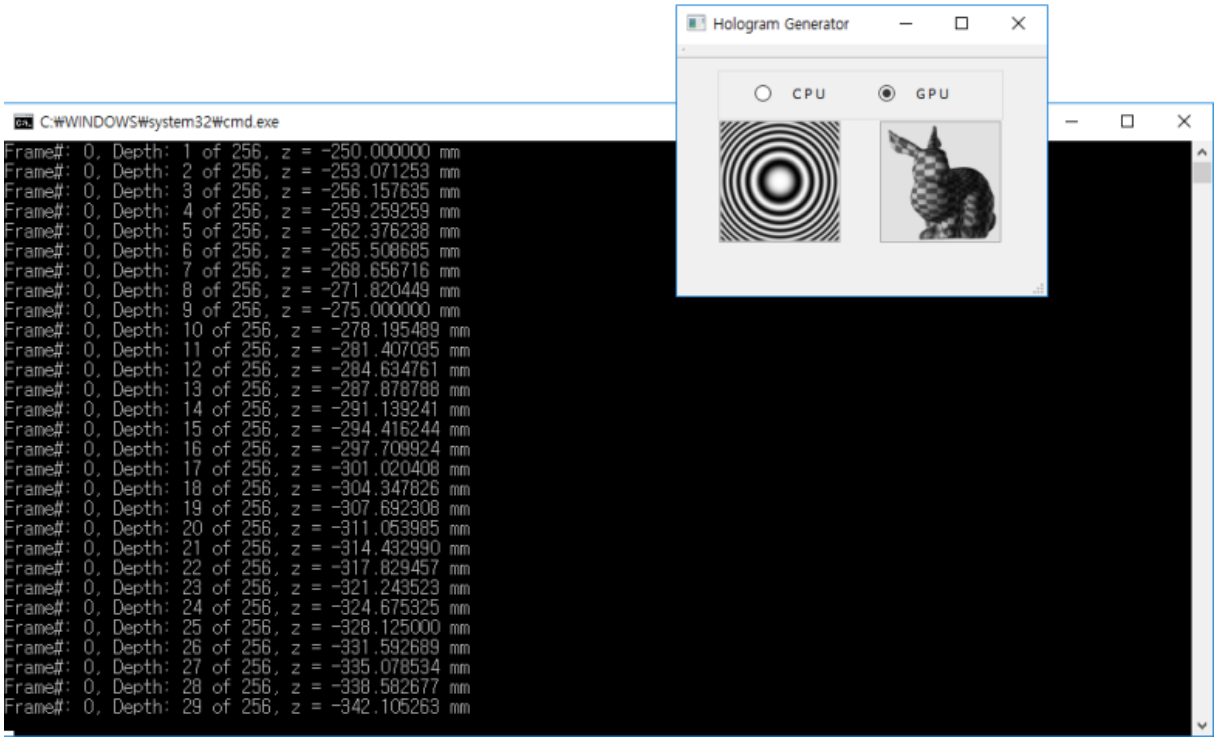


Figure 1.3 the Sample Program & its Execution

Chapter 2

Module Index

2.1 Modules

Here is a list of all modules:

Chapter 3

Namespace Index

Chapter 4

Hierarchical Index

4.1 Class Hierarchy

This inheritance list is sorted roughly, but not completely, alphabetically:

Chapter 5

Class Index

5.1 Class List

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

Chapter 6

File Index

6.1 File List

Here is a list of all files with brief descriptions:

Chapter 7

Module Documentation

7.1 Initialize

Functions

- bool HologramGenerator::readConfig ()

  Read parameters from a config file(config_openholo.txt).
- void HologramGenerator::initialize ()

  Initialize variables for CPU and GPU implementation.

- void HologramGenerator::init_CPU ()

  Initialize variables for the CPU implementation.
- void HologramGenerator::init_GPU ()

  Initialize variables for the GPU implementation.

7.1.1 Detailed Description

7.1.2 Function Documentation

7.1.2.1 init_CPU()

```
void HologramGenerator::init_CPU ( )  [private]
```

Memory allocation for the CPU variables.

See also

initialize

Definition at line 13 of file HologramGenerator_CPU.cpp.

7.1.2.2 init_GPU()

```
void HologramGenerator::init_GPU ( )  [private]
```

Memory allocation for the GPU variables.

See also

initialize

Definition at line 157 of file HologramGenerator_GPU.cpp.

7.1.2.3 initialize()

```
void HologramGenerator::initialize ( )
```

See also

init_CPU, init_GPU

Definition at line 235 of file HologramGenerator.cpp.

7.1.2.4 readConfig()

```
bool HologramGenerator::readConfig ( )
```

Returns

true if config infomation are sucessfully read, flase otherwise.

Definition at line 65 of file HologramGenerator.cpp.

7.2 Loading Data

- bool HologramGenerator::ReadImageDepth (int ftr)

  Read image and depth map.
- bool HologramGenerator::prepare_inputdata_CPU (uchar ∗img, uchar ∗dimg)

  Preprocess input image & depth map data for the CPU implementation.
- bool HologramGenerator::prepare_inputdata_GPU (uchar ∗img, uchar ∗dimg)

  Copy input image & depth map data into a GPU.

7.2.1 Detailed Description

7.2.2 Function Documentation

7.2.2.1 prepare_inputdata_CPU()

```
bool HologramGenerator::prepare_inputdata_CPU (
            uchar * imgptr,
            uchar * dimgptr )  [private]
```

Prepare variables, img_src_, dmap_src_, alpha_map_, depth_index_.

Parameters

imgptr	: input image data pointer
dimgptr	: input depth map data pointer

Returns

true if input data are sucessfully prepared, flase otherwise.

See also

ReadImageDepth

Definition at line 44 of file HologramGenerator_CPU.cpp.

7.2.2.2 prepare_inputdata_GPU()

```
bool HologramGenerator::prepare_inputdata_GPU (
            uchar * imgptr,
            uchar * dimgptr )  [private]
```

Parameters

imgptr	: input image data pointer
dimgptr	: input depth map data pointer

Returns

true if input data are sucessfully copied on GPU, flase otherwise.

See also

ReadImageDepth

Definition at line 194 of file HologramGenerator_GPU.cpp.

7.2.2.3 ReadImageDepth()

```
bool HologramGenerator::ReadImageDepth (
            int ftr )  [private]
```

Read input files and load image & depth map data. If the input image size is different with the dislay resolution, resize the image size.

Parameters

ftr	: the frame number of the image.

Returns

true if image data are sucessfully read, flase otherwise.

See also

prepare_inputdata_CPU, prepare_inputdata_GPU

Definition at line 304 of file HologramGenerator.cpp.

7.3 Computing Depth Value

- void HologramGenerator::GetDepthValues ()

  Calculate the physical distances of depth map layers.
- void HologramGenerator::change_depth_quan_CPU ()

  Quantize depth map on the CPU, when the number of depth quantization is not the default value (i.e. FLAG_CHA↩ NGE_DEPTH_QUANTIZATION == 1).
- void HologramGenerator::change_depth_quan_GPU ()

  Quantize depth map on the GPU, when the number of depth quantization is not the default value (i.e. FLAG_CHA↩ NGE_DEPTH_QUANTIZATION == 1).

7.3.1 Detailed Description

7.3.2 Function Documentation

7.3.2.1 change_depth_quan_CPU()

```
void HologramGenerator::change_depth_quan_CPU ( )  [private]
```

Calculate the value of 'depth_index_'.

See also

GetDepthValues

Definition at line 74 of file HologramGenerator_CPU.cpp.

7.3.2.2 change_depth_quan_GPU()

```
void HologramGenerator::change_depth_quan_GPU ( )  [private]
```

Calculate the value of 'depth_index_gpu_'.

See also

GetDepthValues

Definition at line 211 of file HologramGenerator_GPU.cpp.

7.3.2.3 GetDepthValues()

```
void HologramGenerator::GetDepthValues ( )  [private]
```

Initialize 'dstep_' & 'dlevel_' variables. If FLAG_CHANGE_DEPTH_QUANTIZATION == 1, recalculate 'depth_↩ index_' variable.

See also

change_depth_quan_CPU, change_depth_quan_GPU

Definition at line 391 of file HologramGenerator.cpp.

7.4 Transform

- void HologramGenerator::TransformViewingWindow ()

  Transform target object to reflect the system configuration of holographic display.

7.4.1 Detailed Description

7.4.2 Function Documentation

7.4.2.1 TransformViewingWindow()

```
void HologramGenerator::TransformViewingWindow ( )  [private]
```

Calculate 'dlevel_transform_' variable by using 'field_lens' & 'dlevel_'.

Definition at line 423 of file HologramGenerator.cpp.

7.5 Generation Hologram

Functions

- void HologramGenerator::GenerateHologram ()

  Generate a hologram, main funtion.

- void HologramGenerator::Calc_Holo_by_Depth (int frame)

  Generate a hologram.
- void HologramGenerator::Calc_Holo_CPU (int frame)

  Main method for generating a hologram on the CPU.
- void HologramGenerator::Calc_Holo_GPU (int frame)

  Main method for generating a hologram on the GPU.
- void HologramGenerator::Propagation_AngularSpectrum_CPU (Complex *input_u, double propagation_dist)

  Angular spectrum propagation method for CPU implementation.
- void HologramGenerator::Propagation_AngularSpectrum_GPU (cufftDoubleComplex *input_u, double propagation_dist)

  Angular spectrum propagation method for GPU implementation.

7.5.1 Detailed Description

7.5.2 Function Documentation

7.5.2.1 Calc_Holo_by_Depth()

```
void HologramGenerator::Calc_Holo_by_Depth (
            int frame )  [private]
```

Parameters

frame	: the frame number of the image.

See also

Calc_Holo_CPU, Calc_Holo_GPU

Definition at line 442 of file HologramGenerator.cpp.

7.5.2.2 Calc_Holo_CPU()

```
void HologramGenerator::Calc_Holo_CPU (
            int frame )  [private]
```

For each depth level,

1. find each depth plane of the input image.
2. apply carrier phase delay.
3. propagate it to the hologram plan.
4. accumulate the result of each propagation.

The final result is accumulated in the variable 'U_complex_'.

Parameters

frame	: the frame number of the image.

See also

Calc_Holo_by_Depth, Propagation_AngularSpectrum_CPU

Definition at line 117 of file HologramGenerator_CPU.cpp.

7.5.2.3 Calc_Holo_GPU()

```
void HologramGenerator::Calc_Holo_GPU (
            int frame )  [private]
```

For each depth level,

1. find each depth plane of the input image.
2. apply carrier phase delay.
3. propagate it to the hologram plan.
4. accumulate the result of each propagation.

It uses CUDA kernels, cudaDepthHoloKernel & cudaPropagation_AngularSpKernel.
The final result is accumulated in the variable 'u_complex_gpu_'.

Parameters

frame	: the frame number of the image.

See also

Calc_Holo_by_Depth, Propagation_AngularSpectrum_GPU

Definition at line 246 of file HologramGenerator_GPU.cpp.

7.5.2.4 GenerateHologram()

```
void HologramGenerator::GenerateHologram ( )
```

For each frame,

1. Read image depth data.
2. Compute the physical distance of depth map.
3. Transform target object to reflect the system configuration of holographic display.
4. Generate a hologram.
5. Encode the generated hologram.
6. Write the hologram to a image.

See also

ReadImageDepth, GetDepthValues, TransformViewingWindow, Calc_Holo_by_Depth, Encoding_↩ Symmetrization, Write_Result_image

Definition at line 261 of file HologramGenerator.cpp.

7.5.2.5 Propagation_AngularSpectrum_CPU()

```
void HologramGenerator::Propagation_AngularSpectrum_CPU (
            Complex * input_u,
            double propagation_dist )  [private]
```

The propagation results of all depth levels are accumulated in the variable 'U_complex_'.

Parameters

input_u	: each depth plane data.
propagation_dist	: the distance from the object to the hologram plane.

See also

Calc_Holo_by_Depth, Calc_Holo_CPU, fftwShift

Definition at line 186 of file HologramGenerator_CPU.cpp.

7.5.2.6 Propagation_AngularSpectrum_GPU()

```
void HologramGenerator::Propagation_AngularSpectrum_GPU (
            cufftDoubleComplex * input_u,
            double propagation_dist )  [private]
```

The propagation results of all depth levels are accumulated in the variable 'u_complex_gpu_'.

Parameters

input_u	: each depth plane data.
propagation_dist	: the distance from the object to the hologram plane.

See also

Calc_Holo_by_Depth, Calc_Holo_GPU, cudaFFT

Definition at line 311 of file HologramGenerator_GPU.cpp.

7.6 Encoding

- void HologramGenerator::Encoding_Symmetrization (ivec2 sig_location)

  Encode the CGH according to a signal location parameter.
- void HologramGenerator::encoding_CPU (int cropx1, int cropx2, int cropy1, int cropy2, ivec2 sig_location)

  Encode the CGH according to a signal location parameter on the CPU.
- void HologramGenerator::encoding_GPU (int cropx1, int cropx2, int cropy1, int cropy2, ivec2 sig_location)

  Encode the CGH according to a signal location parameter on GPU.

7.6.1 Detailed Description

7.6.2 Function Documentation

7.6.2.1 encoding_CPU()

```
void HologramGenerator::encoding_CPU (
            int cropx1,
            int cropx2,
            int cropy1,
            int cropy2,
            ivec2 sig_location )  [private]
```

The CPU variable, u255_fringe_ on CPU has the final result.

Parameters

cropx1	: the start x-coordinate to crop.
cropx2	: the end x-coordinate to crop.
cropy1	: the start y-coordinate to crop.
cropy2	: the end y-coordinate to crop.
sig_location	: ivec2 type, sig_location[0]: upper or lower half, sig_location[1]:left or right half.

See also

Encoding_Symmetrization, fftwShift

Definition at line 231 of file HologramGenerator_CPU.cpp.

7.6.2.2 encoding_GPU()

```
void HologramGenerator::encoding_GPU (
            int cropx1,
            int cropx2,
```

```
            int cropy1,
            int cropy2,
            ivec2 sig_location )  [private]
```

The variable, u255_fringe_ has the final result.

Parameters

cropx1	: the start x-coordinate to crop.
cropx2	: the end x-coordinate to crop.
cropy1	: the start y-coordinate to crop.
cropy2	: the end y-coordinate to crop.
sig_location	: ivec2 type, sig_location[0]: upper or lower half, sig_location[1]:left or right half.

See also

Encoding_Symmetrization, cudaCropFringe, cudaFFT, cudaGetFringe

Definition at line 338 of file HologramGenerator_GPU.cpp.

7.6.2.3 Encoding_Symmetrization()

```
void HologramGenerator::Encoding_Symmetrization (
            ivec2 sig_location )  [private]
```

Parameters

sig_location	: ivec2 type, sig_location[0]: upper or lower half, sig_location[1]:left or right half.

See also

encoding_CPU, encoding_GPU

Definition at line 481 of file HologramGenerator.cpp.

7.7 Writing Image

- void HologramGenerator::Write_Result_image (int ftr)

  Write the result image.

7.7.1 Detailed Description

7.7.2 Function Documentation

7.7.2.1 Write_Result_image()

```
void HologramGenerator::Write_Result_image (
            int ftr )  [private]
```

Parameters

ftr	: the frame number of the image.

Definition at line 528 of file HologramGenerator.cpp.

7.8 Reconstruction

Functions

- void HologramGenerator::ReconstructImage ()

  It is a testing function used for the reconstruction.

- void HologramGenerator::Reconstruction (fftw_complex ∗in, fftw_complex ∗out)

  It is a testing function used for the reconstruction.

- void HologramGenerator::Test_Propagation_to_Eye_Pupil (fftw_complex ∗in, fftw_complex ∗out)

  It is a testing function used for the reconstruction.

- void HologramGenerator::Write_Simulation_image (int num, double val)

  It is a testing function used for the reconstruction.

- void HologramGenerator::circshift (Complex ∗in, Complex ∗out, int shift_x, int shift_y, int nx, int ny)

  It is a testing function used for the reconstruction.

7.8.1 Detailed Description

7.8.2 Function Documentation

7.8.2.1 circshift()

```
void HologramGenerator::circshift (
            Complex * in,
            Complex * out,
            int shift_x,
            int shift_y,
            int nx,
            int ny )  [private]
```

Definition at line 663 of file HologramGenerator_CPU.cpp.

7.8.2.2 ReconstructImage()

```
void HologramGenerator::ReconstructImage ( )
```

Definition at line 415 of file HologramGenerator_CPU.cpp.

7.8.2.3 Reconstruction()

```
void HologramGenerator::Reconstruction (
            fftw_complex * in,
            fftw_complex * out )  [private]
```

Definition at line 544 of file HologramGenerator_CPU.cpp.

7.8.2.4 Test_Propagation_to_Eye_Pupil()

```
void HologramGenerator::Test_Propagation_to_Eye_Pupil (
            fftw_complex * in,
            fftw_complex * out )  [private]
```

Definition at line 494 of file HologramGenerator_CPU.cpp.

7.8.2.5 Write_Simulation_image()

```
void HologramGenerator::Write_Simulation_image (
            int num,
            double val )  [private]
```

Definition at line 619 of file HologramGenerator_CPU.cpp.

7.9 GPU Modules

Functions

- void cudaFFT (CUstream_st *stream, int nx, int ny, cufftDoubleComplex *in_filed, cufftDoubleComplex *output_field, int direction, bool bNormailized=false)

  Convert data from the spatial domain to the frequency domain using 2D FFT on GPU.
- void cudaCropFringe (CUstream_st *stream, int nx, int ny, cufftDoubleComplex *in_field, cufftDoubleComplex *out_field, int cropx1, int cropx2, int cropy1, int cropy2)

  Crop input data according to x, y coordinates on GPU.
- void cudaDepthHoloKernel (CUstream_st *stream, int pnx, int pny, cufftDoubleComplex *u_o_gpu_, unsigned char *img_src_gpu_, unsigned char *dimg_src_gpu_, double *depth_index_gpu_, int dtr, double rand_phase_val_a, double rand_phase_val_b, double carrier_phase_delay_a, double carrier_phase_delay_b, int flag_change_depth_quan, unsigned int default_depth_quan)

  Find each depth plane of the input image and apply carrier phase delay to it on GPU.
- void cudaPropagation_AngularSpKernel (CUstream_st *stream_, int pnx, int pny, cufftDoubleComplex *input_d, cufftDoubleComplex *u_complex, double ppx, double ppy, double ssx, double ssy, double lambda, double params_k, double propagation_dist)

  Angular spectrum propagation method for GPU implementation.
- void cudaGetFringe (CUstream_st *stream, int pnx, int pny, cufftDoubleComplex *in_field, cufftDoubleComplex *out_field, int sig_locationx, int sig_locationy, double ssx, double ssy, double ppx, double ppy, double PI)

  Encode the CGH according to a signal location parameter on the GPU.
- void cudaChangeDepthQuanKernel (CUstream_st *stream_, int pnx, int pny, double *depth_index_gpu, unsigned char *dimg_src_gpu, int dtr, double d1, double d2, double params_num_of_depth, double params_far_depthmap, double params_near_depthmap)

  Quantize depth map on the GPU, only when the number of depth quantization is not the default value (i.e. FLAG_CHANGE_DEPTH_QUANTIZATION == 1).

7.9.1 Detailed Description

7.9.2 Function Documentation

7.9.2.1 cudaChangeDepthQuanKernel()

```
void cudaChangeDepthQuanKernel (
            CUstream_st * stream_,
            int pnx,
            int pny,
            double * depth_index_gpu,
            unsigned char * dimg_src_gpu,
            int dtr,
            double d1,
            double d2,
            double params_num_of_depth,
            double params_far_depthmap,
            double params_near_depthmap )
```

Calculate the value of 'depth_index_gpu_'.

Parameters

stream	: CUDA Stream
pnx	: the number of column of the input data
pny	: the number of row of the input data
depth_index_gpu	: output variable
dimg_src_gpu	: input depth map data
dtr	: the current working depth level
d1	: the starting physical point of each depth level
d2	: the ending physical point of each depth level
params_num_of_depth	: the number of depth level
params_far_depthmap	: NEAR_OF_DEPTH_MAP at config file
params_near_depthmap	: FAR_OF_DEPTH_MAP at config file

See also

change_depth_quan_GPU

7.9.2.2 cudaCropFringe()

```
void cudaCropFringe (
            CUstream_st * stream,
            int nx,
            int ny,
            cufftDoubleComplex * in_field,
            cufftDoubleComplex * out_field,
            int cropx1,
            int cropx2,
            int cropy1,
            int cropy2 )
```

call CUDA Kernel - cropFringe.

Parameters

stream	: CUDA Stream
nx	: the number of column of the input data
ny	: the number of row of the input data
in_field	: input complex data variable
output_field	: output complex data variable
cropx1	: the start x-coordinate to crop.
cropx2	: the end x-coordinate to crop.
cropy1	: the start y-coordinate to crop.
cropy2	: the end y-coordinate to crop.

See also

encoding_GPU

7.9.2.3 cudaDepthHoloKernel()

```
void cudaDepthHoloKernel (
            CUstream_st * stream,
            int pnx,
            int pny,
            cufftDoubleComplex * u_o_gpu_,
            unsigned char * img_src_gpu_,
            unsigned char * dimg_src_gpu_,
            double * depth_index_gpu_,
            int dtr,
            double rand_phase_val_a,
            double rand_phase_val_b,
            double carrier_phase_delay_a,
            double carrier_phase_delay_b,
            int flag_change_depth_quan,
            unsigned int default_depth_quan )
```

call CUDA Kernel - depth_sources_kernel.

Parameters

stream	: CUDA Stream
nx	: the number of column of the input data
ny	: the number of row of the input data
*u_o_gpu_*	: output variable
*img_src_gpu_*	: input image data
*dimg_src_gpu_*	: input depth map data
*depth_index_gpu_*	: input quantized depth map data
dtr	: current working depth level
rand_phase_val_a	: the real part of the random phase value
rand_phase_val_b	: the imaginary part of the random phase value
carrier_phase_delay_a	: the real part of the carrier phase delay
carrier_phase_delay_b	: the imaginary part of the carrier phase delay
flag_change_depth_quan	: if true, change the depth quantization from the default value.
default_depth_quan	: default value of the depth quantization - 256

See also

Calc_Holo_GPU

7.9.2.4 cudaFFT()

```
void cudaFFT (
            CUstream_st * stream,
            int nx,
            int ny,
            cufftDoubleComplex * in_filed,
            cufftDoubleComplex * output_field,
            int direction,
            bool bNormailized = false )
```

call CUDA Kernel - fftShift and CUFFT Library.

Parameters

stream	: CUDA Stream
nx	: the number of column of the input data
ny	: the number of row of the input data
in_field	: input complex data variable
output_field	: output complex data variable
direction	: If direction == -1, forward FFT, if type == 1, inverse FFT.
bNomarlized	: If bNomarlized == true, normalize the result after FFT.

See also

Propagation_AngularSpectrum_GPU, encoding_GPU

7.9.2.5 cudaGetFringe()

```
void cudaGetFringe (
            CUstream_st * stream,
            int pnx,
            int pny,
            cufftDoubleComplex * in_field,
            cufftDoubleComplex * out_field,
            int sig_locationx,
            int sig_locationy,
            double ssx,
            double ssy,
            double ppx,
            double ppy,
            double PI )
```

The variable, u255_fringe_ has the final result.

Parameters

stream	: CUDA Stream
pnx	: the number of column of the input data
pny	: the number of row of the input data

Parameters

in_field	: input data
out_field	: output data
sig_locationx	: signal location of x-axis, left or right half
sig_locationy	: signal location of y-axis, upper or lower half
ssx	: pnx ∗ ppx
ssy	: pny ∗ ppy
ppx	: pixel pitch of x-axis
ppy	: pixel pitch of y-axis
PI	: Pi

See also

encoding_GPU

7.9.2.6 cudaPropagation_AngularSpKernel()

```
void cudaPropagation_AngularSpKernel (
            CUstream_st * stream_,
            int pnx,
            int pny,
            cufftDoubleComplex * input_d,
            cufftDoubleComplex * u_complex,
            double ppx,
            double ppy,
            double ssx,
            double ssy,
            double lambda,
            double params_k,
            double propagation_dist )
```

The propagation results of all depth levels are accumulated in the variable 'u_complex_gpu_'.

Parameters

stream	: CUDA Stream
pnx	: the number of column of the input data
pny	: the number of row of the input data
input_d	: input data
u_complex	: output data
ppx	: pixel pitch of x-axis
ppy	: pixel pitch of y-axis
ssx	: pnx ∗ ppx
ssy	: pny ∗ ppy
lambda	: wavelength
params_k	: 2 ∗ PI / lambda
propagation_dist	: the distance from the object to the hologram plane

See also

Propagation_AngularSpectrum_GPU

Chapter 8

Namespace Documentation

8.1 graphics Namespace Reference

Classes

- struct ivec2

  structure for 2-dimensional integer vector and its arithmetic.
- struct ivec3

  structure for 3-dimensional integer vector and its arithmetic.
- struct ivec4

  structure for 4-dimensional integer vector and its arithmetic.
- struct vec2

  structure for 2-dimensional real type vector and its arithmetic.
- struct vec3

  structure for 3-dimensional real type vector and its arithmetic.
- struct vec4

  structure for 4-dimensional real type vector and its arithmetic.

Functions

- void set_u_epsilon (real a)
- void reset_u_epsilon ()
- void set_zero_epsilon (real a)
- void reset_zero_epsilon ()
- int apx_equal (real x, real y)
- int apx_equal (real x, real y, real eps)
- ivec2 operator+ (const ivec2 &a, const ivec2 &b)
- ivec2 operator+ (int a, const ivec2 &b)
- ivec2 operator+ (const ivec2 &a, int b)
- ivec2 operator- (const ivec2 &a, const ivec2 &b)
- ivec2 operator- (int a, const ivec2 &b)
- ivec2 operator- (const ivec2 &a, int b)
- ivec2 operator∗ (const ivec2 &a, const ivec2 &b)
- ivec2 operator∗ (int a, const ivec2 &b)
- ivec2 operator∗ (const ivec2 &a, int b)
- ivec2 operator+= (ivec2 &a, const ivec2 &b)

- ivec2 operator+= (ivec2 &a, int b)
- ivec2 operator-= (ivec2 &a, const ivec2 &b)
- ivec2 operator-= (ivec2 &a, int b)
- ivec2 operator*= (ivec2 &a, const ivec2 &b)
- ivec2 operator*= (ivec2 &a, int b)
- int operator== (const ivec2 &a, const ivec2 &b)
- int operator== (int a, const ivec2 &b)
- int operator== (const ivec2 &a, int b)
- int operator< (const ivec2 &a, const ivec2 &b)
- int operator< (int a, const ivec2 &b)
- int operator< (const ivec2 &a, int b)
- int operator<= (const ivec2 &a, const ivec2 &b)
- int operator<= (int a, const ivec2 &b)
- int operator<= (const ivec2 &a, int b)
- int operator> (const ivec2 &a, const ivec2 &b)
- int operator> (int a, const ivec2 &b)
- int operator> (const ivec2 &a, int b)
- int operator>= (const ivec2 &a, const ivec2 &b)
- int operator>= (int a, const ivec2 &b)
- int operator>= (const ivec2 &a, int b)
- int operator!= (const ivec2 &a, const ivec2 &b)
- ivec2 operator- (const ivec2 &a)
- ivec3 operator+ (const ivec3 &a, const ivec3 &b)
- ivec3 operator+ (int a, const ivec3 &b)
- ivec3 operator+ (const ivec3 &a, int b)
- ivec3 operator- (const ivec3 &a, const ivec3 &b)
- ivec3 operator- (int a, const ivec3 &b)
- ivec3 operator- (const ivec3 &a, int b)
- ivec3 operator* (const ivec3 &a, const ivec3 &b)
- ivec3 operator* (int a, const ivec3 &b)
- ivec3 operator* (const ivec3 &a, int b)
- ivec3 operator+= (ivec3 &a, const ivec3 &b)
- ivec3 operator+= (ivec3 &a, int b)
- ivec3 operator-= (ivec3 &a, const ivec3 &b)
- ivec3 operator-= (ivec3 &a, int b)
- ivec3 operator*= (ivec3 &a, const ivec3 &b)
- ivec3 operator*= (ivec3 &a, int b)
- int operator== (const ivec3 &a, const ivec3 &b)
- int operator== (int a, const ivec3 &b)
- int operator== (const ivec3 &a, int b)
- int operator< (const ivec3 &a, const ivec3 &b)
- int operator< (int a, const ivec3 &b)
- int operator< (const ivec3 &a, int b)
- int operator<= (const ivec3 &a, const ivec3 &b)
- int operator<= (int a, const ivec3 &b)
- int operator<= (const ivec3 &a, int b)
- int operator> (const ivec3 &a, const ivec3 &b)
- int operator> (int a, const ivec3 &b)
- int operator> (const ivec3 &a, int b)
- int operator>= (const ivec3 &a, const ivec3 &b)
- int operator>= (int a, const ivec3 &b)
- int operator>= (const ivec3 &a, int b)
- int operator!= (const ivec3 &a, const ivec3 &b)
- ivec3 operator- (const ivec3 &a)
- ivec4 operator+ (const ivec4 &a, const ivec4 &b)

- ivec4 operator+ (int a, const ivec4 &b)
- ivec4 operator+ (const ivec4 &a, int b)
- ivec4 operator- (const ivec4 &a, const ivec4 &b)
- ivec4 operator- (int a, const ivec4 &b)
- ivec4 operator- (const ivec4 &a, int b)
- ivec4 operator∗ (const ivec4 &a, const ivec4 &b)
- ivec4 operator∗ (int a, const ivec4 &b)
- ivec4 operator∗ (const ivec4 &a, int b)
- ivec4 operator+= (ivec4 &a, const ivec4 &b)
- ivec4 operator+= (ivec4 &a, int b)
- ivec4 operator-= (ivec4 &a, const ivec4 &b)
- ivec4 operator-= (ivec4 &a, int b)
- ivec4 operator∗= (ivec4 &a, const ivec4 &b)
- ivec4 operator∗= (ivec4 &a, int b)
- int operator== (const ivec4 &a, const ivec4 &b)
- int operator== (int a, const ivec4 &b)
- int operator== (const ivec4 &a, int b)
- int operator< (const ivec4 &a, const ivec4 &b)
- int operator< (int a, const ivec4 &b)
- int operator< (const ivec4 &a, int b)
- int operator<= (const ivec4 &a, const ivec4 &b)
- int operator<= (int a, const ivec4 &b)
- int operator<= (const ivec4 &a, int b)
- int operator> (const ivec4 &a, const ivec4 &b)
- int operator> (int a, const ivec4 &b)
- int operator> (const ivec4 &a, int b)
- int operator>= (const ivec4 &a, const ivec4 &b)
- int operator!= (const ivec4 &a, const ivec4 &b)
- int operator>= (int a, const ivec4 &b)
- int operator>= (const ivec4 &a, int b)
- ivec4 operator- (const ivec4 &a)
- void store (FILE ∗fp, const vec2 &v)
- int scan (FILE ∗fp, const vec2 &v)
- int apx_equal (const vec2 &a, const vec2 &b)
- int apx_equal (const vec2 &a, const vec2 &b, real eps)
- void store (FILE ∗fp, const vec3 &v)
- int scan (FILE ∗fp, const vec3 &v)
- int apx_equal (const vec3 &a, const vec3 &b)
- int apx_equal (const vec3 &a, const vec3 &b, real eps)
- void store (FILE ∗fp, const vec4 &v)
- int scan (FILE ∗fp, const vec4 &v)
- int apx_equal (const vec4 &a, const vec4 &b)
- int apx_equal (const vec4 &a, const vec4 &b, real eps)
- vec3 cross (const vec3 &a, const vec3 &b)
- vec2 operator+ (const vec2 &a, const vec2 &b)
- vec2 operator+ (real a, const vec2 &b)
- vec2 operator+ (const vec2 &a, real b)
- vec2 operator- (const vec2 &a, const vec2 &b)
- vec2 operator- (real a, const vec2 &b)
- vec2 operator- (const vec2 &a, real b)
- vec2 operator∗ (const vec2 &a, const vec2 &b)
- vec2 operator∗ (real a, const vec2 &b)
- vec2 operator∗ (const vec2 &a, real b)
- vec2 operator/ (const vec2 &a, const vec2 &b)
- vec2 operator/ (real a, const vec2 &b)

- vec2 operator/ (const vec2 &a, real b)
- vec2 operator+= (vec2 &a, const vec2 &b)
- vec2 operator+= (vec2 &a, real b)
- vec2 operator-= (vec2 &a, const vec2 &b)
- vec2 operator-= (vec2 &a, real b)
- vec2 operator*= (vec2 &a, const vec2 &b)
- vec2 operator*= (vec2 &a, real b)
- vec2 operator/= (vec2 &a, const vec2 &b)
- vec2 operator/= (vec2 &a, real b)
- int operator== (const vec2 &a, const vec2 &b)
- int operator== (real a, const vec2 &b)
- int operator== (const vec2 &a, real b)
- int operator< (const vec2 &a, const vec2 &b)
- int operator< (real a, const vec2 &b)
- int operator< (const vec2 &a, real b)
- int operator<= (const vec2 &a, const vec2 &b)
- int operator<= (real a, const vec2 &b)
- int operator<= (const vec2 &a, real b)
- int operator> (const vec2 &a, const vec2 &b)
- int operator> (real a, const vec2 &b)
- int operator> (const vec2 &a, real b)
- int operator>= (const vec2 &a, const vec2 &b)
- int operator>= (real a, const vec2 &b)
- int operator>= (const vec2 &a, real b)
- vec2 operator- (const vec2 &a)
- real sum (const vec2 &a)
- real inner (const vec2 &a, const vec2 &b)
- real norm (const vec2 &a)
- real squaredNorm (const vec2 &a)
- vec2 unit (const vec2 &a)
- real angle (const vec2 &a, const vec2 &b)
- vec2 proj (const vec2 &axis, const vec2 &a)
- vec2 absolute (const vec2 &val)
- vec3 operator+ (const vec3 &a, const vec3 &b)
- vec3 operator+ (real a, const vec3 &b)
- vec3 operator+ (const vec3 &a, real b)
- vec3 operator- (const vec3 &a, const vec3 &b)
- vec3 operator- (real a, const vec3 &b)
- vec3 operator- (const vec3 &a, real b)
- vec3 operator* (const vec3 &a, const vec3 &b)
- vec3 operator* (real a, const vec3 &b)
- vec3 operator* (const vec3 &a, real b)
- vec3 operator/ (const vec3 &a, const vec3 &b)
- vec3 operator/ (real a, const vec3 &b)
- vec3 operator/ (const vec3 &a, real b)
- vec3 operator+= (vec3 &a, const vec3 &b)
- vec3 operator+= (vec3 &a, real b)
- vec3 operator-= (vec3 &a, const vec3 &b)
- vec3 operator-= (vec3 &a, real b)
- vec3 operator*= (vec3 &a, const vec3 &b)
- vec3 operator*= (vec3 &a, real b)
- vec3 operator/= (vec3 &a, const vec3 &b)
- vec3 operator/= (vec3 &a, real b)
- int operator== (const vec3 &a, const vec3 &b)
- int operator== (real a, const vec3 &b)

- int operator== (const vec3 &a, real b)
- int operator< (const vec3 &a, const vec3 &b)
- int operator< (real a, const vec3 &b)
- int operator< (const vec3 &a, real b)
- int operator<= (const vec3 &a, const vec3 &b)
- int operator<= (real a, const vec3 &b)
- int operator<= (const vec3 &a, real b)
- int operator> (const vec3 &a, const vec3 &b)
- int operator> (real a, const vec3 &b)
- int operator> (const vec3 &a, real b)
- int operator>= (const vec3 &a, const vec3 &b)
- int operator>= (real a, const vec3 &b)
- int operator>= (const vec3 &a, real b)
- vec3 operator- (const vec3 &a)
- vec3 absolute (const vec3 &val)
- real sum (const vec3 &a)
- real inner (const vec3 &a, const vec3 &b)
- real squaredNorm (const vec3 &a)
- real norm (const vec3 &a)
- vec3 unit (const vec3 &a)
- real angle (const vec3 &a, const vec3 &b)
- vec3 proj (const vec3 &axis, const vec3 &a)
- vec4 operator+ (const vec4 &a, const vec4 &b)
- vec4 operator+ (real a, const vec4 &b)
- vec4 operator+ (const vec4 &a, real b)
- vec4 operator- (const vec4 &a, const vec4 &b)
- vec4 operator- (real a, const vec4 &b)
- vec4 operator- (const vec4 &a, real b)
- vec4 operator* (const vec4 &a, const vec4 &b)
- vec4 operator* (real a, const vec4 &b)
- vec4 operator* (const vec4 &a, real b)
- vec4 operator/ (const vec4 &a, const vec4 &b)
- vec4 operator/ (real a, const vec4 &b)
- vec4 operator/ (const vec4 &a, real b)
- vec4 operator+= (vec4 &a, const vec4 &b)
- vec4 operator+= (vec4 &a, real b)
- vec4 operator-= (vec4 &a, const vec4 &b)
- vec4 operator-= (vec4 &a, real b)
- vec4 operator*= (vec4 &a, const vec4 &b)
- vec4 operator*= (vec4 &a, real b)
- vec4 operator/= (vec4 &a, const vec4 &b)
- vec4 operator/= (vec4 &a, real b)
- int operator== (const vec4 &a, const vec4 &b)
- int operator== (real a, const vec4 &b)
- int operator== (const vec4 &a, real b)
- int operator< (const vec4 &a, const vec4 &b)
- int operator< (real a, const vec4 &b)
- int operator< (const vec4 &a, real b)
- int operator<= (const vec4 &a, const vec4 &b)
- int operator<= (real a, const vec4 &b)
- int operator<= (const vec4 &a, real b)
- int operator> (const vec4 &a, const vec4 &b)
- int operator> (real a, const vec4 &b)
- int operator> (const vec4 &a, real b)
- int operator>= (const vec4 &a, const vec4 &b)

- int operator>= (real a, const vec4 &b)
- int operator>= (const vec4 &a, real b)
- vec4 operator- (const vec4 &a)
- vec4 absolute (const vec4 &val)
- real sum (const vec4 &a)
- real inner (const vec4 &a, const vec4 &b)
- real squaredNorm (const vec4 &a)
- real norm (const vec4 &a)
- vec4 unit (const vec4 &a)
- real angle (const vec4 &a, const vec4 &b)
- vec4 proj (const vec4 &axis, const vec4 &a)

Variables

- real epsilon = 1.0e-8
- real user_epsilon = 1.0e-8
- real intersection_epsilon = 1e-6
- real sqrt_epsilon = 1.490116119385000000e-8
- real unset_value = -1.23432101234321e+308
- real zero_tolerance = 1.0e-12
- real angle_tolerance = M_PI/180.0
- real zero_epsilon = 1.0e-12
- real save_zero_epsilon = 1.0e-12

8.1.1 Function Documentation

8.1.1.1 absolute() [1/3]

```
vec2 graphics::absolute (
            const vec2 & val )  [inline]
```

Definition at line 429 of file vec.h.

8.1.1.2 absolute() [2/3]

```
vec3 graphics::absolute (
            const vec3 & val )  [inline]
```

Definition at line 793 of file vec.h.

8.1.1.3 absolute() [3/3]

```
vec4 graphics::absolute (
            const vec4 & val )  [inline]
```

Definition at line 1185 of file vec.h.

8.1.1.4 angle() [1/3]

```
real graphics::angle (
            const vec2 & a,
            const vec2 & b )  [inline]
```

Definition at line 412 of file vec.h.

8.1.1.5 angle() [2/3]

```
real graphics::angle (
            const vec3 & a,
            const vec3 & b )  [inline]
```

Definition at line 838 of file vec.h.

8.1.1.6 angle() [3/3]

```
real graphics::angle (
            const vec4 & a,
            const vec4 & b )  [inline]
```

Definition at line 1229 of file vec.h.

8.1.1.7 apx_equal() [1/8]

```
int graphics::apx_equal (
            real x,
            real y )
```

Definition at line 45 of file epsilon.cpp.

8.1.1.8 apx_equal() [2/8]

```
int graphics::apx_equal (
            real x,
            real y,
            real eps )
```

Definition at line 61 of file epsilon.cpp.

8.1.1.9 apx_equal() [3/8]

```
int graphics::apx_equal (
            const vec2 & a,
            const vec2 & b )
```

Definition at line 101 of file vec.cpp.

8.1.1.10 apx_equal() [4/8]

```
int graphics::apx_equal (
            const vec2 & a,
            const vec2 & b,
            real eps )
```

Definition at line 112 of file vec.cpp.

8.1.1.11 apx_equal() [5/8]

```
int graphics::apx_equal (
            const vec3 & a,
            const vec3 & b )
```

Definition at line 318 of file vec.cpp.

8.1.1.12 apx_equal() [6/8]

```
int graphics::apx_equal (
            const vec3 & a,
            const vec3 & b,
            real eps )
```

Definition at line 329 of file vec.cpp.

8.1.1.13 apx_equal() [7/8]

```
int graphics::apx_equal (
            const vec4 & a,
            const vec4 & b )
```

Definition at line 377 of file vec.cpp.

8.1.1.14 apx_equal() [8/8]

```
int graphics::apx_equal (
            const vec4 & a,
            const vec4 & b,
            real eps )
```

Definition at line 388 of file vec.cpp.

8.1.1.15 cross()

```
vec3 graphics::cross (
            const vec3 & a,
            const vec3 & b )
```

Definition at line 399 of file vec.cpp.

8.1.1.16 inner() [1/3]

```
real graphics::inner (
            const vec2 & a,
            const vec2 & b )  [inline]
```

Definition at line 388 of file vec.h.

8.1.1.17 inner() [2/3]

```
real graphics::inner (
            const vec3 & a,
            const vec3 & b )  [inline]
```

Definition at line 814 of file vec.h.

8.1.1.18 inner() [3/3]

```
real graphics::inner (
            const vec4 & a,
            const vec4 & b )  [inline]
```

Definition at line 1207 of file vec.h.

8.1.1.19 norm() [1/3]

```
real graphics::norm (
            const vec2 & a )  [inline]
```

Definition at line 394 of file vec.h.

8.1.1.20 norm() [2/3]

```
real graphics::norm (
            const vec3 & a )  [inline]
```

Definition at line 824 of file vec.h.

8.1.1.21 norm() [3/3]

```
real graphics::norm (
            const vec4 & a )  [inline]
```

Definition at line 1215 of file vec.h.

8.1.1.22 operator"!=() [1/3]

```
int graphics::operator!= (
            const ivec2 & a,
            const ivec2 & b )  [inline]
```

Definition at line 313 of file ivec.h.

8.1.1.23 operator"!=() [2/3]

```
int graphics::operator!= (
            const ivec3 & a,
            const ivec3 & b )  [inline]
```

Definition at line 625 of file ivec.h.

8.1.1.24 operator"!=() [3/3]

```
int graphics::operator!= (
            const ivec4 & a,
            const ivec4 & b )  [inline]
```

Definition at line 928 of file ivec.h.

8.1.1.25 operator*() [1/18]

```
ivec2 graphics::operator* (
            const ivec2 & a,
            const ivec2 & b )  [inline]
```

Definition at line 100 of file ivec.h.

8.1.1.26 operator*() [2/18]

```
ivec2 graphics::operator* (
            int a,
            const ivec2 & b )  [inline]
```

Definition at line 107 of file ivec.h.

8.1.1.27 operator*() [3/18]

```
ivec2 graphics::operator* (
            const ivec2 & a,
            int b )  [inline]
```

Definition at line 114 of file ivec.h.

8.1.1.28 operator*() [4/18]

```
vec2 graphics::operator* (
            const vec2 & a,
            const vec2 & b )  [inline]
```

Definition at line 153 of file vec.h.

8.1.1.29 operator*() [5/18]

```
vec2 graphics::operator* (
            real a,
            const vec2 & b )  [inline]
```

Definition at line 160 of file vec.h.

8.1.1.30 operator*() [6/18]

```
vec2 graphics::operator* (
            const vec2 & a,
            real b )  [inline]
```

Definition at line 167 of file vec.h.

8.1.1.31 operator*() [7/18]

```
ivec3 graphics::operator* (
            const ivec3 & a,
            const ivec3 & b )  [inline]
```

Definition at line 412 of file ivec.h.

8.1.1.32 operator*() [8/18]

```
ivec3 graphics::operator* (
            int a,
            const ivec3 & b )  [inline]
```

Definition at line 419 of file ivec.h.

8.1.1.33 operator*() [9/18]

```
ivec3 graphics::operator* (
            const ivec3 & a,
            int b )  [inline]
```

Definition at line 426 of file ivec.h.

8.1.1.34 operator*() [10/18]

```
vec3 graphics::operator* (
            const vec3 & a,
            const vec3 & b )  [inline]
```

Definition at line 572 of file vec.h.

8.1.1.35 operator*() [11/18]

```
vec3 graphics::operator* (
            real a,
            const vec3 & b )  [inline]
```

Definition at line 579 of file vec.h.

8.1.1.36 operator*() [12/18]

```
vec3 graphics::operator* (
            const vec3 & a,
            real b )  [inline]
```

Definition at line 586 of file vec.h.

8.1.1.37 operator*() [13/18]

```
ivec4 graphics::operator* (
            const ivec4 & a,
            const ivec4 & b )  [inline]
```

Definition at line 729 of file ivec.h.

8.1.1.38 operator*() [14/18]

```
ivec4 graphics::operator* (
            int a,
            const ivec4 & b )  [inline]
```

Definition at line 736 of file ivec.h.

8.1.1.39 operator*() [15/18]

```
ivec4 graphics::operator* (
            const ivec4 & a,
            int b )  [inline]
```

Definition at line 743 of file ivec.h.

8.1.1.40 operator*() [16/18]

```
vec4 graphics::operator* (
            const vec4 & a,
            const vec4 & b )  [inline]
```

Definition at line 962 of file vec.h.

8.1.1.41 operator*() [17/18]

```
vec4 graphics::operator* (
            real a,
            const vec4 & b )  [inline]
```

Definition at line 969 of file vec.h.

8.1.1.42 operator*() [18/18]

```
vec4 graphics::operator* (
            const vec4 & a,
            real b )  [inline]
```

Definition at line 976 of file vec.h.

8.1.1.43 operator*=() [1/12]

```
ivec2 graphics::operator*= (
            ivec2 & a,
            const ivec2 & b )  [inline]
```

Definition at line 173 of file ivec.h.

8.1.1.44 operator*=() [2/12]

```
ivec2 graphics::operator*= (
            ivec2 & a,
            int b )  [inline]
```

Definition at line 178 of file ivec.h.

8.1.1.45 operator*=() [3/12]

```
vec2 graphics::operator*= (
            vec2 & a,
            const vec2 & b )  [inline]
```

Definition at line 226 of file vec.h.

8.1.1.46 operator*=() [4/12]

```
vec2 graphics::operator*= (
            vec2 & a,
            real b )  [inline]
```

Definition at line 231 of file vec.h.

8.1.1.47 operator*=() [5/12]

```
ivec3 graphics::operator*= (
            ivec3 & a,
            const ivec3 & b )  [inline]
```

Definition at line 485 of file ivec.h.

8.1.1.48 operator*=() [6/12]

```
ivec3 graphics::operator*= (
            ivec3 & a,
            int b )  [inline]
```

Definition at line 490 of file ivec.h.

8.1.1.49 operator*=() [7/12]

```
vec3 graphics::operator*= (
            vec3 & a,
            const vec3 & b )  [inline]
```

Definition at line 643 of file vec.h.

8.1.1.50 operator*=() [8/12]

```
vec3 graphics::operator*= (
            vec3 & a,
            real b )  [inline]
```

Definition at line 648 of file vec.h.

8.1.1.51 operator*=() [9/12]

```
ivec4 graphics::operator*= (
            ivec4 & a,
            const ivec4 & b )  [inline]
```

Definition at line 802 of file ivec.h.

8.1.1.52 operator*=() [10/12]

```
ivec4 graphics::operator*= (
            ivec4 & a,
            int b )  [inline]
```

Definition at line 807 of file ivec.h.

8.1.1.53 operator*=() [11/12]

```
vec4 graphics::operator*= (
            vec4 & a,
            const vec4 & b )  [inline]
```

Definition at line 1035 of file vec.h.

8.1.1.54 operator*=() [12/12]

```
vec4 graphics::operator*= (
            vec4 & a,
            real b )  [inline]
```

Definition at line 1040 of file vec.h.

8.1.1.55 operator+() [1/18]

```
ivec2 graphics::operator+ (
            const ivec2 & a,
            const ivec2 & b )  [inline]
```

Definition at line 54 of file ivec.h.

8.1.1.56 operator+() [2/18]

```
ivec2 graphics::operator+ (
            int a,
            const ivec2 & b )  [inline]
```

Definition at line 61 of file ivec.h.

8.1.1.57 operator+() [3/18]

```
ivec2 graphics::operator+ (
            const ivec2 & a,
            int b )  [inline]
```

Definition at line 68 of file ivec.h.

8.1.1.58 operator+() [4/18]

```
vec2 graphics::operator+ (
            const vec2 & a,
            const vec2 & b )  [inline]
```

Definition at line 107 of file vec.h.

8.1.1.59 operator+() [5/18]

```
vec2 graphics::operator+ (
            real a,
            const vec2 & b )  [inline]
```

Definition at line 114 of file vec.h.

8.1.1.60 operator+() [6/18]

```
vec2 graphics::operator+ (
            const vec2 & a,
            real b )  [inline]
```

Definition at line 121 of file vec.h.

8.1.1.61 operator+() [7/18]

```
ivec3 graphics::operator+ (
            const ivec3 & a,
            const ivec3 & b )  [inline]
```

Definition at line 366 of file ivec.h.

8.1.1.62 operator+() [8/18]

```
ivec3 graphics::operator+ (
            int a,
            const ivec3 & b )  [inline]
```

Definition at line 373 of file ivec.h.

8.1.1.63 operator+() [9/18]

```
ivec3 graphics::operator+ (
            const ivec3 & a,
            int b )  [inline]
```

Definition at line 380 of file ivec.h.

8.1.1.64 operator+() [10/18]

```
vec3 graphics::operator+ (
            const vec3 & a,
            const vec3 & b )  [inline]
```

Definition at line 526 of file vec.h.

8.1.1.65 operator+() [11/18]

```
vec3 graphics::operator+ (
            real a,
            const vec3 & b )  [inline]
```

Definition at line 533 of file vec.h.

8.1.1.66 operator+() [12/18]

```
vec3 graphics::operator+ (
            const vec3 & a,
            real b )  [inline]
```

Definition at line 540 of file vec.h.

8.1.1.67 operator+() [13/18]

```
ivec4 graphics::operator+ (
            const ivec4 & a,
            const ivec4 & b )  [inline]
```

Definition at line 683 of file ivec.h.

8.1.1.68 operator+() [14/18]

```
ivec4 graphics::operator+ (
            int a,
            const ivec4 & b )  [inline]
```

Definition at line 690 of file ivec.h.

8.1.1.69 operator+() [15/18]

```
ivec4 graphics::operator+ (
            const ivec4 & a,
            int b )  [inline]
```

Definition at line 697 of file ivec.h.

8.1.1.70 operator+() [16/18]

```
vec4 graphics::operator+ (
            const vec4 & a,
            const vec4 & b )  [inline]
```

Definition at line 916 of file vec.h.

8.1.1.71 operator+() [17/18]

```
vec4 graphics::operator+ (
            real a,
            const vec4 & b )  [inline]
```

Definition at line 923 of file vec.h.

8.1.1.72 operator+() [18/18]

```
vec4 graphics::operator+ (
            const vec4 & a,
            real b )  [inline]
```

Definition at line 930 of file vec.h.

8.1.1.73 operator+=() [1/12]

```
ivec2 graphics::operator+= (
            ivec2 & a,
            const ivec2 & b )  [inline]
```

Definition at line 149 of file ivec.h.

8.1.1.74 operator+=() [2/12]

```
ivec2 graphics::operator+= (
            ivec2 & a,
            int b )  [inline]
```

Definition at line 154 of file ivec.h.

8.1.1.75 operator+=() [3/12]

```
vec2 graphics::operator+= (
            vec2 & a,
            const vec2 & b )  [inline]
```

Definition at line 202 of file vec.h.

8.1.1.76 operator+=() [4/12]

```
vec2 graphics::operator+= (
            vec2 & a,
            real b )  [inline]
```

Definition at line 207 of file vec.h.

8.1.1.77 operator+=() [5/12]

```
ivec3 graphics::operator+= (
            ivec3 & a,
            const ivec3 & b )  [inline]
```

Definition at line 461 of file ivec.h.

8.1.1.78 operator+=() [6/12]

```
ivec3 graphics::operator+= (
            ivec3 & a,
            int b )  [inline]
```

Definition at line 466 of file ivec.h.

8.1.1.79 operator+=() [7/12]

```
vec3 graphics::operator+= (
            vec3 & a,
            const vec3 & b )  [inline]
```

Definition at line 619 of file vec.h.

8.1.1.80 operator+=() [8/12]

```
vec3 graphics::operator+= (
            vec3 & a,
            real b )  [inline]
```

Definition at line 624 of file vec.h.

8.1.1.81 operator+=() [9/12]

```
ivec4 graphics::operator+= (
            ivec4 & a,
            const ivec4 & b )  [inline]
```

Definition at line 778 of file ivec.h.

8.1.1.82 operator+=() [10/12]

```
ivec4 graphics::operator+= (
            ivec4 & a,
            int b )  [inline]
```

Definition at line 783 of file ivec.h.

8.1.1.83 operator+=() [11/12]

```
vec4 graphics::operator+= (
            vec4 & a,
            const vec4 & b )  [inline]
```

Definition at line 1011 of file vec.h.

8.1.1.84 operator+=() [12/12]

```
vec4 graphics::operator+= (
            vec4 & a,
            real b )  [inline]
```

Definition at line 1016 of file vec.h.

8.1.1.85 operator-() [1/24]

```
ivec2 graphics::operator- (
            const ivec2 & a,
            const ivec2 & b )  [inline]
```

Definition at line 77 of file ivec.h.

8.1.1.86 operator-() [2/24]

```
ivec2 graphics::operator- (
            int a,
            const ivec2 & b )  [inline]
```

Definition at line 84 of file ivec.h.

8.1.1.87 operator-() [3/24]

```
ivec2 graphics::operator- (
            const ivec2 & a,
            int b )  [inline]
```

Definition at line 91 of file ivec.h.

8.1.1.88 operator-() [4/24]

```
vec2 graphics::operator- (
            const vec2 & a,
            const vec2 & b )  [inline]
```

Definition at line 130 of file vec.h.

8.1.1.89 operator-() [5/24]

```
vec2 graphics::operator- (
            real a,
            const vec2 & b )  [inline]
```

Definition at line 137 of file vec.h.

8.1.1.90 operator-() [6/24]

```
vec2 graphics::operator- (
            const vec2 & a,
            real b )  [inline]
```

Definition at line 144 of file vec.h.

8.1.1.91 operator-() [7/24]

```
ivec2 graphics::operator- (
            const ivec2 & a )  [inline]
```

Definition at line 321 of file ivec.h.

8.1.1.92 operator-() [8/24]

```
vec2 graphics::operator- (
            const vec2 & a )  [inline]
```

Definition at line 369 of file vec.h.

8.1.1.93 operator-() [9/24]

```
ivec3 graphics::operator- (
            const ivec3 & a,
            const ivec3 & b )  [inline]
```

Definition at line 389 of file ivec.h.

8.1.1.94 operator-() [10/24]

```
ivec3 graphics::operator- (
            int a,
            const ivec3 & b )  [inline]
```

Definition at line 396 of file ivec.h.

8.1.1.95 operator-() [11/24]

```
ivec3 graphics::operator- (
            const ivec3 & a,
            int b )  [inline]
```

Definition at line 403 of file ivec.h.

8.1.1.96 operator-() [12/24]

```
vec3 graphics::operator- (
            const vec3 & a,
            const vec3 & b )  [inline]
```

Definition at line 549 of file vec.h.

8.1.1.97 operator-() [13/24]

```
vec3 graphics::operator- (
            real a,
            const vec3 & b )  [inline]
```

Definition at line 556 of file vec.h.

8.1.1.98 operator-() [14/24]

```
vec3 graphics::operator- (
            const vec3 & a,
            real b )  [inline]
```

Definition at line 563 of file vec.h.

8.1.1.99 operator-() [15/24]

```
ivec3 graphics::operator- (
            const ivec3 & a )  [inline]
```

Definition at line 633 of file ivec.h.

8.1.1.100 operator-() [16/24]

```
ivec4 graphics::operator- (
            const ivec4 & a,
            const ivec4 & b )  [inline]
```

Definition at line 706 of file ivec.h.

8.1.1.101 operator-() [17/24]

```
ivec4 graphics::operator- (
            int a,
            const ivec4 & b )  [inline]
```

Definition at line 713 of file ivec.h.

8.1.1.102 operator-() [18/24]

```
ivec4 graphics::operator- (
            const ivec4 & a,
            int b )  [inline]
```

Definition at line 720 of file ivec.h.

8.1.1.103 operator-() [19/24]

```
vec3 graphics::operator- (
            const vec3 & a )  [inline]
```

Definition at line 786 of file vec.h.

8.1.1.104 operator-() [20/24]

```
vec4 graphics::operator- (
            const vec4 & a,
            const vec4 & b )  [inline]
```

Definition at line 939 of file vec.h.

8.1.1.105 operator-() [21/24]

```
vec4 graphics::operator- (
            real a,
            const vec4 & b )  [inline]
```

Definition at line 946 of file vec.h.

8.1.1.106 operator-() [22/24]

```
ivec4 graphics::operator- (
            const ivec4 & a )  [inline]
```

Definition at line 952 of file ivec.h.

8.1.1.107 operator-() [23/24]

```
vec4 graphics::operator- (
            const vec4 & a,
            real b )  [inline]
```

Definition at line 953 of file vec.h.

8.1.1.108 operator-() [24/24]

```
vec4 graphics::operator- (
            const vec4 & a )  [inline]
```

Definition at line 1178 of file vec.h.

8.1.1.109 operator-=() [1/12]

```
ivec2 graphics::operator-= (
            ivec2 & a,
            const ivec2 & b )  [inline]
```

Definition at line 161 of file ivec.h.

8.1.1.110 operator-=() [2/12]

```
ivec2 graphics::operator-= (
            ivec2 & a,
            int b )  [inline]
```

Definition at line 166 of file ivec.h.

8.1.1.111 operator-=() [3/12]

```
vec2 graphics::operator-= (
            vec2 & a,
            const vec2 & b )  [inline]
```

Definition at line 214 of file vec.h.

8.1.1.112 operator-=() [4/12]

```
vec2 graphics::operator-= (
            vec2 & a,
            real b )  [inline]
```

Definition at line 219 of file vec.h.

8.1.1.113 operator-=() [5/12]

```
ivec3 graphics::operator-= (
            ivec3 & a,
            const ivec3 & b )  [inline]
```

Definition at line 473 of file ivec.h.

8.1.1.114 operator-=() [6/12]

```
ivec3 graphics::operator-= (
            ivec3 & a,
            int b )  [inline]
```

Definition at line 478 of file ivec.h.

8.1.1.115 operator-=() [7/12]

```
vec3 graphics::operator-= (
            vec3 & a,
            const vec3 & b )  [inline]
```

Definition at line 631 of file vec.h.

8.1.1.116 operator-=() [8/12]

```
vec3 graphics::operator-= (
            vec3 & a,
            real b )  [inline]
```

Definition at line 636 of file vec.h.

8.1.1.117 operator-=() [9/12]

```
ivec4 graphics::operator-= (
            ivec4 & a,
            const ivec4 & b )  [inline]
```

Definition at line 790 of file ivec.h.

8.1.1.118 operator-=() [10/12]

```
ivec4 graphics::operator-= (
            ivec4 & a,
            int b )  [inline]
```

Definition at line 795 of file ivec.h.

8.1.1.119 operator-=() [11/12]

```
vec4 graphics::operator-= (
            vec4 & a,
            const vec4 & b )  [inline]
```

Definition at line 1023 of file vec.h.

8.1.1.120 operator-=() [12/12]

```
vec4 graphics::operator-= (
            vec4 & a,
            real b )  [inline]
```

Definition at line 1028 of file vec.h.

8.1.1.121 operator/() [1/9]

```
vec2 graphics::operator/ (
            const vec2 & a,
            const vec2 & b )  [inline]
```

Definition at line 176 of file vec.h.

8.1.1.122 operator/() [2/9]

```
vec2 graphics::operator/ (
            real a,
            const vec2 & b )  [inline]
```

Definition at line 183 of file vec.h.

8.1.1.123 operator/() [3/9]

```
vec2 graphics::operator/ (
            const vec2 & a,
            real b )  [inline]
```

Definition at line 190 of file vec.h.

8.1.1.124 operator/() [4/9]

```
vec3 graphics::operator/ (
            const vec3 & a,
            const vec3 & b )  [inline]
```

Definition at line 595 of file vec.h.

8.1.1.125 operator/() [5/9]

```
vec3 graphics::operator/ (
            real a,
            const vec3 & b )  [inline]
```

Definition at line 602 of file vec.h.

8.1.1.126 operator/() [6/9]

```
vec3 graphics::operator/ (
            const vec3 & a,
            real b )  [inline]
```

Definition at line 609 of file vec.h.

8.1.1.127 operator/() [7/9]

```
vec4 graphics::operator/ (
            const vec4 & a,
            const vec4 & b )  [inline]
```

Definition at line 985 of file vec.h.

8.1.1.128 operator/() [8/9]

```
vec4 graphics::operator/ (
            real a,
            const vec4 & b )  [inline]
```

Definition at line 992 of file vec.h.

8.1.1.129 operator/() [9/9]

```
vec4 graphics::operator/ (
            const vec4 & a,
            real b )  [inline]
```

Definition at line 999 of file vec.h.

8.1.1.130 operator/=() [1/6]

```
vec2 graphics::operator/= (
            vec2 & a,
            const vec2 & b )  [inline]
```

Definition at line 238 of file vec.h.

8.1.1.131 operator/=() [2/6]

```
vec2 graphics::operator/= (
            vec2 & a,
            real b )  [inline]
```

Definition at line 243 of file vec.h.

8.1.1.132 operator/=() [3/6]

```
vec3 graphics::operator/= (
            vec3 & a,
            const vec3 & b )  [inline]
```

Definition at line 655 of file vec.h.

8.1.1.133 operator/=() [4/6]

```
vec3 graphics::operator/= (
            vec3 & a,
            real b )  [inline]
```

Definition at line 660 of file vec.h.

8.1.1.134 operator/=() [5/6]

```
vec4 graphics::operator/= (
            vec4 & a,
            const vec4 & b )  [inline]
```

Definition at line 1047 of file vec.h.

8.1.1.135 operator/=() [6/6]

```
vec4 graphics::operator/= (
            vec4 & a,
            real b )  [inline]
```

Definition at line 1052 of file vec.h.

8.1.1.136 operator<() [1/18]

```
int graphics::operator< (
            const ivec2 & a,
            const ivec2 & b )  [inline]
```

Definition at line 223 of file ivec.h.

8.1.1.137 operator<() [2/18]

```
int graphics::operator< (
            int a,
            const ivec2 & b )  [inline]
```

Definition at line 230 of file ivec.h.

8.1.1.138 operator<() [3/18]

```
int graphics::operator< (
            const ivec2 & a,
            int b )  [inline]
```

Definition at line 237 of file ivec.h.

8.1.1.139 operator<() [4/18]

```
int graphics::operator< (
            const vec2 & a,
            const vec2 & b )  [inline]
```

Definition at line 276 of file vec.h.

8.1.1.140 operator<() [5/18]

```
int graphics::operator< (
            real a,
            const vec2 & b )  [inline]
```

Definition at line 283 of file vec.h.

8.1.1.141 operator<() [6/18]

```
int graphics::operator< (
            const vec2 & a,
            real b )  [inline]
```

Definition at line 290 of file vec.h.

8.1.1.142 operator<() [7/18]

```
int graphics::operator< (
            const ivec3 & a,
            const ivec3 & b )  [inline]
```

Definition at line 535 of file ivec.h.

8.1.1.143 operator<() [8/18]

```
int graphics::operator< (
            int a,
            const ivec3 & b )  [inline]
```

Definition at line 542 of file ivec.h.

8.1.1.144 operator<() [9/18]

```
int graphics::operator< (
            const ivec3 & a,
            int b )  [inline]
```

Definition at line 549 of file ivec.h.

8.1.1.145 operator<() [10/18]

```
int graphics::operator< (
            const vec3 & a,
            const vec3 & b )  [inline]
```

Definition at line 693 of file vec.h.

8.1.1.146 operator<() [11/18]

```
int graphics::operator< (
            real a,
            const vec3 & b )  [inline]
```

Definition at line 700 of file vec.h.

8.1.1.147 operator<() [12/18]

```
int graphics::operator< (
            const vec3 & a,
            real b )  [inline]
```

Definition at line 707 of file vec.h.

8.1.1.148 operator<() [13/18]

```
int graphics::operator< (
            const ivec4 & a,
            const ivec4 & b )  [inline]
```

Definition at line 852 of file ivec.h.

8.1.1.149 operator<() [14/18]

```
int graphics::operator< (
            int a,
            const ivec4 & b )  [inline]
```

Definition at line 859 of file ivec.h.

8.1.1.150 operator<() [15/18]

```
int graphics::operator< (
            const ivec4 & a,
            int b )  [inline]
```

Definition at line 866 of file ivec.h.

8.1.1.151 operator<() [16/18]

```
int graphics::operator< (
            const vec4 & a,
            const vec4 & b )  [inline]
```

Definition at line 1085 of file vec.h.

8.1.1.152 operator<() [17/18]

```
int graphics::operator< (
            real a,
            const vec4 & b )  [inline]
```

Definition at line 1092 of file vec.h.

8.1.1.153 operator<() [18/18]

```
int graphics::operator< (
            const vec4 & a,
            real b )  [inline]
```

Definition at line 1099 of file vec.h.

8.1.1.154 operator<=() [1/18]

```
int graphics::operator<= (
            const ivec2 & a,
            const ivec2 & b )  [inline]
```

Definition at line 246 of file ivec.h.

8.1.1.155 operator<=() [2/18]

```
int graphics::operator<= (
            int a,
            const ivec2 & b )  [inline]
```

Definition at line 253 of file ivec.h.

8.1.1.156 operator<=() [3/18]

```
int graphics::operator<= (
            const ivec2 & a,
            int b )  [inline]
```

Definition at line 260 of file ivec.h.

8.1.1.157 operator<=() [4/18]

```
int graphics::operator<= (
            const vec2 & a,
            const vec2 & b )  [inline]
```

Definition at line 299 of file vec.h.

8.1.1.158 operator<=() [5/18]

```
int graphics::operator<= (
            real a,
            const vec2 & b )  [inline]
```

Definition at line 306 of file vec.h.

8.1.1.159 operator<=() [6/18]

```
int graphics::operator<= (
            const vec2 & a,
            real b )  [inline]
```

Definition at line 313 of file vec.h.

8.1.1.160 operator<=() [7/18]

```
int graphics::operator<= (
            const ivec3 & a,
            const ivec3 & b )  [inline]
```

Definition at line 558 of file ivec.h.

8.1.1.161 operator<=() [8/18]

```
int graphics::operator<= (
            int a,
            const ivec3 & b )  [inline]
```

Definition at line 565 of file ivec.h.

8.1.1.162 operator<=() [9/18]

```
int graphics::operator<= (
            const ivec3 & a,
            int b )  [inline]
```

Definition at line 572 of file ivec.h.

8.1.1.163 operator<=() [10/18]

```
int graphics::operator<= (
            const vec3 & a,
            const vec3 & b )  [inline]
```

Definition at line 716 of file vec.h.

8.1.1.164 operator<=() [11/18]

```
int graphics::operator<= (
            real a,
            const vec3 & b )  [inline]
```

Definition at line 723 of file vec.h.

8.1.1.165 operator<=() [12/18]

```
int graphics::operator<= (
            const vec3 & a,
            real b )  [inline]
```

Definition at line 730 of file vec.h.

8.1.1.166 operator<=() [13/18]

```
int graphics::operator<= (
            const ivec4 & a,
            const ivec4 & b )  [inline]
```

Definition at line 875 of file ivec.h.

8.1.1.167 operator<=() [14/18]

```
int graphics::operator<= (
            int a,
            const ivec4 & b )  [inline]
```

Definition at line 882 of file ivec.h.

8.1.1.168 operator<=() [15/18]

```
int graphics::operator<= (
            const ivec4 & a,
            int b )  [inline]
```

Definition at line 889 of file ivec.h.

8.1.1.169 operator<=() [16/18]

```
int graphics::operator<= (
            const vec4 & a,
            const vec4 & b )  [inline]
```

Definition at line 1108 of file vec.h.

8.1.1.170 operator<=() [17/18]

```
int graphics::operator<= (
            real a,
            const vec4 & b )  [inline]
```

Definition at line 1115 of file vec.h.

8.1.1.171 operator<=() [18/18]

```
int graphics::operator<= (
            const vec4 & a,
            real b )  [inline]
```

Definition at line 1122 of file vec.h.

8.1.1.172 operator==() [1/18]

```
int graphics::operator== (
            const ivec2 & a,
            const ivec2 & b )  [inline]
```

Definition at line 200 of file ivec.h.

8.1.1.173 operator==() [2/18]

```
int graphics::operator== (
            int a,
            const ivec2 & b )  [inline]
```

Definition at line 207 of file ivec.h.

8.1.1.174 operator==() [3/18]

```
int graphics::operator== (
            const ivec2 & a,
            int b )  [inline]
```

Definition at line 214 of file ivec.h.

8.1.1.175 operator==() [4/18]

```
int graphics::operator== (
            const vec2 & a,
            const vec2 & b )  [inline]
```

Definition at line 253 of file vec.h.

8.1.1.176 operator==() [5/18]

```
int graphics::operator== (
            real a,
            const vec2 & b )  [inline]
```

Definition at line 260 of file vec.h.

8.1.1.177 operator==() [6/18]

```
int graphics::operator== (
            const vec2 & a,
            real b )  [inline]
```

Definition at line 267 of file vec.h.

8.1.1.178 operator==() [7/18]

```
int graphics::operator== (
            const ivec3 & a,
            const ivec3 & b )  [inline]
```

Definition at line 512 of file ivec.h.

8.1.1.179 operator==() [8/18]

```
int graphics::operator== (
            int a,
            const ivec3 & b )  [inline]
```

Definition at line 519 of file ivec.h.

8.1.1.180 operator==() [9/18]

```
int graphics::operator== (
            const ivec3 & a,
            int b )  [inline]
```

Definition at line 526 of file ivec.h.

8.1.1.181 operator==() [10/18]

```
int graphics::operator== (
            const vec3 & a,
            const vec3 & b )  [inline]
```

Definition at line 670 of file vec.h.

8.1.1.182 operator==() [11/18]

```
int graphics::operator== (
            real a,
            const vec3 & b )  [inline]
```

Definition at line 677 of file vec.h.

8.1.1.183 operator==() [12/18]

```
int graphics::operator== (
            const vec3 & a,
            real b )  [inline]
```

Definition at line 684 of file vec.h.

8.1.1.184 operator==() [13/18]

```
int graphics::operator== (
            const ivec4 & a,
            const ivec4 & b )  [inline]
```

Definition at line 829 of file ivec.h.

8.1.1.185 operator==() [14/18]

```
int graphics::operator== (
            int a,
            const ivec4 & b )  [inline]
```

Definition at line 836 of file ivec.h.

8.1.1.186 operator==() [15/18]

```
int graphics::operator== (
            const ivec4 & a,
            int b )  [inline]
```

Definition at line 843 of file ivec.h.

8.1.1.187 operator==() [16/18]

```
int graphics::operator== (
            const vec4 & a,
            const vec4 & b )  [inline]
```

Definition at line 1062 of file vec.h.

8.1.1.188 operator==() [17/18]

```
int graphics::operator== (
            real a,
            const vec4 & b )  [inline]
```

Definition at line 1069 of file vec.h.

8.1.1.189 operator==() [18/18]

```
int graphics::operator== (
            const vec4 & a,
            real b )  [inline]
```

Definition at line 1076 of file vec.h.

8.1.1.190 operator>() [1/18]

```
int graphics::operator> (
            const ivec2 & a,
            const ivec2 & b )  [inline]
```

Definition at line 269 of file ivec.h.

8.1.1.191 operator>() [2/18]

```
int graphics::operator> (
            int a,
            const ivec2 & b )  [inline]
```

Definition at line 276 of file ivec.h.

8.1.1.192 operator>() [3/18]

```
int graphics::operator> (
            const ivec2 & a,
            int b )  [inline]
```

Definition at line 283 of file ivec.h.

8.1.1.193 operator>() [4/18]

```
int graphics::operator> (
            const vec2 & a,
            const vec2 & b )  [inline]
```

Definition at line 322 of file vec.h.

8.1.1.194 operator>() [5/18]

```
int graphics::operator> (
            real a,
            const vec2 & b )  [inline]
```

Definition at line 329 of file vec.h.

8.1.1.195 operator>() [6/18]

```
int graphics::operator> (
            const vec2 & a,
            real b )  [inline]
```

Definition at line 336 of file vec.h.

8.1.1.196 operator>() [7/18]

```
int graphics::operator> (
            const ivec3 & a,
            const ivec3 & b )  [inline]
```

Definition at line 581 of file ivec.h.

8.1.1.197 operator>() [8/18]

```
int graphics::operator> (
            int a,
            const ivec3 & b )  [inline]
```

Definition at line 588 of file ivec.h.

8.1.1.198 operator>() [9/18]

```
int graphics::operator> (
            const ivec3 & a,
            int b )  [inline]
```

Definition at line 595 of file ivec.h.

8.1.1.199 operator>() [10/18]

```
int graphics::operator> (
            const vec3 & a,
            const vec3 & b )  [inline]
```

Definition at line 739 of file vec.h.

8.1.1.200 operator>() [11/18]

```
int graphics::operator> (
            real a,
            const vec3 & b )  [inline]
```

Definition at line 746 of file vec.h.

8.1.1.201 operator>() [12/18]

```
int graphics::operator> (
            const vec3 & a,
            real b )  [inline]
```

Definition at line 753 of file vec.h.

8.1.1.202 operator>() [13/18]

```
int graphics::operator> (
            const ivec4 & a,
            const ivec4 & b )  [inline]
```

Definition at line 898 of file ivec.h.

8.1.1.203 operator>() [14/18]

```
int graphics::operator> (
            int a,
            const ivec4 & b )  [inline]
```

Definition at line 905 of file ivec.h.

8.1.1.204 operator>() [15/18]

```
int graphics::operator> (
            const ivec4 & a,
            int b )  [inline]
```

Definition at line 912 of file ivec.h.

8.1.1.205 operator>() [16/18]

```
int graphics::operator> (
            const vec4 & a,
            const vec4 & b )  [inline]
```

Definition at line 1131 of file vec.h.

8.1.1.206 operator>() [17/18]

```
int graphics::operator> (
            real a,
            const vec4 & b )  [inline]
```

Definition at line 1138 of file vec.h.

8.1.1.207 operator>() [18/18]

```
int graphics::operator> (
            const vec4 & a,
            real b )  [inline]
```

Definition at line 1145 of file vec.h.

8.1.1.208 operator>=() [1/18]

```
int graphics::operator>= (
            const ivec2 & a,
            const ivec2 & b )  [inline]
```

Definition at line 293 of file ivec.h.

8.1.1.209 operator>=() [2/18]

```
int graphics::operator>= (
            int a,
            const ivec2 & b )  [inline]
```

Definition at line 299 of file ivec.h.

8.1.1.210 operator>=() [3/18]

```
int graphics::operator>= (
            const ivec2 & a,
            int b )  [inline]
```

Definition at line 306 of file ivec.h.

8.1.1.211 operator>=() [4/18]

```
int graphics::operator>= (
            const vec2 & a,
            const vec2 & b )  [inline]
```

Definition at line 345 of file vec.h.

8.1.1.212 operator>=() [5/18]

```
int graphics::operator>= (
            real a,
            const vec2 & b )  [inline]
```

Definition at line 352 of file vec.h.

8.1.1.213 operator>=() [6/18]

```
int graphics::operator>= (
            const vec2 & a,
            real b )  [inline]
```

Definition at line 359 of file vec.h.

8.1.1.214 operator>=() [7/18]

```
int graphics::operator>= (
            const ivec3 & a,
            const ivec3 & b )  [inline]
```

Definition at line 604 of file ivec.h.

8.1.1.215 operator>=() [8/18]

```
int graphics::operator>= (
            int a,
            const ivec3 & b )  [inline]
```

Definition at line 611 of file ivec.h.

8.1.1.216 operator>=() [9/18]

```
int graphics::operator>= (
            const ivec3 & a,
            int b )  [inline]
```

Definition at line 618 of file ivec.h.

8.1.1.217 operator>=() [10/18]

```
int graphics::operator>= (
            const vec3 & a,
            const vec3 & b )  [inline]
```

Definition at line 762 of file vec.h.

8.1.1.218 operator>=() [11/18]

```
int graphics::operator>= (
            real a,
            const vec3 & b )  [inline]
```

Definition at line 769 of file vec.h.

8.1.1.219 operator>=() [12/18]

```
int graphics::operator>= (
            const vec3 & a,
            real b )  [inline]
```

Definition at line 776 of file vec.h.

8.1.1.220 operator>=() [13/18]

```
int graphics::operator>= (
            const ivec4 & a,
            const ivec4 & b )  [inline]
```

Definition at line 921 of file ivec.h.

8.1.1.221 operator>=() [14/18]

```
int graphics::operator>= (
            int a,
            const ivec4 & b )  [inline]
```

Definition at line 935 of file ivec.h.

8.1.1.222 operator>=() [15/18]

```
int graphics::operator>= (
            const ivec4 & a,
            int b )  [inline]
```

Definition at line 942 of file ivec.h.

8.1.1.223 operator>=() [16/18]

```
int graphics::operator>= (
            const vec4 & a,
            const vec4 & b )  [inline]
```

Definition at line 1154 of file vec.h.

8.1.1.224 operator>=() [17/18]

```
int graphics::operator>= (
            real a,
            const vec4 & b )  [inline]
```

Definition at line 1161 of file vec.h.

8.1.1.225 operator>=() [18/18]

```
int graphics::operator>= (
            const vec4 & a,
            real b )  [inline]
```

Definition at line 1168 of file vec.h.

8.1.1.226 proj() [1/3]

```
vec2 graphics::proj (
            const vec2 & axis,
            const vec2 & a )  [inline]
```

Definition at line 423 of file vec.h.

8.1.1.227 proj() [2/3]

```
vec3 graphics::proj (
            const vec3 & axis,
            const vec3 & a )  [inline]
```

Definition at line 849 of file vec.h.

8.1.1.228 proj() [3/3]

```
vec4 graphics::proj (
            const vec4 & axis,
            const vec4 & a )  [inline]
```

Definition at line 1240 of file vec.h.

8.1.1.229 reset_u_epsilon()

```
void graphics::reset_u_epsilon ( )
```

Definition at line 27 of file epsilon.cpp.

8.1.1.230 reset_zero_epsilon()

```
void graphics::reset_zero_epsilon ( )
```

Definition at line 37 of file epsilon.cpp.

8.1.1.231 scan() [1/3]

```
int graphics::scan (
            FILE * fp,
            const vec2 & v )
```

Definition at line 91 of file vec.cpp.

8.1.1.232 scan() [2/3]

```
int graphics::scan (
            FILE * fp,
            const vec3 & v )
```

Definition at line 308 of file vec.cpp.

8.1.1.233 scan() [3/3]

```
int graphics::scan (
            FILE * fp,
            const vec4 & v )
```

Definition at line 367 of file vec.cpp.

8.1.1.234 set_u_epsilon()

```
void graphics::set_u_epsilon (
            real a )
```

Definition at line 22 of file epsilon.cpp.

8.1.1.235 set_zero_epsilon()

```
void graphics::set_zero_epsilon (
            real a )
```

Definition at line 31 of file epsilon.cpp.

8.1.1.236 squaredNorm() [1/3]

```
real graphics::squaredNorm (
            const vec2 & a )  [inline]
```

Definition at line 399 of file vec.h.

8.1.1.237 squaredNorm() [2/3]

```
real graphics::squaredNorm (
            const vec3 & a )  [inline]
```

Definition at line 820 of file vec.h.

8.1.1.238 squaredNorm() [3/3]

```
real graphics::squaredNorm (
            const vec4 & a )  [inline]
```

Definition at line 1212 of file vec.h.

8.1.1.239 store() [1/3]

```
void graphics::store (
            FILE * fp,
            const vec2 & v )
```

Definition at line 82 of file vec.cpp.

8.1.1.240 store() [2/3]

```
void graphics::store (
            FILE * fp,
            const vec3 & v )
```

Definition at line 299 of file vec.cpp.

8.1.1.241 store() [3/3]

```
void graphics::store (
            FILE * fp,
            const vec4 & v )
```

Definition at line 358 of file vec.cpp.

8.1.1.242 sum() [1/3]

```
real graphics::sum (
            const vec2 & a )  [inline]
```

Definition at line 377 of file vec.h.

8.1.1.243 sum() [2/3]

```
real graphics::sum (
            const vec3 & a )  [inline]
```

Definition at line 801 of file vec.h.

8.1.1.244 sum() [3/3]

```
real graphics::sum (
            const vec4 & a )  [inline]
```

Definition at line 1192 of file vec.h.

8.1.1.245 unit() [1/3]

```
vec2 graphics::unit (
            const vec2 & a )  [inline]
```

Definition at line 403 of file vec.h.

8.1.1.246 unit() [2/3]

```
vec3 graphics::unit (
            const vec3 & a )  [inline]
```

Definition at line 829 of file vec.h.

8.1.1.247 unit() [3/3]

```
vec4 graphics::unit (
            const vec4 & a )  [inline]
```

Definition at line 1220 of file vec.h.

8.1.2 Variable Documentation

8.1.2.1 angle_tolerance

```
real graphics::angle_tolerance = M_PI/180.0
```

Definition at line 14 of file epsilon.cpp.

8.1.2.2 epsilon

```
real graphics::epsilon = 1.0e-8
```

Definition at line 7 of file epsilon.cpp.

8.1.2.3 intersection_epsilon

```
real graphics::intersection_epsilon = 1e-6
```

Definition at line 9 of file epsilon.cpp.

8.1.2.4 save_zero_epsilon

```
real graphics::save_zero_epsilon = 1.0e-12
```

Definition at line 15 of file epsilon.cpp.

8.1.2.5 sqrt_epsilon

```
real graphics::sqrt_epsilon = 1.490116119385000000e-8
```

Definition at line 10 of file epsilon.cpp.

8.1.2.6 unset_value

```
real graphics::unset_value = -1.23432101234321e+308
```

Definition at line 11 of file epsilon.cpp.

8.1.2.7 user_epsilon

```
real graphics::user_epsilon = 1.0e-8
```

Definition at line 8 of file epsilon.cpp.

8.1.2.8 zero_epsilon

```
real graphics::zero_epsilon = 1.0e-12
```

Definition at line 13 of file epsilon.cpp.

8.1.2.9 zero_tolerance

```
real graphics::zero_tolerance = 1.0e-12
```

Definition at line 12 of file epsilon.cpp.

Chapter 9

Class Documentation

9.1 Complex Class Reference

class for the complex number and its arithmetic.

`#include <complex.h>`

Public Member Functions

- Complex ()
- Complex (double ta, double tb)
- Complex (const Complex &p)
- double mag2 () const
- double mag () const
- double arg () const
- void euler (double &r, double &theta)
- Complex conj () const
- const Complex & operator= (const Complex &p)
- const Complex & operator+= (const Complex &p)
- const Complex & operator-= (const Complex &p)
- const Complex & operator*= (const double k)
- const Complex & operator*= (const Complex &p)
- const Complex & operator/= (const double k)

Public Attributes

- double a
- double b

Friends

- const Complex operator+ (const Complex &p, const Complex &q)
- const Complex operator- (const Complex &p, const Complex &q)
- const Complex operator* (const double k, const Complex &p)
- const Complex operator* (const Complex &p, const double k)
- const Complex operator* (const Complex &p, const Complex &q)
- const Complex operator/ (const Complex &p, const Complex &q)
- std::ostream & operator<< (std::ostream &os, const Complex &p)

9.1.1 Detailed Description

Definition at line 22 of file complex.h.

9.1.2 Constructor & Destructor Documentation

9.1.2.1 Complex() [1/3]

```
Complex::Complex ( )  [inline]
```

Definition at line 25 of file complex.h.

9.1.2.2 Complex() [2/3]

```
Complex::Complex (
            double ta,
            double tb )  [inline]
```

Definition at line 26 of file complex.h.

9.1.2.3 Complex() [3/3]

```
Complex::Complex (
            const Complex & p )  [inline]
```

Definition at line 27 of file complex.h.

9.1.3 Member Function Documentation

9.1.3.1 arg()

```
double Complex::arg ( ) const  [inline]
```

Definition at line 36 of file complex.h.

9.1.3.2 conj()

```
Complex Complex::conj ( ) const  [inline]
```

Definition at line 53 of file complex.h.

9.1.3.3 euler()

```
void Complex::euler (
            double & r,
            double & theta )  [inline]
```

Definition at line 47 of file complex.h.

9.1.3.4 mag()

```
double Complex::mag ( ) const  [inline]
```

Definition at line 34 of file complex.h.

9.1.3.5 mag2()

```
double Complex::mag2 ( ) const  [inline]
```

Definition at line 33 of file complex.h.

9.1.3.6 operator*=() [1/2]

```
const Complex& Complex::operator*= (
            const double k )  [inline]
```

Definition at line 80 of file complex.h.

9.1.3.7 operator*=() [2/2]

```
const Complex& Complex::operator*= (
            const Complex & p )  [inline]
```

Definition at line 88 of file complex.h.

9.1.3.8 operator+=()

```
const Complex& Complex::operator+= (
            const Complex & p )  [inline]
```

Definition at line 64 of file complex.h.

9.1.3.9 operator-=()

```
const Complex& Complex::operator-= (
            const Complex & p )  [inline]
```

Definition at line 72 of file complex.h.

9.1.3.10 operator/=()

```
const Complex& Complex::operator/= (
            const double k )  [inline]
```

Definition at line 99 of file complex.h.

9.1.3.11 operator=()

```
const Complex& Complex::operator= (
            const Complex & p )  [inline]
```

Definition at line 56 of file complex.h.

9.1.4 Friends And Related Function Documentation

9.1.4.1 operator* [1/3]

```
const Complex operator* (
            const double k,
            const Complex & p )  [friend]
```

Definition at line 117 of file complex.h.

9.1.4.2 operator* [2/3]

```
const Complex operator* (
            const Complex & p,
            const double k )  [friend]
```

Definition at line 122 of file complex.h.

9.1.4.3 operator* [3/3]

```
const Complex operator* (
            const Complex & p,
            const Complex & q )  [friend]
```

Definition at line 127 of file complex.h.

9.1.4.4 operator+

```
const Complex operator+ (
            const Complex & p,
            const Complex & q )  [friend]
```

Definition at line 107 of file complex.h.

9.1.4.5 operator-

```
const Complex operator- (
            const Complex & p,
            const Complex & q )  [friend]
```

Definition at line 112 of file complex.h.

9.1.4.6 operator/

```
const Complex operator/ (
            const Complex & p,
            const Complex & q )  [friend]
```

Definition at line 132 of file complex.h.

9.1.4.7 operator<<

```
std::ostream& operator<< (
            std::ostream & os,
            const Complex & p )  [friend]
```

Definition at line 138 of file complex.h.

9.1.5 Member Data Documentation

9.1.5.1 a

```
double Complex::a
```

Definition at line 145 of file complex.h.

9.1.5.2 b

```
double Complex::b
```

Definition at line 145 of file complex.h.

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

- graphics/complex.h

9.2 HologramDepthmap Class Reference

Test class for executing the sample program, which shows how to use a hologram library.

```
#include <hologramdepthmap.h>
```

Inherits QMainWindow.

Public Member Functions

- HologramDepthmap (QWidget *parent=0)
- ~HologramDepthmap ()

Private Slots

- void GenHologram ()
- void ReconImage ()

Private Attributes

- Ui::HologramDepthmapClass ui
- HologramGenerator * hologram_

9.2.1 Detailed Description

The sample program has a main window form and the user can choose the execution type - CPU and GPU.

Definition at line 13 of file hologramdepthmap.h.

9.2.2 Constructor & Destructor Documentation

9.2.2.1 HologramDepthmap()

```
HologramDepthmap::HologramDepthmap (
            QWidget * parent = 0 )
```

Definition at line 4 of file hologramdepthmap.cpp.

9.2.2.2 ~HologramDepthmap()

```
HologramDepthmap::~HologramDepthmap ( )
```

Definition at line 17 of file hologramdepthmap.cpp.

9.2.3 Member Function Documentation

9.2.3.1 GenHologram

```
void HologramDepthmap::GenHologram ( )  [private], [slot]
```

Definition at line 22 of file hologramdepthmap.cpp.

9.2.3.2 ReconImage

```
void HologramDepthmap::ReconImage ( )  [private], [slot]
```

Definition at line 47 of file hologramdepthmap.cpp.

9.2.4 Member Data Documentation

9.2.4.1 hologram_

```
HologramGenerator* HologramDepthmap::hologram_  [private]
```

Definition at line 30 of file hologramdepthmap.h.

9.2.4.2 ui

```
Ui::HologramDepthmapClass HologramDepthmap::ui  [private]
```

Definition at line 28 of file hologramdepthmap.h.

The documentation for this class was generated from the following files:

- HologramDepthmap/hologramdepthmap.h
- HologramDepthmap/hologramdepthmap.cpp

9.3 HologramGenerator Class Reference

Main class for generating a hologram using depth map data.

```
#include <HologramGenerator.h>
```

Public Member Functions

- HologramGenerator ()
  Constructor.
- ~HologramGenerator ()
  Destructor.
- void setMode (bool isCPU)
  Set the value of a variable isCPU_(true or false)
- bool readConfig ()
  Read parameters from a config file(config_openholo.txt).
- void initialize ()
  Initialize variables for CPU and GPU implementation.
- void GenerateHologram ()
  Generate a hologram, main funtion.
- void ReconstructImage ()
  It is a testing function used for the reconstruction.

Private Member Functions

- void get_rand_phase_value (Complex &rand_phase_val)

  Assign random phase value if RANDOM_PHASE == 1.
- void get_shift_phase_value (Complex &shift_phase_val, int idx, ivec2 sig_location)

  Calculate the shift phase value.
- void fftwShift (Complex ∗src, Complex ∗dst, fftw_complex ∗in, fftw_complex ∗out, int nx, int ny, int type, bool bNomalized=false)

  Convert data from the spatial domain to the frequency domain using 2D FFT on CPU.
- void exponent_complex (Complex ∗val)

  Calculate the exponential of the complex number.
- void fftShift (int nx, int ny, Complex ∗input, Complex ∗output)

  Swap the top-left quadrant of data with the bottom-right , and the top-right quadrant with the bottom-left.

- void init_CPU ()

  Initialize variables for the CPU implementation.
- void init_GPU ()

  Initialize variables for the GPU implementation.

- bool ReadImageDepth (int ftr)

  Read image and depth map.
- bool prepare_inputdata_CPU (uchar ∗img, uchar ∗dimg)

  Preprocess input image & depth map data for the CPU implementation.
- bool prepare_inputdata_GPU (uchar ∗img, uchar ∗dimg)

  Copy input image & depth map data into a GPU.

- void GetDepthValues ()

  Calculate the physical distances of depth map layers.
- void change_depth_quan_CPU ()

  Quantize depth map on the CPU, when the number of depth quantization is not the default value (i.e. FLAG_CHA↩ NGE_DEPTH_QUANTIZATION == 1).
- void change_depth_quan_GPU ()

  Quantize depth map on the GPU, when the number of depth quantization is not the default value (i.e. FLAG_CHA↩ NGE_DEPTH_QUANTIZATION == 1).

- void TransformViewingWindow ()

  Transform target object to reflect the system configuration of holographic display.

- void Calc_Holo_by_Depth (int frame)

  Generate a hologram.
- void Calc_Holo_CPU (int frame)

  Main method for generating a hologram on the CPU.
- void Calc_Holo_GPU (int frame)

  Main method for generating a hologram on the GPU.
- void Propagation_AngularSpectrum_CPU (Complex ∗input_u, double propagation_dist)

  Angular spectrum propagation method for CPU implementation.
- void Propagation_AngularSpectrum_GPU (cufftDoubleComplex ∗input_u, double propagation_dist)

  Angular spectrum propagation method for GPU implementation.

- void Encoding_Symmetrization (ivec2 sig_location)

  Encode the CGH according to a signal location parameter.
- void encoding_CPU (int cropx1, int cropx2, int cropy1, int cropy2, ivec2 sig_location)

  Encode the CGH according to a signal location parameter on the CPU.
- void encoding_GPU (int cropx1, int cropx2, int cropy1, int cropy2, ivec2 sig_location)

  Encode the CGH according to a signal location parameter on GPU.

- void Write_Result_image (int ftr)

  Write the result image.

- void Reconstruction (fftw_complex ∗in, fftw_complex ∗out)

  It is a testing function used for the reconstruction.
- void Test_Propagation_to_Eye_Pupil (fftw_complex ∗in, fftw_complex ∗out)

  It is a testing function used for the reconstruction.
- void Write_Simulation_image (int num, double val)

  It is a testing function used for the reconstruction.
- void circshift (Complex ∗in, Complex ∗out, int shift_x, int shift_y, int nx, int ny)

  It is a testing function used for the reconstruction.

Private Attributes

- bool isCPU_

  if true, it is implemented on the CPU, otherwise on the GPU.
- unsigned char ∗ img_src_gpu_

  GPU variable - image source data, values are from 0 to 255.
- unsigned char ∗ dimg_src_gpu_

  GPU variable - depth map data, values are from 0 to 255.
- double ∗ depth_index_gpu_

  GPU variable - quantized depth map data.
- double ∗ img_src_

CPU variable - image source data, values are from 0 to 1.

- double * dmap_src_

  CPU variable - depth map data, values are from 0 to 1.
- double * depth_index_

  CPU variable - quantized depth map data.
- int * alpha_map_

  CPU variable - calculated alpha map data, values are 0 or 1.
- double * dmap_

  CPU variable - physical distances of depth map.
- double dstep_

  the physical increment of each depth map layer.
- std::vector< double > dlevel_

  the physical value of all depth map layer.
- std::vector< double > dlevel_transform_

  transfomed dlevel_ variable
- Complex * U_complex_

  CPU variable - the generated hologram before encoding.
- double * u255_fringe_

  the final hologram, used for writing the result image.
- HologramParams params_

  structure variable for hologram parameters
- std::string SOURCE_FOLDER

  input source folder - config file.
- std::string IMAGE_PREFIX

  the prefix of the input image file - config file.
- std::string DEPTH_PREFIX

  the prefix of the deptmap file - config file
- std::string RESULT_FOLDER

  the name of the result folder - config file
- std::string RESULT_PREFIX

  the prefix of the result file - config file
- bool FLAG_STATIC_IMAGE

  if true, the input image is static.
- uint START_OF_FRAME_NUMBERING

  the start frame number.
- uint NUMBER_OF_FRAME

  the total number of the frame.
- uint NUMBER_OF_DIGIT_OF_FRAME_NUMBERING

  the number of digit of frame number.
- int Transform_Method_

  transform method
- int Propagation_Method_

  propagation method - currently AngularSpectrum
- int Encoding_Method_

  encoding method - currently Symmetrization
- double WAVELENGTH

  wave length
- bool FLAG_CHANGE_DEPTH_QUANTIZATION

  if true, change the depth quantization from the default value.
- uint DEFAULT_DEPTH_QUANTIZATION

  default value of the depth quantization - 256

- uint NUMBER_OF_DEPTH_QUANTIZATION

  depth level of input depthmap.
- bool RANDOM_PHASE

  If true, random phase is imposed on each depth layer.
- std::string Simulation_Result_File_Prefix_

  reconstruction variable for testing
- int test_pixel_number_scale_

  reconstruction variable for testing
- vec2 Pixel_pitch_xy_

  reconstruction variable for testing
- ivec2 SLM_pixel_number_xy_

  reconstruction variable for testing
- double f_field_

  reconstruction variable for testing
- double eye_length_

  reconstruction variable for testing
- double eye_pupil_diameter_

  reconstruction variable for testing
- vec2 eye_center_xy_

  reconstruction variable for testing
- double focus_distance_

  reconstruction variable for testing
- int sim_type_

  reconstruction variable for testing
- double sim_from_

  reconstruction variable for testing
- double sim_to_

  reconstruction variable for testing
- int sim_step_num_

  reconstruction variable for testing
- double * sim_final_

  reconstruction variable for testing
- Complex * hh_complex_

  reconstruction variable for testing

9.3.1 Detailed Description

This is a main class for generating a digital hologram using depth map data. It is implemented on the CPU and GPU.

1. Read Config file. - to set all parameters needed for generating a hologram.
2. Initialize all variables. - memory allocation on the CPU and GPU.
3. Generate a digital hologram using depth map data.
4. For the testing purpose, reconstruct a image from the generated hologram.

Definition at line 130 of file HologramGenerator.h.

9.3.2 Constructor & Destructor Documentation

9.3.2.1 HologramGenerator()

```
HologramGenerator::HologramGenerator ( )
```

Initialize variables.

Definition at line 15 of file HologramGenerator.cpp.

9.3.2.2 ~HologramGenerator()

```
HologramGenerator::~HologramGenerator ( )
```

Definition at line 43 of file HologramGenerator.cpp.

9.3.3 Member Function Documentation

9.3.3.1 exponent_complex()

```
void HologramGenerator::exponent_complex (
            Complex * val )  [private]
```

Parameters

val	: input & ouput value

See also

Propagation_AngularSpectrum_CPU, Calc_Holo_CPU

Definition at line 351 of file HologramGenerator_CPU.cpp.

9.3.3.2 fftShift()

```
void HologramGenerator::fftShift (
            int nx,
            int ny,
            Complex * input,
            Complex * output )  [private]
```

Parameters

nx	: the number of column of the input data
ny	: the number of row of the input data
input	: input data variable
output	: output data variable

See also

fftwShift

Definition at line 332 of file HologramGenerator_CPU.cpp.

9.3.3.3 fftwShift()

```
void HologramGenerator::fftwShift (
            Complex * src,
            Complex * dst,
            fftw_complex * in,
            fftw_complex * out,
            int nx,
            int ny,
            int type,
            bool bNomarlized = false )  [private]
```

It is equivalent to Matlab code, dst = ifftshift(fft2(fftshift(src))).

Parameters

src	: input data variable
dst	: output data variable
in	: input data pointer connected with FFTW plan
out	: ouput data pointer connected with FFTW plan
nx	: the number of column of the input data
ny	: the number of row of the input data
type	: If type == 1, forward FFT, if type == -1, backward FFT.
bNomarlized	: If bNomarlized == true, normalize the result after FFT.

See also

Propagation_AngularSpectrum_CPU, encoding_CPU

Definition at line 285 of file HologramGenerator_CPU.cpp.

9.3.3.4 get_rand_phase_value()

```
void HologramGenerator::get_rand_phase_value (
            Complex & rand_phase_val )  [private]
```

If RANDOM_PHASE == 1, calculate a random phase value using random generator; otherwise, random phase value is 1.

Parameters

rand_phase_val	: Input & Ouput value.

Definition at line 457 of file HologramGenerator.cpp.

9.3.3.5 get_shift_phase_value()

```
void HologramGenerator::get_shift_phase_value (
            Complex & shift_phase_val,
            int idx,
            ivec2 sig_location )  [private]
```

Parameters

shift_phase_val	: output variable.
idx	: the current pixel position.
sig_location	: signal location.

See also

encoding_CPU

Definition at line 367 of file HologramGenerator_CPU.cpp.

9.3.3.6 setMode()

```
void HologramGenerator::setMode (
            bool isCPU )
```

```
  if isCPU_ == true
     CPU implementation
  else
     GPU implementation
```

Parameters

isCPU	: the value for specifying whether the hologram generation method is implemented on the CPU or GPU

Definition at line 56 of file HologramGenerator.cpp.

9.3.4 Member Data Documentation

9.3.4.1 alpha_map_

```
int* HologramGenerator::alpha_map_  [private]
```

Definition at line 234 of file HologramGenerator.h.

9.3.4.2 DEFAULT_DEPTH_QUANTIZATION

```
uint HologramGenerator::DEFAULT_DEPTH_QUANTIZATION  [private]
```

Definition at line 264 of file HologramGenerator.h.

9.3.4.3 depth_index_

```
double* HologramGenerator::depth_index_  [private]
```

Definition at line 233 of file HologramGenerator.h.

9.3.4.4 depth_index_gpu_

```
double* HologramGenerator::depth_index_gpu_  [private]
```

Definition at line 229 of file HologramGenerator.h.

9.3.4.5 DEPTH_PREFIX

```
std::string HologramGenerator::DEPTH_PREFIX  [private]
```

Definition at line 249 of file HologramGenerator.h.

9.3.4.6 dimg_src_gpu_

```
unsigned char* HologramGenerator::dimg_src_gpu_  [private]
```

Definition at line 228 of file HologramGenerator.h.

9.3.4.7 dlevel_

```
std::vector<double> HologramGenerator::dlevel_  [private]
```

Definition at line 239 of file HologramGenerator.h.

9.3.4.8 dlevel_transform_

```
std::vector<double> HologramGenerator::dlevel_transform_  [private]
```

Definition at line 240 of file HologramGenerator.h.

9.3.4.9 dmap_

```
double* HologramGenerator::dmap_  [private]
```

Definition at line 236 of file HologramGenerator.h.

9.3.4.10 dmap_src_

```
double* HologramGenerator::dmap_src_  [private]
```

Definition at line 232 of file HologramGenerator.h.

9.3.4.11 dstep_

```
double HologramGenerator::dstep_  [private]
```

Definition at line 238 of file HologramGenerator.h.

9.3.4.12 Encoding_Method_

```
int HologramGenerator::Encoding_Method_  [private]
```

Definition at line 259 of file HologramGenerator.h.

9.3.4.13 eye_center_xy_

```
vec2 HologramGenerator::eye_center_xy_  [private]
```

Definition at line 277 of file HologramGenerator.h.

9.3.4.14 eye_length_

```
double HologramGenerator::eye_length_  [private]
```

Definition at line 275 of file HologramGenerator.h.

9.3.4.15 eye_pupil_diameter_

```
double HologramGenerator::eye_pupil_diameter_  [private]
```

Definition at line 276 of file HologramGenerator.h.

9.3.4.16 f_field_

```
double HologramGenerator::f_field_  [private]
```

Definition at line 274 of file HologramGenerator.h.

9.3.4.17 FLAG_CHANGE_DEPTH_QUANTIZATION

```
bool HologramGenerator::FLAG_CHANGE_DEPTH_QUANTIZATION  [private]
```

Definition at line 263 of file HologramGenerator.h.

9.3.4.18 FLAG_STATIC_IMAGE

```
bool HologramGenerator::FLAG_STATIC_IMAGE  [private]
```

Definition at line 252 of file HologramGenerator.h.

9.3.4.19 focus_distance_

```
double HologramGenerator::focus_distance_  [private]
```

Definition at line 278 of file HologramGenerator.h.

9.3.4.20 hh_complex_

```
Complex* HologramGenerator::hh_complex_  [private]
```

Definition at line 284 of file HologramGenerator.h.

9.3.4.21 IMAGE_PREFIX

```
std::string HologramGenerator::IMAGE_PREFIX  [private]
```

Definition at line 248 of file HologramGenerator.h.

9.3.4.22 img_src_

```
double* HologramGenerator::img_src_  [private]
```

Definition at line 231 of file HologramGenerator.h.

9.3.4.23 img_src_gpu_

```
unsigned char* HologramGenerator::img_src_gpu_  [private]
```

Definition at line 227 of file HologramGenerator.h.

9.3.4.24 isCPU_

```
bool HologramGenerator::isCPU_  [private]
```

Definition at line 225 of file HologramGenerator.h.

9.3.4.25 NUMBER_OF_DEPTH_QUANTIZATION

```
uint HologramGenerator::NUMBER_OF_DEPTH_QUANTIZATION  [private]
```

Definition at line 265 of file HologramGenerator.h.

9.3.4.26 NUMBER_OF_DIGIT_OF_FRAME_NUMBERING

```
uint HologramGenerator::NUMBER_OF_DIGIT_OF_FRAME_NUMBERING  [private]
```

Definition at line 255 of file HologramGenerator.h.

9.3.4.27 NUMBER_OF_FRAME

```
uint HologramGenerator::NUMBER_OF_FRAME  [private]
```

Definition at line 254 of file HologramGenerator.h.

9.3.4.28 params_

```
HologramParams HologramGenerator::params_  [private]
```

Definition at line 245 of file HologramGenerator.h.

9.3.4.29 Pixel_pitch_xy_

```
vec2 HologramGenerator::Pixel_pitch_xy_  [private]
```

Definition at line 272 of file HologramGenerator.h.

9.3.4.30 Propagation_Method_

```
int HologramGenerator::Propagation_Method_  [private]
```

Definition at line 258 of file HologramGenerator.h.

9.3.4.31 RANDOM_PHASE

```
bool HologramGenerator::RANDOM_PHASE  [private]
```

Definition at line 266 of file HologramGenerator.h.

9.3.4.32 RESULT_FOLDER

```
std::string HologramGenerator::RESULT_FOLDER  [private]
```

Definition at line 250 of file HologramGenerator.h.

9.3.4.33 RESULT_PREFIX

```
std::string HologramGenerator::RESULT_PREFIX  [private]
```

Definition at line 251 of file HologramGenerator.h.

9.3.4.34 sim_final_

```
double* HologramGenerator::sim_final_  [private]
```

Definition at line 283 of file HologramGenerator.h.

9.3.4.35 sim_from_

```
double HologramGenerator::sim_from_  [private]
```

Definition at line 280 of file HologramGenerator.h.

9.3.4.36 sim_step_num_

```
int HologramGenerator::sim_step_num_  [private]
```

Definition at line 282 of file HologramGenerator.h.

9.3.4.37 sim_to_

```
double HologramGenerator::sim_to_  [private]
```

Definition at line 281 of file HologramGenerator.h.

9.3.4.38 sim_type_

```
int HologramGenerator::sim_type_  [private]
```

Definition at line 279 of file HologramGenerator.h.

9.3.4.39 Simulation_Result_File_Prefix_

```
std::string HologramGenerator::Simulation_Result_File_Prefix_  [private]
```

Definition at line 270 of file HologramGenerator.h.

9.3.4.40 SLM_pixel_number_xy_

```
ivec2 HologramGenerator::SLM_pixel_number_xy_  [private]
```

Definition at line 273 of file HologramGenerator.h.

9.3.4.41 SOURCE_FOLDER

```
std::string HologramGenerator::SOURCE_FOLDER  [private]
```

Definition at line 247 of file HologramGenerator.h.

9.3.4.42 START_OF_FRAME_NUMBERING

```
uint HologramGenerator::START_OF_FRAME_NUMBERING  [private]
```

Definition at line 253 of file HologramGenerator.h.

9.3.4.43 test_pixel_number_scale_

```
int HologramGenerator::test_pixel_number_scale_  [private]
```

Definition at line 271 of file HologramGenerator.h.

9.3.4.44 Transform_Method_

```
int HologramGenerator::Transform_Method_  [private]
```

Definition at line 257 of file HologramGenerator.h.

9.3.4.45 u255_fringe_

```
double* HologramGenerator::u255_fringe_  [private]
```

Definition at line 243 of file HologramGenerator.h.

9.3.4.46 U_complex_

```
Complex* HologramGenerator::U_complex_  [private]
```

Definition at line 242 of file HologramGenerator.h.

9.3.4.47 WAVELENGTH

```
double HologramGenerator::WAVELENGTH  [private]
```

Definition at line 261 of file HologramGenerator.h.

The documentation for this class was generated from the following files:

- Hologram/HologramGenerator.h
- Hologram/src/HologramGenerator.cpp
- Hologram/src/HologramGenerator_CPU.cpp
- Hologram/src/HologramGenerator_GPU.cpp

9.4 HologramParams Struct Reference

Structure variable for hologram paramemters.

`#include <HologramGenerator.h>`

Public Attributes

- double field_lens
  FIELD_LENS at config file.
- double lambda
  WAVELENGTH at config file.
- double k
  2 ∗ PI / lambda
- ivec2 pn
  SLM_PIXEL_NUMBER_X & SLM_PIXEL_NUMBER_Y.
- vec2 pp
  SLM_PIXEL_PITCH_X & SLM_PIXEL_PITCH_Y.
- vec2 ss
  pn ∗ pp
- double near_depthmap
  NEAR_OF_DEPTH_MAP at config file.
- double far_depthmap
  FAR_OF_DEPTH_MAP at config file.
- uint num_of_depth
  the number of depth level.
- std::vector< int > render_depth
  Used when only few specific depth levels are rendered, usually for test purpose.

9.4.1 Detailed Description

This structure has all necessary parameters for generating a hologram. It is read from the configuration file, 'config↩_openholo.txt'.

Definition at line 100 of file HologramGenerator.h.

9.4.2 Member Data Documentation

9.4.2.1 far_depthmap

`double HologramParams::far_depthmap`

Definition at line 110 of file HologramGenerator.h.

9.4.2.2 field_lens

```
double HologramParams::field_lens
```

Definition at line 102 of file HologramGenerator.h.

9.4.2.3 k

```
double HologramParams::k
```

Definition at line 104 of file HologramGenerator.h.

9.4.2.4 lambda

```
double HologramParams::lambda
```

Definition at line 103 of file HologramGenerator.h.

9.4.2.5 near_depthmap

```
double HologramParams::near_depthmap
```

Definition at line 109 of file HologramGenerator.h.

9.4.2.6 num_of_depth

```
uint HologramParams::num_of_depth
```

```
if FLAG_CHANGE_DEPTH_QUANTIZATION == 0
   num_of_depth = DEFAULT_DEPTH_QUANTIZATION
else
   num_of_depth = NUMBER_OF_DEPTH_QUANTIZATION
```

Definition at line 112 of file HologramGenerator.h.

9.4.2.7 pn

```
ivec2 HologramParams::pn
```

Definition at line 105 of file HologramGenerator.h.

9.4.2.8 pp

```
vec2 HologramParams::pp
```

Definition at line 106 of file HologramGenerator.h.

9.4.2.9 render_depth

```
std::vector<int> HologramParams::render_depth
```

Definition at line 119 of file HologramGenerator.h.

9.4.2.10 ss

```
vec2 HologramParams::ss
```

Definition at line 107 of file HologramGenerator.h.

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

- Hologram/HologramGenerator.h

9.5 graphics::ivec2 Struct Reference

structure for 2-dimensional integer vector and its arithmetic.

```
#include <ivec.h>
```

Public Member Functions

- ivec2 ()
- ivec2 (int a)
- ivec2 (int v_1, int v_2)
- ivec2 (const ivec2 &a)
- ivec2 & operator= (const ivec2 &a)
- int & operator[ ] (int i)
- const int & operator[ ] (int i) const
- int & operator() (int i)
- const int & operator() (int i) const

Public Attributes

- int v [2]

Static Public Attributes

- static const int n

9.5.1 Detailed Description

Definition at line 14 of file ivec.h.

9.5.2 Constructor & Destructor Documentation

9.5.2.1 ivec2() [1/4]

```
graphics::ivec2::ivec2 ( )  [inline]
```

Definition at line 18 of file ivec.h.

9.5.2.2 ivec2() [2/4]

```
graphics::ivec2::ivec2 (
            int a )  [inline]
```

Definition at line 20 of file ivec.h.

9.5.2.3 ivec2() [3/4]

```
graphics::ivec2::ivec2 (
            int v_1,
            int v_2 )  [inline]
```

Definition at line 25 of file ivec.h.

9.5.2.4 ivec2() [4/4]

```
graphics::ivec2::ivec2 (
            const ivec2 & a )  [inline]
```

Definition at line 30 of file ivec.h.

9.5.3 Member Function Documentation

9.5.3.1 operator()() [1/2]

```
int& graphics::ivec2::operator() (
            int i )  [inline]
```

Definition at line 44 of file ivec.h.

9.5.3.2 operator()() [2/2]

```
const int& graphics::ivec2::operator() (
            int i ) const  [inline]
```

Definition at line 45 of file ivec.h.

9.5.3.3 operator=()

```
ivec2& graphics::ivec2::operator= (
            const ivec2 & a )  [inline]
```

Definition at line 35 of file ivec.h.

9.5.3.4 operator[]() [1/2]

```
int& graphics::ivec2::operator[] (
            int i )  [inline]
```

Definition at line 42 of file ivec.h.

9.5.3.5 operator[]() [2/2]

```
const int& graphics::ivec2::operator[] (
            int i ) const  [inline]
```

Definition at line 43 of file ivec.h.

9.5.4 Member Data Documentation

9.5.4.1 n

```
const int graphics::ivec2::n  [static]
```

Definition at line 16 of file ivec.h.

9.5.4.2 v

```
int graphics::ivec2::v[2]
```

Definition at line 15 of file ivec.h.

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

- graphics/ivec.h

9.6 graphics::ivec3 Struct Reference

structure for 3-dimensional integer vector and its arithmetic.

```
#include <ivec.h>
```

Public Member Functions

- ivec3 ()
- ivec3 (int a)
- ivec3 (int v_1, int v_2, int v_3)
- ivec3 (const ivec3 &a)
- ivec3 & operator= (const ivec3 &a)
- int & operator[ ] (int i)
- const int & operator[ ] (int i) const
- int & operator() (int i)
- const int & operator() (int i) const

Public Attributes

- int v [3]

Static Public Attributes

- static const int n

9.6.1 Detailed Description

Definition at line 331 of file ivec.h.

9.6.2 Constructor & Destructor Documentation

9.6.2.1 ivec3() [1/4]

```
graphics::ivec3::ivec3 ( )  [inline]
```

Definition at line 335 of file ivec.h.

9.6.2.2 ivec3() [2/4]

```
graphics::ivec3::ivec3 (
            int a )  [inline]
```

Definition at line 337 of file ivec.h.

9.6.2.3 ivec3() [3/4]

```
graphics::ivec3::ivec3 (
            int v_1,
            int v_2,
            int v_3 )  [inline]
```

Definition at line 342 of file ivec.h.

9.6.2.4 ivec3() [4/4]

```
graphics::ivec3::ivec3 (
            const ivec3 & a )  [inline]
```

Definition at line 347 of file ivec.h.

9.6.3 Member Function Documentation

9.6.3.1 operator()() [1/2]

```
int& graphics::ivec3::operator() (
            int i )  [inline]
```

Definition at line 361 of file ivec.h.

9.6.3.2 operator()() [2/2]

```
const int& graphics::ivec3::operator() (
            int i ) const  [inline]
```

Definition at line 362 of file ivec.h.

9.6.3.3 operator=()

```
ivec3& graphics::ivec3::operator= (
            const ivec3 & a )  [inline]
```

Definition at line 352 of file ivec.h.

9.6.3.4 operator[]() [1/2]

```
int& graphics::ivec3::operator[] (
            int i )  [inline]
```

Definition at line 359 of file ivec.h.

9.6.3.5 operator[]() [2/2]

```
const int& graphics::ivec3::operator[] (
            int i ) const  [inline]
```

Definition at line 360 of file ivec.h.

9.6.4 Member Data Documentation

9.6.4.1 n

```
const int graphics::ivec3::n  [static]
```

Definition at line 333 of file ivec.h.

9.6.4.2 v

```
int graphics::ivec3::v[3]
```

Definition at line 332 of file ivec.h.

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

- graphics/ivec.h

9.7 graphics::ivec4 Struct Reference

structure for 4-dimensional integer vector and its arithmetic.

```
#include <ivec.h>
```

Public Member Functions

- ivec4 ()
- ivec4 (int a)
- ivec4 (int v_1, int v_2, int v_3, int v_4)
- ivec4 (const ivec4 &a)
- ivec4 & operator= (const ivec4 &a)
- int & operator[ ] (int i)
- const int & operator[ ] (int i) const
- int & operator() (int i)
- const int & operator() (int i) const

Public Attributes

- int v [4]

Static Public Attributes

- static const int n

9.7.1 Detailed Description

Definition at line 643 of file ivec.h.

9.7.2 Constructor & Destructor Documentation

9.7.2.1 ivec4() [1/4]

```
graphics::ivec4::ivec4 ( )  [inline]
```

Definition at line 647 of file ivec.h.

9.7.2.2 ivec4() [2/4]

```
graphics::ivec4::ivec4 (
            int a )  [inline]
```

Definition at line 649 of file ivec.h.

9.7.2.3 ivec4() [3/4]

```
graphics::ivec4::ivec4 (
            int v_1,
            int v_2,
            int v_3,
            int v_4 )  [inline]
```

Definition at line 654 of file ivec.h.

9.7.2.4 ivec4() [4/4]

```
graphics::ivec4::ivec4 (
            const ivec4 & a )  [inline]
```

Definition at line 659 of file ivec.h.

9.7.3 Member Function Documentation

9.7.3.1 operator()() [1/2]

```
int& graphics::ivec4::operator() (
            int i )  [inline]
```

Definition at line 673 of file ivec.h.

9.7.3.2 operator()() [2/2]

```
const int& graphics::ivec4::operator() (
            int i ) const  [inline]
```

Definition at line 674 of file ivec.h.

9.7.3.3 operator=()

```
ivec4& graphics::ivec4::operator= (
            const ivec4 & a )  [inline]
```

Definition at line 664 of file ivec.h.

9.7.3.4 operator[]() [1/2]

```
int& graphics::ivec4::operator[] (
            int i )  [inline]
```

Definition at line 671 of file ivec.h.

9.7.3.5 operator[]() [2/2]

```
const int& graphics::ivec4::operator[] (
            int i ) const  [inline]
```

Definition at line 672 of file ivec.h.

9.7.4 Member Data Documentation

9.7.4.1 n

```
const int graphics::ivec4::n  [static]
```

Definition at line 645 of file ivec.h.

9.7.4.2 v

```
int graphics::ivec4::v[4]
```

Definition at line 644 of file ivec.h.

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

- graphics/ivec.h

9.8 graphics::vec2 Struct Reference

structure for 2-dimensional real type vector and its arithmetic.

```
#include <vec.h>
```

Public Member Functions

- vec2 ()
- vec2 (real a)
- vec2 (real v_1, real v_2)
- vec2 (const ivec2 &a)
- vec2 (const vec2 &a)
- vec2 & operator= (const vec2 &a)
- real & operator[ ] (int i)
- const real & operator[ ] (int i) const
- real & operator() (int i)
- const real & operator() (int i) const
- bool unit ()
- real length () const
- bool is_zero () const
- bool is_tiny (real tiny_tol=epsilon) const
- int is_parallel (const vec2 &, real=angle_tolerance) const
- bool is_perpendicular (const vec2 &, real=angle_tolerance) const
- bool perpendicular (const vec2 &)
- bool perpendicular (const vec2 &, const vec2 &)

Public Attributes

- real v [2]

Static Public Attributes

- static const int n = 2

9.8.1 Detailed Description

Definition at line 22 of file vec.h.

9.8.2 Constructor & Destructor Documentation

9.8.2.1 vec2() [1/5]

```
graphics::vec2::vec2 ( )  [inline]
```

Definition at line 26 of file vec.h.

9.8.2.2 vec2() [2/5]

```
graphics::vec2::vec2 (
            real a )  [inline]
```

Definition at line 27 of file vec.h.

9.8.2.3 vec2() [3/5]

```
graphics::vec2::vec2 (
            real v_1,
            real v_2 )  [inline]
```

Definition at line 32 of file vec.h.

9.8.2.4 vec2() [4/5]

```
graphics::vec2::vec2 (
            const ivec2 & a )  [inline]
```

Definition at line 37 of file vec.h.

9.8.2.5 vec2() [5/5]

```
graphics::vec2::vec2 (
            const vec2 & a )  [inline]
```

Definition at line 42 of file vec.h.

9.8.3 Member Function Documentation

9.8.3.1 is_parallel()

```
int graphics::vec2::is_parallel (
            const vec2 & vv,
            real angle_tolerance = angle_tolerance ) const
```

Definition at line 22 of file vec.cpp.

9.8.3.2 is_perpendicular()

```
bool graphics::vec2::is_perpendicular (
            const vec2 & vv,
            real angle_tolerance = angle_tolerance ) const
```

Definition at line 44 of file vec.cpp.

9.8.3.3 is_tiny()

```
bool graphics::vec2::is_tiny (
            real tiny_tol = epsilon ) const  [inline]
```

Definition at line 62 of file vec.h.

9.8.3.4 is_zero()

```
bool graphics::vec2::is_zero ( ) const  [inline]
```

Definition at line 61 of file vec.h.

9.8.3.5 length()

```
real graphics::vec2::length ( ) const
```

Definition at line 17 of file vec.cpp.

9.8.3.6 operator()() [1/2]

```
real& graphics::vec2::operator() (
            int i )  [inline]
```

Definition at line 55 of file vec.h.

9.8.3.7 operator()() [2/2]

```
const real& graphics::vec2::operator() (
            int i ) const  [inline]
```

Definition at line 56 of file vec.h.

9.8.3.8 operator=()

```
vec2& graphics::vec2::operator= (
            const vec2 & a )  [inline]
```

Definition at line 47 of file vec.h.

9.8.3.9 operator[]() [1/2]

```
real& graphics::vec2::operator[] (
            int i )  [inline]
```

Definition at line 53 of file vec.h.

9.8.3.10 operator[]() [2/2]

```
const real& graphics::vec2::operator[] (
            int i ) const  [inline]
```

Definition at line 54 of file vec.h.

9.8.3.11 perpendicular() [1/2]

```
bool graphics::vec2::perpendicular (
            const vec2 & vv )
```

Definition at line 62 of file vec.cpp.

9.8.3.12 perpendicular() [2/2]

```
bool graphics::vec2::perpendicular (
            const vec2 & p,
            const vec2 & q )
```

Definition at line 73 of file vec.cpp.

9.8.3.13 unit()

```
bool graphics::vec2::unit ( )
```

Definition at line 8 of file vec.cpp.

9.8.4 Member Data Documentation

9.8.4.1 n

```
const int graphics::vec2::n = 2  [static]
```

Definition at line 24 of file vec.h.

9.8.4.2 v

```
real graphics::vec2::v[2]
```

Definition at line 23 of file vec.h.

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

- graphics/vec.h
- graphics/src/vec.cpp

9.9 graphics::vec3 Struct Reference

structure for 3-dimensional real type vector and its arithmetic.

```
#include <vec.h>
```

Public Member Functions

- vec3 ()
- vec3 (real a)
- vec3 (real v_1, real v_2, real v_3)
- vec3 (const ivec3 &a)
- vec3 (const vec3 &a)
- vec3 & operator= (const vec3 &a)
- real & operator[ ] (int i)
- const real & operator[ ] (int i) const
- real & operator() (int i)
- const real & operator() (int i) const
- bool is_zero () const
- bool is_tiny (real tiny_tol=epsilon) const
- bool unit ()
- real length () const
- int is_parallel (const vec3 &, real=angle_tolerance) const
- bool is_perpendicular (const vec3 &, real=angle_tolerance) const
- bool perpendicular (const vec3 &)
- bool perpendicular (const vec3 &, const vec3 &, const vec3 &)

Public Attributes

- real v [3]

Static Public Attributes

- static const int n = 3

9.9.1 Detailed Description

Definition at line 444 of file vec.h.

9.9.2 Constructor & Destructor Documentation

9.9.2.1 vec3() [1/5]

```
graphics::vec3::vec3 ( )  [inline]
```

Definition at line 448 of file vec.h.

9.9.2.2 vec3() [2/5]

```
graphics::vec3::vec3 (
            real a )  [inline]
```

Definition at line 449 of file vec.h.

9.9.2.3 vec3() [3/5]

```
graphics::vec3::vec3 (
            real v_1,
            real v_2,
            real v_3 )  [inline]
```

Definition at line 454 of file vec.h.

9.9.2.4 vec3() [4/5]

```
graphics::vec3::vec3 (
            const ivec3 & a )  [inline]
```

Definition at line 459 of file vec.h.

9.9.2.5 vec3() [5/5]

```
graphics::vec3::vec3 (
            const vec3 & a )  [inline]
```

Definition at line 464 of file vec.h.

9.9.3 Member Function Documentation

9.9.3.1 is_parallel()

```
int graphics::vec3::is_parallel (
            const vec3 & vv,
            real angle_tolerance = angle_tolerance ) const
```

Definition at line 142 of file vec.cpp.

9.9.3.2 is_perpendicular()

```
bool graphics::vec3::is_perpendicular (
            const vec3 & vv,
            real angle_tolerance = angle_tolerance ) const
```

Definition at line 164 of file vec.cpp.

9.9.3.3 is_tiny()

```
bool graphics::vec3::is_tiny (
            real tiny_tol = epsilon ) const  [inline]
```

Definition at line 481 of file vec.h.

9.9.3.4 is_zero()

```
bool graphics::vec3::is_zero ( ) const  [inline]
```

Definition at line 480 of file vec.h.

9.9.3.5 length()

```
real graphics::vec3::length ( ) const
```

Definition at line 137 of file vec.cpp.

9.9.3.6 operator()() [1/2]

```
real& graphics::vec3::operator() (
            int i )  [inline]
```

Definition at line 477 of file vec.h.

9.9.3.7 operator()() [2/2]

```
const real& graphics::vec3::operator() (
            int i ) const  [inline]
```

Definition at line 478 of file vec.h.

9.9.3.8 operator=()

```
vec3& graphics::vec3::operator= (
            const vec3 & a )  [inline]
```

Definition at line 469 of file vec.h.

9.9.3.9 operator[]() [1/2]

```
real& graphics::vec3::operator[] (
            int i )  [inline]
```

Definition at line 475 of file vec.h.

9.9.3.10 operator[]() [2/2]

```
const real& graphics::vec3::operator[] (
            int i ) const  [inline]
```

Definition at line 476 of file vec.h.

9.9.3.11 perpendicular() [1/2]

```
bool graphics::vec3::perpendicular (
            const vec3 & vv )
```

Definition at line 182 of file vec.cpp.

9.9.3.12 perpendicular() [2/2]

```
bool graphics::vec3::perpendicular (
            const vec3 & P0,
            const vec3 & P1,
            const vec3 & P2 )
```

Definition at line 244 of file vec.cpp.

9.9.3.13 unit()

```
bool graphics::vec3::unit ( )
```

Definition at line 128 of file vec.cpp.

9.9.4 Member Data Documentation

9.9.4.1 n

```
const int graphics::vec3::n = 3  [static]
```

Definition at line 446 of file vec.h.

9.9.4.2 v

```
real graphics::vec3::v[3]
```

Definition at line 445 of file vec.h.

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

- graphics/vec.h
- graphics/src/vec.cpp

9.10 graphics::vec4 Struct Reference

structure for 4-dimensional real type vector and its arithmetic.

`#include <vec.h>`

Public Member Functions

- vec4 ()
- vec4 (real a)
- vec4 (real v_1, real v_2, real v_3, real v_4)
- vec4 (const ivec4 &a)
- vec4 (const vec4 &a)
- vec4 & operator= (const vec4 &a)
- real & operator[ ] (int i)
- const real & operator[ ] (int i) const
- real & operator() (int i)
- const real & operator() (int i) const
- bool is_zero () const
- bool is_tiny (real tiny_tol=epsilon) const
- bool unit ()
- real length () const

Public Attributes

- real v [4]

Static Public Attributes

- static const int n = 4

9.10.1 Detailed Description

Definition at line 864 of file vec.h.

9.10.2 Constructor & Destructor Documentation

9.10.2.1 vec4() [1/5]

`graphics::vec4::vec4 ( ) [inline]`

Definition at line 868 of file vec.h.

9.10.2.2 vec4() [2/5]

```
graphics::vec4::vec4 (
            real a )  [inline]
```

Definition at line 869 of file vec.h.

9.10.2.3 vec4() [3/5]

```
graphics::vec4::vec4 (
            real v_1,
            real v_2,
            real v_3,
            real v_4 )  [inline]
```

Definition at line 874 of file vec.h.

9.10.2.4 vec4() [4/5]

```
graphics::vec4::vec4 (
            const ivec4 & a )  [inline]
```

Definition at line 879 of file vec.h.

9.10.2.5 vec4() [5/5]

```
graphics::vec4::vec4 (
            const vec4 & a )  [inline]
```

Definition at line 884 of file vec.h.

9.10.3 Member Function Documentation

9.10.3.1 is_tiny()

```
bool graphics::vec4::is_tiny (
            real tiny_tol = epsilon ) const  [inline]
```

Definition at line 901 of file vec.h.

9.10.3.2 is_zero()

```
bool graphics::vec4::is_zero ( ) const  [inline]
```

Definition at line 900 of file vec.h.

9.10.3.3 length()

```
real graphics::vec4::length ( ) const
```

Definition at line 353 of file vec.cpp.

9.10.3.4 operator()() [1/2]

```
real& graphics::vec4::operator() (
            int i )  [inline]
```

Definition at line 897 of file vec.h.

9.10.3.5 operator()() [2/2]

```
const real& graphics::vec4::operator() (
            int i ) const  [inline]
```

Definition at line 898 of file vec.h.

9.10.3.6 operator=()

```
vec4& graphics::vec4::operator= (
            const vec4 & a )  [inline]
```

Definition at line 889 of file vec.h.

9.10.3.7 operator[]() [1/2]

```
real& graphics::vec4::operator[] (
            int i )  [inline]
```

Definition at line 895 of file vec.h.

9.10.3.8 operator[]() [2/2]

```
const real& graphics::vec4::operator[] (
            int i ) const  [inline]
```

Definition at line 896 of file vec.h.

9.10.3.9 unit()

```
bool graphics::vec4::unit ( )
```

Definition at line 344 of file vec.cpp.

9.10.4 Member Data Documentation

9.10.4.1 n

```
const int graphics::vec4::n = 4  [static]
```

Definition at line 866 of file vec.h.

9.10.4.2 v

```
real graphics::vec4::v[4]
```

Definition at line 865 of file vec.h.

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

- graphics/vec.h
- graphics/src/vec.cpp

Chapter 10

File Documentation

10.1 graphics/complex.h File Reference

```
#include <iostream>
#include <cmath>
```

Classes

- class Complex

  class for the complex number and its arithmetic.

Variables

- const double PI = 3.14159265358979323846264338327950288419716939937510582097494459230 8
- const double TWO_PI = 2.0∗PI

10.1.1 Variable Documentation

10.1.1.1 PI

```
const double PI = 3.14159265358979323846264338327950288419716939937510582097494459230 8
```

Definition at line 16 of file complex.h.

10.1.1.2 TWO_PI

```
const double TWO_PI = 2.0∗PI
```

Definition at line 17 of file complex.h.

10.2 graphics/epsilon.h File Reference

```
#include "graphics/real.h"
```

Namespaces

- graphics

Functions

- void graphics::set_u_epsilon (real a)
- void graphics::reset_u_epsilon ()
- void graphics::set_zero_epsilon (real a)
- void graphics::reset_zero_epsilon ()
- int graphics::apx_equal (real x, real y)
- int graphics::apx_equal (real x, real y, real eps)

Variables

- real graphics::epsilon = 1.0e-8
- real graphics::user_epsilon = 1.0e-8
- real graphics::intersection_epsilon = 1e-6
- real graphics::sqrt_epsilon = 1.490116119385000000e-8
- real graphics::unset_value = -1.23432101234321e+308
- real graphics::zero_tolerance = 1.0e-12
- real graphics::angle_tolerance = M_PI/180.0
- real graphics::zero_epsilon = 1.0e-12

10.3 graphics/ivec.h File Reference

```
#include <stdio.h>
```

Classes

- struct graphics::ivec2

  structure for 2-dimensional integer vector and its arithmetic.
- struct graphics::ivec3

  structure for 3-dimensional integer vector and its arithmetic.
- struct graphics::ivec4

  structure for 4-dimensional integer vector and its arithmetic.

Namespaces

- graphics

Functions

- ivec2 graphics::operator+ (const ivec2 &a, const ivec2 &b)
- ivec2 graphics::operator+ (int a, const ivec2 &b)
- ivec2 graphics::operator+ (const ivec2 &a, int b)
- ivec2 graphics::operator- (const ivec2 &a, const ivec2 &b)
- ivec2 graphics::operator- (int a, const ivec2 &b)
- ivec2 graphics::operator- (const ivec2 &a, int b)
- ivec2 graphics::operator∗ (const ivec2 &a, const ivec2 &b)
- ivec2 graphics::operator∗ (int a, const ivec2 &b)
- ivec2 graphics::operator∗ (const ivec2 &a, int b)
- ivec2 graphics::operator+= (ivec2 &a, const ivec2 &b)
- ivec2 graphics::operator+= (ivec2 &a, int b)
- ivec2 graphics::operator-= (ivec2 &a, const ivec2 &b)
- ivec2 graphics::operator-= (ivec2 &a, int b)
- ivec2 graphics::operator∗= (ivec2 &a, const ivec2 &b)
- ivec2 graphics::operator∗= (ivec2 &a, int b)
- int graphics::operator== (const ivec2 &a, const ivec2 &b)
- int graphics::operator== (int a, const ivec2 &b)
- int graphics::operator== (const ivec2 &a, int b)
- int graphics::operator< (const ivec2 &a, const ivec2 &b)
- int graphics::operator< (int a, const ivec2 &b)
- int graphics::operator< (const ivec2 &a, int b)
- int graphics::operator<= (const ivec2 &a, const ivec2 &b)
- int graphics::operator<= (int a, const ivec2 &b)
- int graphics::operator<= (const ivec2 &a, int b)
- int graphics::operator> (const ivec2 &a, const ivec2 &b)
- int graphics::operator> (int a, const ivec2 &b)
- int graphics::operator> (const ivec2 &a, int b)
- int graphics::operator>= (const ivec2 &a, const ivec2 &b)
- int graphics::operator>= (int a, const ivec2 &b)
- int graphics::operator>= (const ivec2 &a, int b)
- int graphics::operator!= (const ivec2 &a, const ivec2 &b)
- ivec2 graphics::operator- (const ivec2 &a)
- ivec3 graphics::operator+ (const ivec3 &a, const ivec3 &b)
- ivec3 graphics::operator+ (int a, const ivec3 &b)
- ivec3 graphics::operator+ (const ivec3 &a, int b)
- ivec3 graphics::operator- (const ivec3 &a, const ivec3 &b)
- ivec3 graphics::operator- (int a, const ivec3 &b)
- ivec3 graphics::operator- (const ivec3 &a, int b)
- ivec3 graphics::operator∗ (const ivec3 &a, const ivec3 &b)
- ivec3 graphics::operator∗ (int a, const ivec3 &b)
- ivec3 graphics::operator∗ (const ivec3 &a, int b)
- ivec3 graphics::operator+= (ivec3 &a, const ivec3 &b)
- ivec3 graphics::operator+= (ivec3 &a, int b)
- ivec3 graphics::operator-= (ivec3 &a, const ivec3 &b)
- ivec3 graphics::operator-= (ivec3 &a, int b)
- ivec3 graphics::operator∗= (ivec3 &a, const ivec3 &b)
- ivec3 graphics::operator∗= (ivec3 &a, int b)
- int graphics::operator== (const ivec3 &a, const ivec3 &b)
- int graphics::operator== (int a, const ivec3 &b)
- int graphics::operator== (const ivec3 &a, int b)
- int graphics::operator< (const ivec3 &a, const ivec3 &b)
- int graphics::operator< (int a, const ivec3 &b)
- int graphics::operator< (const ivec3 &a, int b)

- int graphics::operator<= (const ivec3 &a, const ivec3 &b)
- int graphics::operator<= (int a, const ivec3 &b)
- int graphics::operator<= (const ivec3 &a, int b)
- int graphics::operator> (const ivec3 &a, const ivec3 &b)
- int graphics::operator> (int a, const ivec3 &b)
- int graphics::operator> (const ivec3 &a, int b)
- int graphics::operator>= (const ivec3 &a, const ivec3 &b)
- int graphics::operator>= (int a, const ivec3 &b)
- int graphics::operator>= (const ivec3 &a, int b)
- int graphics::operator!= (const ivec3 &a, const ivec3 &b)
- ivec3 graphics::operator- (const ivec3 &a)
- ivec4 graphics::operator+ (const ivec4 &a, const ivec4 &b)
- ivec4 graphics::operator+ (int a, const ivec4 &b)
- ivec4 graphics::operator+ (const ivec4 &a, int b)
- ivec4 graphics::operator- (const ivec4 &a, const ivec4 &b)
- ivec4 graphics::operator- (int a, const ivec4 &b)
- ivec4 graphics::operator- (const ivec4 &a, int b)
- ivec4 graphics::operator* (const ivec4 &a, const ivec4 &b)
- ivec4 graphics::operator* (int a, const ivec4 &b)
- ivec4 graphics::operator* (const ivec4 &a, int b)
- ivec4 graphics::operator+= (ivec4 &a, const ivec4 &b)
- ivec4 graphics::operator+= (ivec4 &a, int b)
- ivec4 graphics::operator-= (ivec4 &a, const ivec4 &b)
- ivec4 graphics::operator-= (ivec4 &a, int b)
- ivec4 graphics::operator*= (ivec4 &a, const ivec4 &b)
- ivec4 graphics::operator*= (ivec4 &a, int b)
- int graphics::operator== (const ivec4 &a, const ivec4 &b)
- int graphics::operator== (int a, const ivec4 &b)
- int graphics::operator== (const ivec4 &a, int b)
- int graphics::operator< (const ivec4 &a, const ivec4 &b)
- int graphics::operator< (int a, const ivec4 &b)
- int graphics::operator< (const ivec4 &a, int b)
- int graphics::operator<= (const ivec4 &a, const ivec4 &b)
- int graphics::operator<= (int a, const ivec4 &b)
- int graphics::operator<= (const ivec4 &a, int b)
- int graphics::operator> (const ivec4 &a, const ivec4 &b)
- int graphics::operator> (int a, const ivec4 &b)
- int graphics::operator> (const ivec4 &a, int b)
- int graphics::operator>= (const ivec4 &a, const ivec4 &b)
- int graphics::operator!= (const ivec4 &a, const ivec4 &b)
- int graphics::operator>= (int a, const ivec4 &b)
- int graphics::operator>= (const ivec4 &a, int b)
- ivec4 graphics::operator- (const ivec4 &a)

10.4 graphics/real.h File Reference

Namespaces

- graphics

Macros

- #define REAL_T_IS_FLOAT 1
- #define _MAXFLOAT ((float)3.40282347e+38)
- #define _MAXDOUBLE ((double)1.7976931348623158e+308)
- #define _MINFLOAT ((float)1.17549435e-38)
- #define _MINDOUBLE ((double)2.2250738585072014e-308)
- #define M_PI 3.14159265358979323846264338327950288419716939937510582097494459230 8
- #define MINREAL _MINDOUBLE;
- #define MAXREAL _MAXDOUBLE;

Typedefs

- typedef double real
- typedef float real_t

10.4.1 Macro Definition Documentation

10.4.1.1 _MAXDOUBLE

```
#define _MAXDOUBLE ((double)1.7976931348623158e+308)
```

Definition at line 16 of file real.h.

10.4.1.2 _MAXFLOAT

```
#define _MAXFLOAT ((float)3.40282347e+38)
```

Definition at line 12 of file real.h.

10.4.1.3 _MINDOUBLE

```
#define _MINDOUBLE ((double)2.2250738585072014e-308)
```

Definition at line 20 of file real.h.

10.4.1.4 _MINFLOAT

```
#define _MINFLOAT ((float)1.17549435e-38)
```

Definition at line 19 of file real.h.

10.4.1.5 M_PI

```
#define M_PI 3.14159265358979323846264338327950288419716939937510582097494459230 8
```

Definition at line 23 of file real.h.

10.4.1.6 MAXREAL

```
#define MAXREAL _MAXDOUBLE;
```

Definition at line 27 of file real.h.

10.4.1.7 MINREAL

```
#define MINREAL _MINDOUBLE;
```

Definition at line 26 of file real.h.

10.4.1.8 REAL_T_IS_FLOAT

```
#define REAL_T_IS_FLOAT 1
```

Definition at line 7 of file real.h.

10.4.2 Typedef Documentation

10.4.2.1 real

```
typedef double real
```

Definition at line 4 of file real.h.

10.4.2.2 real_t

```
typedef float real_t
```

Definition at line 5 of file real.h.

10.5 graphics/src/epsilon.cpp File Reference

```
#include "graphics/epsilon.h"
#include <math.h>
#include "graphics/sys.h"
```

Namespaces

- graphics

Functions

- void graphics::set_u_epsilon (real a)
- void graphics::reset_u_epsilon ()
- void graphics::set_zero_epsilon (real a)
- void graphics::reset_zero_epsilon ()
- int graphics::apx_equal (real x, real y)
- int graphics::apx_equal (real x, real y, real eps)

Variables

- real graphics::save_zero_epsilon = 1.0e-12

10.6 graphics/src/sys.cpp File Reference

```
#include "graphics/sys.h"
#include <stdarg.h>
#include <stdio.h>
```

Functions

- void file_log (const char *fmt,...)
- FILE * file_read_open (const WChar *fname)
- FILE * file_write_open (const WChar *fname)
- FILE * file_read_open (const WChar *fname, const WChar *mode)
- FILE * file_write_open (const WChar *fname, const WChar *mode)
- WChar * string_cpy (WChar *dest, const WChar *src)
- WChar * string_cat (WChar *dest, const WChar *src)
- int string_cmp (const WChar *str1, const WChar *str2)

Variables

- static FILE * fp

10.6.1 Function Documentation

10.6.1.1 file_log()

```
void file_log (
            const char * fmt,
             ...  )
```

Definition at line 7 of file sys.cpp.

10.6.1.2 file_read_open() [1/2]

```
FILE* file_read_open (
            const WChar * fname )
```

Definition at line 38 of file sys.cpp.

10.6.1.3 file_read_open() [2/2]

```
FILE* file_read_open (
            const WChar * fname,
            const WChar * mode )
```

Definition at line 56 of file sys.cpp.

10.6.1.4 file_write_open() [1/2]

```
FILE* file_write_open (
            const WChar * fname )
```

Definition at line 47 of file sys.cpp.

10.6.1.5 file_write_open() [2/2]

```
FILE* file_write_open (
            const WChar * fname,
            const WChar * mode )
```

Definition at line 65 of file sys.cpp.

10.6.1.6 string_cat()

```
WChar* string_cat (
            WChar * dest,
            const WChar * src )
```

Definition at line 83 of file sys.cpp.

10.6.1.7 string_cmp()

```
int string_cmp (
            const WChar * str1,
            const WChar * str2 )
```

Definition at line 92 of file sys.cpp.

10.6.1.8 string_cpy()

```
WChar* string_cpy (
            WChar * dest,
            const WChar * src )
```

Definition at line 74 of file sys.cpp.

10.6.2 Variable Documentation

10.6.2.1 fp

```
FILE* fp  [static]
```

Definition at line 5 of file sys.cpp.

10.7 graphics/src/vec.cpp File Reference

```
#include "graphics/vec.h"
```

Namespaces

- graphics

Functions

- void graphics::store (FILE *fp, const vec2 &v)
- int graphics::scan (FILE *fp, const vec2 &v)
- int graphics::apx_equal (const vec2 &a, const vec2 &b)
- int graphics::apx_equal (const vec2 &a, const vec2 &b, real eps)
- void graphics::store (FILE *fp, const vec3 &v)
- int graphics::scan (FILE *fp, const vec3 &v)
- int graphics::apx_equal (const vec3 &a, const vec3 &b)
- int graphics::apx_equal (const vec3 &a, const vec3 &b, real eps)
- void graphics::store (FILE *fp, const vec4 &v)
- int graphics::scan (FILE *fp, const vec4 &v)
- int graphics::apx_equal (const vec4 &a, const vec4 &b)
- int graphics::apx_equal (const vec4 &a, const vec4 &b, real eps)
- vec3 graphics::cross (const vec3 &a, const vec3 &b)

10.8 graphics/sys.h File Reference

```
#include <stdio.h>
#include <sys/stat.h>
#include <fcntl.h>
#include <sys/types.h>
```

Macros

- #define FLOG fprintf

Functions

- FILE * file_read_open (const WChar *fname)
- FILE * file_write_open (const WChar *fname)
- FILE * file_read_open (const WChar *fname, const WChar *mode)
- FILE * file_write_open (const WChar *fname, const WChar *mode)
- WChar * string_cpy (WChar *dest, const WChar *src)
- WChar * string_cat (WChar *dest, const WChar *src)
- int string_cmp (const WChar *str1, const WChar *str2)

10.8.1 Macro Definition Documentation

10.8.1.1 FLOG

```
#define FLOG fprintf
```

Definition at line 73 of file sys.h.

10.8.2 Function Documentation

10.8.2.1 file_read_open() [1/2]

```
FILE* file_read_open (
            const WChar * fname )
```

Definition at line 38 of file sys.cpp.

10.8.2.2 file_read_open() [2/2]

```
FILE* file_read_open (
            const WChar * fname,
            const WChar * mode )
```

Definition at line 56 of file sys.cpp.

10.8.2.3 file_write_open() [1/2]

```
FILE* file_write_open (
            const WChar * fname )
```

Definition at line 47 of file sys.cpp.

10.8.2.4 file_write_open() [2/2]

```
FILE* file_write_open (
            const WChar * fname,
            const WChar * mode )
```

Definition at line 65 of file sys.cpp.

10.8.2.5 string_cat()

```
WChar* string_cat (
            WChar * dest,
            const WChar * src )
```

Definition at line 83 of file sys.cpp.

10.8.2.6 string_cmp()

```
int string_cmp (
            const WChar * str1,
            const WChar * str2 )
```

Definition at line 92 of file sys.cpp.

10.8.2.7 string_cpy()

```
WChar* string_cpy (
            WChar * dest,
            const WChar * src )
```

Definition at line 74 of file sys.cpp.

10.9 graphics/vec.h File Reference

```
#include "graphics/real.h"
#include "graphics/ivec.h"
#include "graphics/epsilon.h"
#include <math.h>
#include <stdio.h>
```

Classes

- struct graphics::vec2

  structure for 2-dimensional real type vector and its arithmetic.
- struct graphics::vec3

  structure for 3-dimensional real type vector and its arithmetic.
- struct graphics::vec4

  structure for 4-dimensional real type vector and its arithmetic.

Namespaces

- graphics

Functions

- vec2 graphics::operator+ (const vec2 &a, const vec2 &b)
- vec2 graphics::operator+ (real a, const vec2 &b)
- vec2 graphics::operator+ (const vec2 &a, real b)
- vec2 graphics::operator- (const vec2 &a, const vec2 &b)
- vec2 graphics::operator- (real a, const vec2 &b)
- vec2 graphics::operator- (const vec2 &a, real b)
- vec2 graphics::operator∗ (const vec2 &a, const vec2 &b)
- vec2 graphics::operator∗ (real a, const vec2 &b)
- vec2 graphics::operator∗ (const vec2 &a, real b)
- vec2 graphics::operator/ (const vec2 &a, const vec2 &b)
- vec2 graphics::operator/ (real a, const vec2 &b)
- vec2 graphics::operator/ (const vec2 &a, real b)
- vec2 graphics::operator+= (vec2 &a, const vec2 &b)
- vec2 graphics::operator+= (vec2 &a, real b)
- vec2 graphics::operator-= (vec2 &a, const vec2 &b)
- vec2 graphics::operator-= (vec2 &a, real b)
- vec2 graphics::operator∗= (vec2 &a, const vec2 &b)
- vec2 graphics::operator∗= (vec2 &a, real b)
- vec2 graphics::operator/= (vec2 &a, const vec2 &b)
- vec2 graphics::operator/= (vec2 &a, real b)
- int graphics::operator== (const vec2 &a, const vec2 &b)
- int graphics::operator== (real a, const vec2 &b)
- int graphics::operator== (const vec2 &a, real b)
- int graphics::operator< (const vec2 &a, const vec2 &b)
- int graphics::operator< (real a, const vec2 &b)
- int graphics::operator< (const vec2 &a, real b)
- int graphics::operator<= (const vec2 &a, const vec2 &b)
- int graphics::operator<= (real a, const vec2 &b)
- int graphics::operator<= (const vec2 &a, real b)
- int graphics::operator> (const vec2 &a, const vec2 &b)
- int graphics::operator> (real a, const vec2 &b)
- int graphics::operator> (const vec2 &a, real b)
- int graphics::operator>= (const vec2 &a, const vec2 &b)
- int graphics::operator>= (real a, const vec2 &b)
- int graphics::operator>= (const vec2 &a, real b)
- vec2 graphics::operator- (const vec2 &a)
- real graphics::sum (const vec2 &a)
- real graphics::inner (const vec2 &a, const vec2 &b)
- real graphics::norm (const vec2 &a)
- real graphics::squaredNorm (const vec2 &a)
- vec2 graphics::unit (const vec2 &a)
- real graphics::angle (const vec2 &a, const vec2 &b)
- vec2 graphics::proj (const vec2 &axis, const vec2 &a)
- vec2 graphics::absolute (const vec2 &val)
- void graphics::store (FILE ∗fp, const vec2 &v)
- int graphics::scan (FILE ∗fp, const vec2 &v)
- int graphics::apx_equal (const vec2 &a, const vec2 &b)
- int graphics::apx_equal (const vec2 &a, const vec2 &b, real eps)
- vec3 graphics::operator+ (const vec3 &a, const vec3 &b)
- vec3 graphics::operator+ (real a, const vec3 &b)
- vec3 graphics::operator+ (const vec3 &a, real b)
- vec3 graphics::operator- (const vec3 &a, const vec3 &b)
- vec3 graphics::operator- (real a, const vec3 &b)

- vec3 graphics::operator- (const vec3 &a, real b)
- vec3 graphics::operator∗ (const vec3 &a, const vec3 &b)
- vec3 graphics::operator∗ (real a, const vec3 &b)
- vec3 graphics::operator∗ (const vec3 &a, real b)
- vec3 graphics::operator/ (const vec3 &a, const vec3 &b)
- vec3 graphics::operator/ (real a, const vec3 &b)
- vec3 graphics::operator/ (const vec3 &a, real b)
- vec3 graphics::operator+= (vec3 &a, const vec3 &b)
- vec3 graphics::operator+= (vec3 &a, real b)
- vec3 graphics::operator-= (vec3 &a, const vec3 &b)
- vec3 graphics::operator-= (vec3 &a, real b)
- vec3 graphics::operator∗= (vec3 &a, const vec3 &b)
- vec3 graphics::operator∗= (vec3 &a, real b)
- vec3 graphics::operator/= (vec3 &a, const vec3 &b)
- vec3 graphics::operator/= (vec3 &a, real b)
- int graphics::operator== (const vec3 &a, const vec3 &b)
- int graphics::operator== (real a, const vec3 &b)
- int graphics::operator== (const vec3 &a, real b)
- int graphics::operator< (const vec3 &a, const vec3 &b)
- int graphics::operator< (real a, const vec3 &b)
- int graphics::operator< (const vec3 &a, real b)
- int graphics::operator<= (const vec3 &a, const vec3 &b)
- int graphics::operator<= (real a, const vec3 &b)
- int graphics::operator<= (const vec3 &a, real b)
- int graphics::operator> (const vec3 &a, const vec3 &b)
- int graphics::operator> (real a, const vec3 &b)
- int graphics::operator> (const vec3 &a, real b)
- int graphics::operator>= (const vec3 &a, const vec3 &b)
- int graphics::operator>= (real a, const vec3 &b)
- int graphics::operator>= (const vec3 &a, real b)
- vec3 graphics::operator- (const vec3 &a)
- vec3 graphics::absolute (const vec3 &val)
- real graphics::sum (const vec3 &a)
- real graphics::inner (const vec3 &a, const vec3 &b)
- real graphics::squaredNorm (const vec3 &a)
- real graphics::norm (const vec3 &a)
- vec3 graphics::unit (const vec3 &a)
- real graphics::angle (const vec3 &a, const vec3 &b)
- vec3 graphics::proj (const vec3 &axis, const vec3 &a)
- void graphics::store (FILE ∗fp, const vec3 &v)
- int graphics::scan (FILE ∗fp, const vec3 &v)
- int graphics::apx_equal (const vec3 &a, const vec3 &b)
- int graphics::apx_equal (const vec3 &a, const vec3 &b, real eps)
- vec4 graphics::operator+ (const vec4 &a, const vec4 &b)
- vec4 graphics::operator+ (real a, const vec4 &b)
- vec4 graphics::operator+ (const vec4 &a, real b)
- vec4 graphics::operator- (const vec4 &a, const vec4 &b)
- vec4 graphics::operator- (real a, const vec4 &b)
- vec4 graphics::operator- (const vec4 &a, real b)
- vec4 graphics::operator∗ (const vec4 &a, const vec4 &b)
- vec4 graphics::operator∗ (real a, const vec4 &b)
- vec4 graphics::operator∗ (const vec4 &a, real b)
- vec4 graphics::operator/ (const vec4 &a, const vec4 &b)
- vec4 graphics::operator/ (real a, const vec4 &b)
- vec4 graphics::operator/ (const vec4 &a, real b)

- vec4 graphics::operator+= (vec4 &a, const vec4 &b)
- vec4 graphics::operator+= (vec4 &a, real b)
- vec4 graphics::operator-= (vec4 &a, const vec4 &b)
- vec4 graphics::operator-= (vec4 &a, real b)
- vec4 graphics::operator*= (vec4 &a, const vec4 &b)
- vec4 graphics::operator*= (vec4 &a, real b)
- vec4 graphics::operator/= (vec4 &a, const vec4 &b)
- vec4 graphics::operator/= (vec4 &a, real b)
- int graphics::operator== (const vec4 &a, const vec4 &b)
- int graphics::operator== (real a, const vec4 &b)
- int graphics::operator== (const vec4 &a, real b)
- int graphics::operator< (const vec4 &a, const vec4 &b)
- int graphics::operator< (real a, const vec4 &b)
- int graphics::operator< (const vec4 &a, real b)
- int graphics::operator<= (const vec4 &a, const vec4 &b)
- int graphics::operator<= (real a, const vec4 &b)
- int graphics::operator<= (const vec4 &a, real b)
- int graphics::operator> (const vec4 &a, const vec4 &b)
- int graphics::operator> (real a, const vec4 &b)
- int graphics::operator> (const vec4 &a, real b)
- int graphics::operator>= (const vec4 &a, const vec4 &b)
- int graphics::operator>= (real a, const vec4 &b)
- int graphics::operator>= (const vec4 &a, real b)
- vec4 graphics::operator- (const vec4 &a)
- vec4 graphics::absolute (const vec4 &val)
- real graphics::sum (const vec4 &a)
- real graphics::inner (const vec4 &a, const vec4 &b)
- real graphics::squaredNorm (const vec4 &a)
- real graphics::norm (const vec4 &a)
- vec4 graphics::unit (const vec4 &a)
- real graphics::angle (const vec4 &a, const vec4 &b)
- vec4 graphics::proj (const vec4 &axis, const vec4 &a)
- void graphics::store (FILE *fp, const vec4 &v)
- int graphics::scan (FILE *fp, const vec4 &v)
- int graphics::apx_equal (const vec4 &a, const vec4 &b)
- int graphics::apx_equal (const vec4 &a, const vec4 &b, real eps)
- vec3 graphics::cross (const vec3 &a, const vec3 &b)

10.10 Hologram/HologramGenerator.h File Reference

```
#include <graphics/vec.h>
#include <graphics/complex.h>
#include <QtCore/QDir>
#include <QtCore/QFile>
#include <QtGui/QImage>
#include <QtWidgets/qmessagebox.h>
#include <vector>
#include <cufft.h>
#include "Hologram/fftw3.h"
```

Classes

- struct HologramParams

  Structure variable for hologram paramemters.
- class HologramGenerator

  Main class for generating a hologram using depth map data.

10.11 Hologram/src/HologramGenerator.cpp File Reference

```
#include "Hologram/HologramGenerator.h"
#include <fstream>
#include <sstream>
#include <random>
#include "graphics/sys.h"
#include <QtScript/QScriptEngine>
#include <QtCore/QRegularExpression>
```

10.12 Hologram/src/HologramGenerator_CPU.cpp File Reference

```
#include "Hologram/HologramGenerator.h"
#include "graphics/sys.h"
```

Variables

- fftw_plan fft_plan_fwd_
- fftw_plan fft_plan_bwd_

10.12.1 Variable Documentation

10.12.1.1 fft_plan_bwd_

```
fftw_plan fft_plan_bwd_
```

Definition at line 6 of file HologramGenerator_CPU.cpp.

10.12.1.2 fft_plan_fwd_

```
fftw_plan fft_plan_fwd_
```

Definition at line 5 of file HologramGenerator_CPU.cpp.

10.13 Hologram/src/HologramGenerator_GPU.cpp File Reference

```
#include "Hologram/HologramGenerator.h"
#include "graphics/sys.h"
#include <cuda_runtime.h>
#include <cufft.h>
```

Macros

- #define HANDLE_ERROR(err) (HandleError(err, __FILE__, __LINE__))
- #define HANDLE_NULL(a)

Functions

- static void HandleError (cudaError_t err, const char *file, int line)
- void cudaFFT (CUstream_st *stream, int nx, int ny, cufftDoubleComplex *in_filed, cufftDoubleComplex *output_field, int direction, bool bNormailized=false)

  Convert data from the spatial domain to the frequency domain using 2D FFT on GPU.
- void cudaCropFringe (CUstream_st *stream, int nx, int ny, cufftDoubleComplex *in_field, cufftDoubleComplex *out_field, int cropx1, int cropx2, int cropy1, int cropy2)

  Crop input data according to x, y coordinates on GPU.
- void cudaDepthHoloKernel (CUstream_st *stream, int pnx, int pny, cufftDoubleComplex *u_o_gpu_, unsigned char *img_src_gpu_, unsigned char *dimg_src_gpu_, double *depth_index_gpu_, int dtr, double rand_phase_val_a, double rand_phase_val_b, double carrier_phase_delay_a, double carrier_phase_delay_b, int flag_change_depth_quan, unsigned int default_depth_quan)

  Find each depth plane of the input image and apply carrier phase delay to it on GPU.
- void cudaPropagation_AngularSpKernel (CUstream_st *stream_, int pnx, int pny, cufftDoubleComplex *input_d, cufftDoubleComplex *u_complex, double ppx, double ppy, double ssx, double ssy, double lambda, double params_k, double propagation_dist)

  Angular spectrum propagation method for GPU implementation.
- void cudaGetFringe (CUstream_st *stream, int pnx, int pny, cufftDoubleComplex *in_field, cufftDoubleComplex *out_field, int sig_locationx, int sig_locationy, double ssx, double ssy, double ppx, double ppy, double PI)

  Encode the CGH according to a signal location parameter on the GPU.
- void cudaChangeDepthQuanKernel (CUstream_st *stream_, int pnx, int pny, double *depth_index_gpu, unsigned char *dimg_src_gpu, int dtr, double d1, double d2, double params_num_of_depth, double params_far_depthmap, double params_near_depthmap)

  Quantize depth map on the GPU, only when the number of depth quantization is not the default value (i.e. FLAG_CHANGE_DEPTH_QUANTIZATION == 1).

Variables

- cufftDoubleComplex * u_o_gpu_
- cufftDoubleComplex * u_complex_gpu_
- cufftDoubleComplex * k_temp_d_
- cudaStream_t stream_
- cudaEvent_t start
- cudaEvent_t stop

10.13.1 Macro Definition Documentation

10.13.1.1 HANDLE_ERROR

```
#define HANDLE_ERROR(
              err ) (HandleError( err, __FILE__, __LINE__ ))
```

Definition at line 16 of file HologramGenerator_GPU.cpp.

10.13.1.2 HANDLE_NULL

```
#define HANDLE_NULL(
              a )
```

Value:

```
{if (a == NULL) { \
                            printf( "Host memory failed in %s at line %d\n", \
                                    __FILE__, __LINE__ ); \
                            exit( EXIT_FAILURE );}}
```

Definition at line 19 of file HologramGenerator_GPU.cpp.

10.13.2 Function Documentation

10.13.2.1 HandleError()

```
static void HandleError (
             cudaError_t err,
             const char * file,
             int line )  [static]
```

Definition at line 7 of file HologramGenerator_GPU.cpp.

10.13.3 Variable Documentation

10.13.3.1 k_temp_d_

```
cufftDoubleComplex* k_temp_d_
```

Definition at line 26 of file HologramGenerator_GPU.cpp.

10.13.3.2 start

```
cudaEvent_t start
```

Definition at line 29 of file HologramGenerator_GPU.cpp.

10.13.3.3 stop

```
cudaEvent_t stop
```

Definition at line 29 of file HologramGenerator_GPU.cpp.

10.13.3.4 stream_

```
cudaStream_t stream_
```

Definition at line 28 of file HologramGenerator_GPU.cpp.

10.13.3.5 u_complex_gpu_

```
cufftDoubleComplex* u_complex_gpu_
```

Definition at line 25 of file HologramGenerator_GPU.cpp.

10.13.3.6 u_o_gpu_

```
cufftDoubleComplex* u_o_gpu_
```

Definition at line 24 of file HologramGenerator_GPU.cpp.

10.14 Hologram/src/HologramKernel.cu File Reference

10.15 HologramDepthmap/hologramdepthmap.cpp File Reference

```
#include "hologramdepthmap.h"
#include <QtCore/QTime>
```

10.16 HologramDepthmap/hologramdepthmap.h File Reference

```
#include <QtWidgets/QMainWindow>
#include "ui_hologramdepthmap.h"
#include "Hologram/HologramGenerator.h"
#include "graphics/sys.h"
```

Classes

- class HologramDepthmap

  Test class for executing the sample program, which shows how to use a hologram library.

10.17 HologramDepthmap/main.cpp File Reference

```
#include "hologramdepthmap.h"
#include <QtWidgets/QApplication>
```

Functions

- int main (int argc, char ∗argv[ ])

10.17.1 Function Documentation

10.17.1.1 main()

```
int main (
            int argc,
            char * argv[] )
```

Definition at line 4 of file main.cpp.

Index