

zoomasm-1.0

Claude Heiland-Allen

2020-10-07

Contents

<i>zoomasm</i>	2
Example Videos	2
Prerequisites	2
Prepare Input	3
Using <i>Kalle's Fraktaler 2 +</i>	3
Soundtrack	3
User Guide	3
Quick Start	3
Session	4
Audio	4
Input	5
Colour	5
Timeline	5
Output	6
Keyboard Controls	6
Command Line	6
Build Guide	7
From Linux	7
Prerequisites	7
For Linux	7
Prerequisites	7
Build	7
Run	8
For Windows From Linux	8
Prerequisites	8
Build	9
Run	9
To Do	10
Audio	10
Input	10
Colour	10
Timeline	10
Output	10
Miscellaneous	10
Hacking	10

zoomasm/	10
zoomasm/src/	11
Tips	11
Releases	11
1.0	11
Legal	11
zoomasm	11
GLEW	12
GLFW	13
ingui	13
ingui-filebrowser	14
zlib	14
OpenEXR	15
miniaudio	15
FTW	16
toml++	16

zoomasm

Zoom videos are a genre of 2D fractal animation. The rendering of the final video can be accelerated by computing exponentially spaced rings around the zoom center, before reprojecting to a sequence of flat images.

Some fractal software supports rendering EXR keyframes in exponential map form, which *zoomasm* can assemble into a zoom video. *zoomasm* works from EXR, including raw iteration data, and colouring algorithms can be written in OpenGL shader source code fragments.

Home: <https://mathr.co.uk/zoomasm>

Code: <https://code.mathr.co.uk/zoomasm>

Support: <mailto:zoomasm@mathr.co.uk?subject=zoomasm>

Donate: <https://ko-fi.com/claudeha>

Download: `zoomasm-1.0`

Example Videos

- <https://archive.org/details/charred-bard> / https://www.youtube.com/watch?v=NMKBBk-yf_4
- <https://archive.org/details/special-branch> / <https://www.youtube.com/watch?v=uQDV87vVIxk>
- <https://archive.org/details/kf-exp-map-flat-1>

Prerequisites

- 64bit CPU and OS:
 - Linux works (Debian Buster, Debian Bullseye).
 - Windows not tested (but Wine works on Linux).
 - MacOS not tested.
- 8GB RAM recommended (works with 4GB at low resolutions).
- GPU and drivers supporting OpenGL 3.3 or later (OpenGL 4 is used when available).

- 8GB GPU VRAM recommended (works with 512MB at low resolutions).
- FFmpeg program binary.

Prepare Input

Using *Kalle's Fraktaler 2* +

- Get KF <https://mathr.co.uk/kf/kf.html#kf-2.15>.
KF version 2.15+ is required for exponential map export.
- Launch it and zoom to where you want. It is recommended to enable **Derivatives** computation for analytic distance and slope colouring in *zoomasm*. Enabling **Jitter** is also recommended to avoid Moiré artifacts.
- Set the **Window Size** in KF to 1152x128 (aspect ratio 9:1).
- Set **Image Size** in KF to correspond to desired final video output resolution:
 - 320x180 / 1152x128
 - 640x360 / 2304x256
 - 1280x720 / 4608x512
 - 1920x1080 / 6912x768
 - 3840x2160 / 12288x1365

These are minimum recommendations, going bigger will give a higher quality final output video (you can go smaller too, for lower quality to save time).

The maximum keyframe size in *zoomasm* is limited by GPU capabilities, it is recommended to do a small test first to check that *zoomasm* will be able to handle your keyframes on your hardware.

- Activate **Exponential Map** in the **View** menu. You may use **PageUp** and **PageDown** to fine tune final zoom level.
- Choose which **EXR Channels** you want to save.
- **Store the zoom out sequence** (be sure to save EXR!).
- Wait while it renders (this is often the slow part of the process). You may use the about dialog (? menu) to block accidental input. Alternatively you can render from the command line without any window at all.
- Quit KF.

Soundtrack

- Prepare your soundtrack and save as WAV, FLAC, Ogg Vorbis, or MP3. Alternatively you can work with silence (specify duration).

User Guide

Quick Start

- Select **Audio/Silence** duration or **Audio/Soundtrack** audio file (top left drop-down combo box widget).
- Select **Input/Input** keyframe directory.
- Select **Colour/Colour** and choose one of the **presets/*.gls1**. If a blank image results, pick a different one or check which image channels they need.
- If **Output/FFmpeg** version is not detected, choose your **ffmpeg** (**ffmpeg.exe** on Windows).



Figure 1: Screenshot of zoomasm example session.

- Select **Output/Output** video file (`output.mp4`). Select **Output/Overwrite** if the file already exists and you want to overwrite it.
- Select **Output/Record** to render the zoom video.
- Wait until it finishes rendering.
- Play `output.mp4` in VLC or similar.

Session

- **Save** saves session to TOML text file (`*.toml`).
- **Load** loads session from TOML text file (`*.toml`). **WARNING** do not load session files from untrusted sources, because the path to the FFmpeg binary is stored in the file, which is invoked on load to get FFmpeg version information.
- **Version** displays program version information.
- **Source** exports this *zoomasm*'s source code archive (`*.7z`).

Audio

- **Silence** combo box option to work without audio. Specify duration in seconds. No audio track will be present in the output video file.
- **Soundtrack** combo box option to choose audio file (`*.wav`, `*.flac`, `*.ogg`, `*.mp3`). Detected sample rate, channels and duration are displayed below.
- **Time** slider bar displays current time and allows seeking in the input.
- **Rewind** button resets time to 0.000s (start of file).
- **Stop** button turns off automatic advance.
- **Play** button turns on automatic advance.
- **Loop** checkbox activates loop play mode.
- **1x** button resets playback speed to 1.000x.
- **Speed** slider sets playback speed (reverse and freeze are possible, *zoomasm* uses a phase vocoder for time warping).

- **Mute** checkbox silences output.
- **Volume** slider sets playback volume.
- Counts of any realtime errors (ring buffer overruns, silence due to sample data not being loaded in time) are displayed below, with a **Reset** button to clear.

Input

- **Input** button to choose directory containing exponential map strip keyframes (*.exr).
- Detected count and resolution are displayed.
- **Channels** checkboxes choose which channels from the files to upload to the GPU. Defaults to all channels if there is enough VRAM, no channels otherwise.
- An estimate of GPU VRAM (video memory) usage is displayed.
- **Override** checkbox forces all selected channels to be uploaded, even if there is not enough video memory detected.
- **Reverse** checkbox should be activated if keyframes are stored in zoom-out order (like KF).
- **Flip** checkbox flips each keyframe vertically (for compatibility with other software).
- **Invert** checkbox inverts zoom projection (for special effects).

Colour

- **Colour** button to choose colouring OpenGL GLSL shader fragment (*.glsl). Compilation status is displayed below including compilation error log. Examples in the `presets/` folder include:
 - `binary-decomposition.glsl`: works best with linear smoothing and a custom bailout radius of 25. Uses N and T image channels. Needs a high sample count not to look awful.
 - `cycling-waves.glsl`: colour cycling demo. Uses N and NF image channels for the base colouring, as well as DEX and DEY for slope lighting effect. Uses the T argument (time) to animate colour cycling.
 - `rainbow-fringe.glsl`: simple black on white distance estimate with surrounding rainbows based on the DE direction. Uses the DEX and DEY image channels.
 - `rgb-passthrough.glsl`: just passes through the R, G, B image channels. Tends to look bad if the source keyframes used distance estimates or slopes in their colouring algorithm as the details near the center will be smaller than the edges (*zoomasm* has special compensation for the DEX and DEY channels).
 - `text-overlay.glsl`: same as the previous, but with text overlay using the Z argument (zoom depth in 2x zoom levels) displayed in the top-right corner (assumes 16:9 aspect ratio).
- **Watch** checkbox to reload shader automatically when it is changed (hit save in your favourite text editor, see live colouring changes). The last successfully compiled shader is kept instead of displaying a blank image on errors (this is better for live coding).
- **Samples per pixel** can be increased for better quality (smoother appearance in the center, less “sparkling” during animation) but at higher computational cost (on the GPU).
- **Shutter speed** can be adjusted for motion blur, between 0% and 100% of frame duration (see **Output/FPS**).

Timeline

- **Import** button to import timeline from CSV.
- **Export** button to export timeline to CSV.
- **Headerless** checkbox to import/export CSV without a header line.
- **Interpolated** checkbox to export interpolated timeline (cannot be imported back into *zoomasm*). Set **Output/FPS** for resolution control.

Waypoints in the zoom animation are shown below.

The first (at the start of the soundtrack) and last (at the end of the soundtrack) cannot be deleted, the rest have a - button to remove them (permanently, no undo). If the **Audio/Time** slider is between two waypoints, a cursor appears in red, pressing its + button adds a new waypoint at that time. Each waypoint has a **Z** slider to set zoom depth (in terms of input EXR keyframe index) at the corresponding time (displayed on the left). The interpolation between waypoints is set by the **Interpolation** dropdown combo box, defaulting to (monotone) **Cubic** for smoother speed changes (other options are **Step** and **Linear**). Instantaneous zoom speed in 2x and 10x zooms per second is displayed below the cursor.

Output

- **Record** button launches the video encoder, with a modal dialog blocking input with a progress bar and **Stop** button. The Record button is only displayed when recording is possible (hint: the widgets in red need to be completed). The recording speed is not limited to display vsync (display updates target 20fps). Time elapsed and ETA to completion is displayed.
- **Status** displays current application update frame rate.
- **FFmpeg** button to choose `ffmpeg` (or `ffmpeg.exe` on Windows) program binary. Detected `ffmpeg` version is displayed below.
- **Output** button to choose output video file (`*.mp4`, `*.mkv`, `*.mov`).
- **Overwrite** checkbox to allow overwriting an existing file.
- **Resolution** dropdown (with custom size option) to set video frame size. Information on anti-aliasing level is displayed below (higher texels per pixel is better).
- **FPS** dropdown (with custom framerate option) to set video frames per second.
- **Video CRF** number box to set video encoder Constant Rate Factor quality (0 is lossless/incompatible, 1 is best quality/largest size, 51 is lowest quality/smallest size). Changing the value by 6 will change the file size by a factor of 2, approximately.
- **Audio Bitrate** dropdown (with custom bitrate option) to set audio bitrate in kbps. The special option **Copy** attempts to put the soundtrack into output video file without transcoding (be sure to check encoder messages to see if it worked).
- **FFmpeg log** contains video encoder messages.

Keyboard Controls

When no widget is active:

- Press **Space** to toggle pause/play (when not recording).
- Press **Backspace** to reverse playback speed.
- Press **Enter** or **Return** to add a new waypoint at the current time.
- Press **F10** to toggle the user interface visibility.
- Press **F11** to toggle fullscreen (only on primary monitor so far).

You can press **Tab** to navigate between widgets, and **Ctrl**-clicking a slider allows to enter numbers more precisely.

Command Line

- `--help` (`-h`, `-H`, `-?`) displays `zoomasm` usage information.
- `--version` (`-v`, `-V`) displays version information of `zoomasm` and its supporting libraries.
- `--source` (`-S`) exports `zoomasm`'s source code archive to a file in the current working directory.
- `--fullscreen` (`-f`) starts in fullscreen mode (on primary monitor).
- `--no-fullscreen` (`-F`) starts in windowed mode (default).
- `--gui` (`-g`) show GUI on startup (default).
- `--no-gui` (`-G`) hide GUI on startup.
- `--record` (`-r`) activates recording on startup and quits when it has finished. Requires a session filename to do anything useful.

- `--no-record` (-R) normal interactive mode (default).
- One saved session filename (*.toml) can be added to the command line, which will be loaded before anything else happens.

Build Guide

From Linux

Prerequisites

Whether you are building for Windows or for Linux, you need:

```
sudo apt install git wget xz-utils build-essential p7zip pandoc texlive-latex-recommended
```

For Linux

Prerequisites

- Debian Buster (current stable) works, but newer is recommended.
- Depending on compiler version you might need to add `-lstdc++fs` to the build command in the `src/Makefile`.
- You need an OpenEXR version compatible with C++17; Debian Buster's version is too old, you can upgrade (at time of writing, to version 2.5.3) by:

```
sudo nano /etc/apt/sources.list
# add the line:
deb-src http://deb.debian.org/debian unstable main contrib non-free
# then save and exit nano
sudo apt update
sudo apt install devscripts debhelper
sudo apt build-dep ilmbase
sudo apt build-dep openexr
apt source ilmbase
cd ilmbase-*/
debuild -uc -us -b -d
cd ..
sudo dpkg -i *.deb
sudo apt --fix-broken install
apt source openexr
cd openexr-*/
debuild -uc -us -b -d
cd ..
sudo dpkg -i *.deb
sudo apt --fix-broken install
```

Build

```
sudo apt install git libglew-dev libglfw3-dev libz-dev libopenexr-dev libfftw3-dev ffmpeg pkg-config
mkdir z
cd z
git clone https://code.mathr.co.uk/zoomasm.git
git clone https://github.com/ocornut/imgui.git
git clone https://github.com/AirGuanZ/imgui-filebrowser.git
git clone https://github.com/mackron/miniaudio.git
git clone https://github.com/marzer/tomlplusplus.git
cd zoomasm
```

```
make -C src zoomasm
```

Run

```
./src/zoomasm
```

For Windows From Linux

Prerequisites

- Debian Bullseye (current testing) or newer is recommended
- Install the compiler and runtime:

```
sudo apt install mingw-w64 wine64 cmake unzip
```

- Depending on compiler version you might need to add `-lstdc++fs` to the build command in the `src/Makefile`.
- Debian Buster (current stable) has `mingw-w64 6.0.0-3`, which has a bug that prevents linking with the error:

```
/usr/bin/x86_64-w64-mingw32-ld: \  
/usr/lib/gcc/x86_64-w64-mingw32/8.3-win32/libstdc++fs.a(path.o):(.text$\  
_ZNSt12experimental10filesystem2v17__cxx1116filesystem_error11_M_gen_whatEv+0x639):\  
undefined reference to 'std::filesystem::fs_err_concat(\  
std::__cxx11::basic_string<char, std::char_traits<char>, std::allocator<char> > const&, \  
std::__cxx11::basic_string<char, std::char_traits<char>, std::allocator<char> > const&, \  
std::__cxx11::basic_string<char, std::char_traits<char>, std::allocator<char> > const&)'\  
collect2: error: ld returned 1 exit status
```

- MINGW64 POSIX threading model is needed for C++ `std::thread` etc, so configure that globally:

```
sudo update-alternatives --config x86_64-w64-mingw32-g++  
# select posix variant  
sudo update-alternatives --config x86_64-w64-mingw32-gcc  
# select posix variant  
sudo update-alternatives --config x86_64-w64-mingw32-gfortran  
# select posix variant (if installed)  
sudo update-alternatives --config x86_64-w64-mingw32-gnat  
# select posix variant (if installed)
```

- `*zoomasm` expects dependencies to be installed into `~/win64/`.
- You need `zlib`:

```
mkdir -p ~/win64/src  
cd ~/win64/src  
wget -c https://zlib.net/zlib-1.2.11.tar.xz  
tar xaf zlib-*.tar.xz  
cd zlib-*/  
export CPPFLAGS="-D__USE_MINGW_ANSI_STDIO=1"  
export LDFLAGS="-static-libgcc -static-libstdc++ -Wl,-Bstatic -lpthread -Wl,-Bdynamic"  
CC=x86_64-w64-mingw32-gcc ./configure --static --prefix=$HOME/win64  
CC=x86_64-w64-mingw32-gcc make -j "$(nproc)"  
CC=x86_64-w64-mingw32-gcc make install
```

- You need `OpenEXR` (version 2.5):

```
mkdir -p ~/win64/src  
cd ~/win64/src  
wget -c https://github.com/AcademySoftwareFoundation/openexr/archive/v2.5.3.tar.gz \  

```



```

-0 openexr-2.5.3.tar.gz
tar xaf openexr-*.tar.gz
cd openexr-*/
export CPPFLAGS="-D__USE_MINGW_ANSI_STDIO=1"
export LDFLAGS="-static-libgcc -static-libstdc++ -Wl,-Bstatic -lpthread -Wl,-Bdynamic"
mkdir -p build
cd build
cmake -DBUILD_SHARED_LIBS=OFF -DCMAKE_TOOLCHAIN_FILE=./cmake/Toolchain-mingw.cmake \
  -DCMAKE_INSTALL_PREFIX=$HOME/win64 -DCMAKE_CXX_FLAGS=-I$HOME/win64/include \
  -DZLIB_INCLUDE_DIR=$HOME/win64/include -DZLIB_LIBRARY=$HOME/win64/lib/libz.a ..
make -j "$(nproc)"
make install

```

- You need FFTW (version 3):

```

mkdir -p ~/win64/src
cd ~/win64/src
wget -c http://fftw.org/fftw-3.3.8.tar.gz
tar xaf fftw-*.tar.gz
cd fftw-*/
export CPPFLAGS="-D__USE_MINGW_ANSI_STDIO=1"
export LDFLAGS="-static-libgcc -static-libstdc++ -Wl,-Bstatic -lpthread -Wl,-Bdynamic"
./configure --host=x86_64-w64-mingw32 --prefix="${HOME}/win64" \
  --enable-static --disable-shared --disable-doc --disable-alloca \
  --enable-sse2 --enable-avx --enable-avx2 --enable-avx512 --enable-avx-128-fma \
  --enable-generic-simd128 --enable-generic-simd256 --enable-fma \
  --disable-dependency-tracking --disable-fortran --disable-threads \
  --with-our-malloc --with-our-malloc16 --with-incoming-stack-boundary=2 \
  --enable-portable-binary
make -j "$(nproc)"
make install
make check

```

Build

```

mkdir -p ~/win64/src
cd ~/win64/src
git clone https://code.mathr.co.uk/zoomasm.git
git clone https://github.com/ocornut/imgui.git
git clone https://github.com/AirGuanZ/imgui-filebrowser.git
git clone https://github.com/mackron/miniaudio.git
git clone https://github.com/marzer/tomlplusplus.git
wget -c https://github.com/nigels-com/glew/releases/download/glew-2.1.0/glew-2.1.0.tgz
tar xaf glew-2.1.0.tgz
wget -c https://github.com/glwf/glwf/releases/download/3.3.2/glwf-3.3.2.bin.WIN64.zip
unzip glwf-3.3.2.bin.WIN64.zip
cd zoomasm
make -C src zoomasm.exe

```

Run

```
wine ./src/zoomasm.exe
```

To encode videos, zoomasm.exe needs ffmpeg.exe. Builds are available via: <https://ffmpeg.org/download.html#build-windows>.

To Do

Audio

- Sample-accurate looping with read-ahead for the other side of the loop. (zoomasm-2.0)
- Figure out a way to avoid leaking buffers from the realtime thread if the ringbuffer to the non-realtime thread is full, or prove that it can't happen. (zoomasm-2.0)
- Recycle audio buffer memory instead of freeing and allocating so often. (zoomasm-2.0)
- Investigate zero-padding for FFT (might improve timestretch quality?). (zoomasm-2.0)
- Investigate bad noise with JACK (might be PulseAudio bridge issue?). (zoomasm-2.0)
- Investigate why `miniaudio` takes so long to open a file (might need to decode the whole file to determine length, even for WAV?). (zoomasm-2.0)
- Don't close and reopen device if channels/samplerate didn't change. (zoomasm-2.0)
- Do audio device opening and audio file decoding in a background thread, to decouple from the GUI. (zoomasm-2.0)
- Soundtrack generation from input EXR data. (zoomasm-3.0)
- Soundtrack generation from output RGB data. (zoomasm-3.0)

Input

- Speculatively load EXR keyframes in background thread(s), so hopefully they will be ready when demanded by the main thread. Set size of thread pool according to CPU count (with override). Controls for maximum speculation distance. (zoomasm-2.0)

Colour

- Preset GLSL with default implementation that emulates KF's KFP colouring, and file browser for `*.kfp` or `*.kfr`. (zoomasm-2.0)
- 360 equirectangular projection with selectable zoom focus (up/down, forward/back, left/right). (zoomasm-2.0)
- Built-in text-editor for colouring shader fragment, with save/load to global session settings and export/import to separate `.glsl` file. (zoomasm-2.0)
- Detect active non-internal uniforms in the colouring shader fragment and expose controls in the GUI. (zoomasm-3.0)

Timeline

- Sequence custom uniform values. (zoomasm-3.0)
- Lua (or other embedded language) scripting for controlling uniforms (zoomasm-3.0).

Output

- Advanced mode to set all encoder options manually. (zoomasm-2.0)
- Two-pass encoding (advanced mode only). (zoomasm-2.0)

Miscellaneous

- Display OpenGL debug log in program. (zoomasm-2.0)
- Improve `Makefile` to support parallel builds and object reuse. (zoomasm-2.0)

Hacking

zoomasm/

- `COPYING.md`: GNU Affero General Public License.

- `README.md`: documentation.
- `INDEX.txt`: list of files to include in source code release bundles. Remember to update when adding/removing files, and check that the source code release bundles build correctly.
- `VERSION.txt`: current *zoomasm* version. Should not be checked into version control (it is regenerated from git version information).
- `zoomasm.css`: style sheet for HTML website.
- `zoomasm.png`: screenshot for documentation.
- `Makefile`: top-level build system.

zoomasm/src/

- `Makefile`: build system.
- `s2c.sh`: build system helper (text file contents to C source code).
- `audio.cc`, `audio.h`: audio playback and realtime scheduling.
- `colour.cc`, `colour.h`, `main_frag.glsl`, `main_vert.glsl`: colouring shader management.
- `ffmpeg.cc`, `ffmpeg.h`: interface to FFmpeg process.
- `input.cc`, `input.h`: input EXR keyframe loading.
- `main.cc`: main program
- `output.cc`, `output.h`: recording from OpenGL, and encoder settings.
- `process.h`, `process_posix.cc`, `process_win32.cc`: abstraction for launching subprocesses with bidirectional communication on different operating systems.
- `resource.h`: common constants.
- `session.cc`, `session.h`: session management, version information and source code archive export.
- `timeline.cc`, `timeline.h`: waypoint sequencing.
- `utility.cc`, `utility.h`: miscellaneous utilities.

Tips

- Prevent breakage when writing to FFmpeg pipe fails in `gdb`:

```
handle SIGPIPE nostop noprint pass
```

Releases

Releases are signed with GPG key id EC470ECD90DDE39B6ED67CA6EBC1FED7E3FA39B0.

1.0

- Codename: “felicitats”
- Released: 2020-10-07
- Source: `zoomasm-1.0.7z` (sig)
- Windows: `zoomasm-1.0.exe.7z` (sig)
- Manual: HTML PDF
- Changes:
 - First released version.

Legal

zoomasm

zoomasm – zoom video assembler

Copyright (C) 2019,2020 Claude Heiland-Allen

This program is free software: you can redistribute it and/or modify it under the terms of the GNU Affero General Public License as published by the Free Software Foundation, either version 3 of the License, or (at your option) any later version.

This program is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU Affero General Public License for more details.

You should have received a copy of the GNU Affero General Public License along with this program. If not, see <https://www.gnu.org/licenses/>.

GLEW

GLEW is used under the Modified BSD License, the Mesa 3-D License (MIT) and the Khronos License (MIT). <http://glew.sourceforge.net/>

The OpenGL Extension Wrangler Library

Copyright (C) 2008-2016, Nigel Stewart <nigels@users.sourceforge.net>

Copyright (C) 2002-2008, Milan Ikits <milan.ikits@ieee.org>

Copyright (C) 2002-2008, Marcelo E. Magallon <mmagallo@debian.org>

Copyright (C) 2002, Lev Povalahev

All rights reserved.

Redistribution and use in source and binary forms, with or without modification, are permitted provided that the following conditions are met:

- Redistributions of source code must retain the above copyright notice, this list of conditions and the following disclaimer.
- Redistributions in binary form must reproduce the above copyright notice, this list of conditions and the following disclaimer in the documentation and/or other materials provided with the distribution.
- The name of the author may be used to endorse or promote products derived from this software without specific prior written permission.

THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT OWNER OR CONTRIBUTORS BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

Mesa 3-D graphics library

Version: 7.0

Copyright (C) 1999-2007 Brian Paul All Rights Reserved.

Permission is hereby granted, free of charge, to any person obtaining a copy of this software and associated documentation files (the "Software"), to deal in the Software without restriction, including without limitation the rights to use, copy, modify, merge, publish, distribute, sublicense, and/or sell copies of the Software, and to permit persons to whom the Software is furnished to do so, subject to the following conditions:

The above copyright notice and this permission notice shall be included in all copies or substantial portions of the Software.

THE SOFTWARE IS PROVIDED “AS IS”, WITHOUT WARRANTY OF ANY KIND, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO THE WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE AND NONINFRINGEMENT. IN NO EVENT SHALL BRIAN PAUL BE LIABLE FOR ANY CLAIM, DAMAGES OR OTHER LIABILITY, WHETHER IN AN ACTION OF CONTRACT, TORT OR OTHERWISE, ARISING FROM, OUT OF OR IN CONNECTION WITH THE SOFTWARE OR THE USE OR OTHER DEALINGS IN THE SOFTWARE.

Copyright (c) 2007 The Khronos Group Inc.

Permission is hereby granted, free of charge, to any person obtaining a copy of this software and/or associated documentation files (the “Materials”), to deal in the Materials without restriction, including without limitation the rights to use, copy, modify, merge, publish, distribute, sublicense, and/or sell copies of the Materials, and to permit persons to whom the Materials are furnished to do so, subject to the following conditions:

The above copyright notice and this permission notice shall be included in all copies or substantial portions of the Materials.

THE MATERIALS ARE PROVIDED “AS IS”, WITHOUT WARRANTY OF ANY KIND, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO THE WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE AND NONINFRINGEMENT. IN NO EVENT SHALL THE AUTHORS OR COPYRIGHT HOLDERS BE LIABLE FOR ANY CLAIM, DAMAGES OR OTHER LIABILITY, WHETHER IN AN ACTION OF CONTRACT, TORT OR OTHERWISE, ARISING FROM, OUT OF OR IN CONNECTION WITH THE MATERIALS OR THE USE OR OTHER DEALINGS IN THE MATERIALS.

GLFW

GLFW is used under zlib/libpng license (BSD-style) <https://www.glfw.org/>

Copyright © 2002-2006 Marcus Geelard

Copyright © 2006-2019 Camilla Löwy

This software is provided ‘as-is’, without any express or implied warranty. In no event will the authors be held liable for any damages arising from the use of this software.

Permission is granted to anyone to use this software for any purpose, including commercial applications, and to alter it and redistribute it freely, subject to the following restrictions:

- The origin of this software must not be misrepresented; you must not claim that you wrote the original software. If you use this software in a product, an acknowledgment in the product documentation would be appreciated but is not required.
- Altered source versions must be plainly marked as such, and must not be misrepresented as being the original software.
- This notice may not be removed or altered from any source distribution.

imgui

imgui is used under MIT license (with public domain portions) <https://www.dearimgui.org/>

The MIT License (MIT)

Copyright (c) 2014-2020 Omar Cornut

Permission is hereby granted, free of charge, to any person obtaining a copy of this software and associated documentation files (the “Software”), to deal in the Software without restriction, including without limitation the rights to use, copy, modify, merge, publish, distribute, sublicense, and/or sell copies of the Software, and to permit persons to whom the Software is furnished to do so, subject to the following conditions:

The above copyright notice and this permission notice shall be included in all copies or substantial portions of the Software.

THE SOFTWARE IS PROVIDED “AS IS”, WITHOUT WARRANTY OF ANY KIND, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO THE WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE AND NONINFRINGEMENT. IN NO EVENT SHALL THE AUTHORS OR COPYRIGHT HOLDERS BE LIABLE FOR ANY CLAIM, DAMAGES OR OTHER LIABILITY, WHETHER IN AN ACTION OF CONTRACT, TORT OR OTHERWISE, ARISING FROM, OUT OF OR IN CONNECTION WITH THE SOFTWARE OR THE USE OR OTHER DEALINGS IN THE SOFTWARE.

imgui-filebrowser

imgui-filebrowser is used under MIT license <https://github.com/AirGuanZ/imgui-filebrowser>

MIT License

Copyright (c) 2019-2020 Zhuang Guan

Permission is hereby granted, free of charge, to any person obtaining a copy of this software and associated documentation files (the “Software”), to deal in the Software without restriction, including without limitation the rights to use, copy, modify, merge, publish, distribute, sublicense, and/or sell copies of the Software, and to permit persons to whom the Software is furnished to do so, subject to the following conditions:

The above copyright notice and this permission notice shall be included in all copies or substantial portions of the Software.

THE SOFTWARE IS PROVIDED “AS IS”, WITHOUT WARRANTY OF ANY KIND, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO THE WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE AND NONINFRINGEMENT. IN NO EVENT SHALL THE AUTHORS OR COPYRIGHT HOLDERS BE LIABLE FOR ANY CLAIM, DAMAGES OR OTHER LIABILITY, WHETHER IN AN ACTION OF CONTRACT, TORT OR OTHERWISE, ARISING FROM, OUT OF OR IN CONNECTION WITH THE SOFTWARE OR THE USE OR OTHER DEALINGS IN THE SOFTWARE.

zlib

zlib is used under zlib license (BSD-style) <https://zlib.net/>

Copyright (C) 1995-2017 Jean-loup Gailly and Mark Adler

This software is provided ‘as-is’, without any express or implied warranty. In no event will the authors be held liable for any damages arising from the use of this software.

Permission is granted to anyone to use this software for any purpose, including commercial applications, and to alter it and redistribute it freely, subject to the following restrictions:

1. The origin of this software must not be misrepresented; you must not claim that you wrote the original software. If you use this software in a product, an acknowledgment in the product documentation would be appreciated but is not required.
2. Altered source versions must be plainly marked as such, and must not be misrepresented as being the original software.
3. This notice may not be removed or altered from any source distribution.

Jean-loup Gailly Mark Adler
jloup [] gzip.org madler [] alumni.caltech.edu

OpenEXR

OpenEXR is used under OpenEXR license (BSD-style) <https://www.openexr.com/>

Copyright Contributors to the OpenEXR Project. All rights reserved.

Redistribution and use in source and binary forms, with or without modification, are permitted provided that the following conditions are met:

1. Redistributions of source code must retain the above copyright notice, this list of conditions and the following disclaimer.
2. Redistributions in binary form must reproduce the above copyright notice, this list of conditions and the following disclaimer in the documentation and/or other materials provided with the distribution.
3. Neither the name of the copyright holder nor the names of its contributors may be used to endorse or promote products derived from this software without specific prior written permission.

THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS “AS IS” AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

miniaudio

miniaudio is used under MIT-0 license (or public domain) <https://miniaud.io/>

This software is available as a choice of the following licenses. Choose whichever you prefer.

ALTERNATIVE 1 - Public Domain

This is free and unencumbered software released into the public domain.

Anyone is free to copy, modify, publish, use, compile, sell, or distribute this software, either in source code form or as a compiled binary, for any purpose, commercial or non-commercial, and by any means.

In jurisdictions that recognize copyright laws, the author or authors of this software dedicate any and all copyright interest in the software to the public domain. We make this dedication for the benefit of the public at large and to the detriment of our heirs and successors. We intend this dedication to be an overt act of relinquishment in perpetuity of all present and future rights to this software under copyright law.

THE SOFTWARE IS PROVIDED “AS IS”, WITHOUT WARRANTY OF ANY KIND, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO THE WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE AND NONINFRINGEMENT. IN NO EVENT SHALL THE AUTHORS BE LIABLE FOR ANY CLAIM, DAMAGES OR OTHER LIABILITY, WHETHER IN AN ACTION OF CONTRACT, TORT OR OTHERWISE,

ARISING FROM, OUT OF OR IN CONNECTION WITH THE SOFTWARE OR THE USE OR OTHER DEALINGS IN THE SOFTWARE.

For more information, please refer to <http://unlicense.org/>

ALTERNATIVE 2 - MIT No Attribution

Copyright 2020 David Reid

Permission is hereby granted, free of charge, to any person obtaining a copy of this software and associated documentation files (the “Software”), to deal in the Software without restriction, including without limitation the rights to use, copy, modify, merge, publish, distribute, sublicense, and/or sell copies of the Software, and to permit persons to whom the Software is furnished to do so.

THE SOFTWARE IS PROVIDED “AS IS”, WITHOUT WARRANTY OF ANY KIND, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO THE WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE AND NONINFRINGEMENT. IN NO EVENT SHALL THE AUTHORS OR COPYRIGHT HOLDERS BE LIABLE FOR ANY CLAIM, DAMAGES OR OTHER LIABILITY, WHETHER IN AN ACTION OF CONTRACT, TORT OR OTHERWISE, ARISING FROM, OUT OF OR IN CONNECTION WITH THE SOFTWARE OR THE USE OR OTHER DEALINGS IN THE SOFTWARE.

FFTW

FFTW is used under GPL license (version 2 or later) <http://fftw.org/>

FFTW is Copyright © 2003, 2007-11 Matteo Frigo, Copyright © 2003, 2007-11 Massachusetts Institute of Technology.

FFTW is free software; you can redistribute it and/or modify it under the terms of the GNU General Public License as published by the Free Software Foundation; either version 2 of the License, or (at your option) any later version.

This program is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU General Public License for more details.

You should have received a copy of the GNU General Public License along with this program; if not, write to the Free Software Foundation, Inc., 51 Franklin Street, Fifth Floor, Boston, MA 02110-1301 USA. You can also find the GPL on the GNU web site: <http://www.gnu.org/licenses/gpl-2.0.html>

toml++

toml++ is used under MIT license <https://github.com/marzer/tomlplusplus>

MIT License

Copyright (c) 2019-2020 Mark Gillard <mark.gillard@outlook.com.au>

Permission is hereby granted, free of charge, to any person obtaining a copy of this software and associated documentation files (the “Software”), to deal in the Software without restriction, including without limitation the rights to use, copy, modify, merge, publish, distribute, sublicense, and/or sell copies of the Software, and to permit persons to whom the Software is furnished to do so, subject to the following conditions:

The above copyright notice and this permission notice shall be included in all copies or substantial portions of the Software.

THE SOFTWARE IS PROVIDED “AS IS”, WITHOUT WARRANTY OF ANY KIND, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO THE WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE AND NONINFRINGEMENT. IN NO EVENT SHALL THE AUTHORS OR COPYRIGHT HOLDERS BE LIABLE FOR ANY CLAIM, DAMAGES OR OTHER LIABILITY, WHETHER IN AN ACTION OF CONTRACT, TORT OR OTHERWISE, ARISING FROM, OUT OF OR IN CONNECTION WITH THE SOFTWARE OR THE USE OR OTHER DEALINGS IN THE SOFTWARE.

<https://mathr.co.uk>