ARM® Mali™ Graphics Debugger v1.3.0

User Guide

Non-Confidential

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ARM® MALI™

Visual Computing

Contents

1 Introduction

1.1 Overview

The Mali Graphics Debugger is a tool to help OpenGL® ES and OpenCL™ developers get the best out of their applications through analysis at the API level. The tool allows the user to observe OpenGL ES and OpenCL API call arguments and return values, and to interact with a running target application so as to investigate the effect of individual calls on the target. Attempted misuse of the API is highlighted, as are recommendations for improvement on a Mali-based system. Trace information may also be captured to a file on one system and be analyzed later. The state of the underlying GPU subsystem is observable at any point.

This document describes how to install and use the Mali Graphics Debugger on Windows, Linux and Mac OS X®. It describes how to examine an OpenGL ES 2.0 or OpenGL ES 3.0 application running on a Linux target or an OpenGL ES 2.0 application running on an Android™ target.

1.2 Installation Package

The installation package for the Mali Graphics Debugger contains everything you need to start investigating OpenGL ES 2.0 or 3.0 applications on a desktop computer. Limited support for OpenCL 1.1 is also provided.

You should have downloaded the installation package appropriate to your platform. The Mali Graphics Debugger is available for Windows, Linux and Mac OS X, and comes in both 32-bit and 64-bit variants. Typically, you should download the package that most closely resembles your host environment. If you aren't sure which package to choose, the 32-bit version will work across the widest variety of platforms.

1.3 Components

The installation package contains three main components: the GUI application, the target intercept components and Mali Graphics Debugger sample traces.

1.4 This Release

This is a major release following the 1.2.2 release of the tool and provides the following features, bug fixes, and improvements:

- New frame replay feature (see section 5.2.10 for details)
- A new binary format for tracing (allows for faster tracing)
- Memory performance improvements (allows for longer traces and improved performance of the tool in general)
- Various small GUI tweaks
- Multiple bugs fixes (see section 9.1 for details)

2 Minimum Requirements

The Mali Graphics Debugger has a GUI that runs on a host system, and a shared library that intercepts OpenGL ES 2.0, 3.0 and/or OpenCL calls made by an application running on a target system. The two systems should allow network traffic to pass between them on port 5002. It is possible for a single system to act both as host and target if it meets the criteria for both as set out below.

2.1 Host System Requirements

Your host system should have Oracle Java installed at version 1.6 or later. The host should be able to connect to the target via TCP/IP (for online analysis) and should have port 5002 open.

The installation requires 50MB of disk space.

Up to 2GB of RAM will be claimed by the installed application as it runs. If available, more memory may be allocated to the application, which will allow larger traces to be accommodated.

Up-to-date operating system components and graphics drivers are recommended.

2.2 Increasing Available Memory

Increasing the amount of memory made available to the application will increase the maximum trace size that may be accommodated. To do this, locate the *mgd.ini* file within the application installation and open it with a text editor. Find the Java Virtual Machine (JVM) argument starting with '-Xmx…'. The number that follows the argument defines the maximum amount of memory that the application will claim when running, with a trailing 'm' for megabytes. This number can be increased to match the capabilities of your system. Please note the format for the argument and ensure that your modifications follow the same format exactly (i.e. no spaces, trailing lower-case 'm'). The number you enter must be a multiple of 4.

2.3 Target System Requirements

In general, the Mali Graphics Debugger should work on any Linux system that supports OpenGL ES 2.0 or OpenGL ES 3.0. Limited support is provided in this release for OpenCL 1.1. The system should be able to substitute the existing OpenGL ES or OpenCL system libraries with the supplied intercept libraries. The specific method for doing this is platform-specific.

In addition the application supports Android™ 4.2 & 4.3 (Jelly Bean) and Android 4.4 (KitKat) on the Google Nexus 10 platform (only OpenGL ES 2.0). Other platforms should also work correctly although these have not been tested.

MGD is supported only on target systems using an ARM Mali GPU.

3 Host Installation

3.1 Linux

On Linux, the Mali Graphics Debugger is provided as a gzipped tar archive that can be extracted to any location on disk. This package can be extracted using any modern version (i.e. > 1.13) of GNU `tar`:

```
tar xvzf Mali_Graphics_Debugger_v1.3.0.<build>_Linux_<arch>.tgz
```

The GUI executable is ‘mgd’ within the gui directory.

3.2 Windows

On Windows, the Mali Graphics Debugger is provided as an executable installer package. To install the software, run the installer and follow the instructions on screen. A link to the installed GUI will be added to the Start menu.

3.3 Mac OS X

On Mac OS X, the Mali Graphics Debugger is provided as a dmg package. It can be mounted by double-clicking on it. The GUI executable is ‘mgd’ within the gui directory and can be launched either from the dmg package or from the local filesystem after copying the mounted folder to the local disk.

On Mac OS X version 10.9 (Mavericks) and later, the system will prevent you from running MGD as the package is not signed. The workaround is to hold the CTRL key down when opening the app.

3.4 Target Deliverables

The extracted directory hierarchy on the host will contain a ‘target’ directory containing the following additional directories:

- arm_fbdev
  Containing daemon and libraries for Linux-based ARM target devices.
- armhf_fbdev
  Containing daemon and libraries for Linux-based ARM Hard Float target devices.
- arm_android
  Containing daemon and libraries for Android-based target devices.

Note: you will be required to manually add the libraries to your execution environment, see below for details.

4 Target Installation

4.1 Overview

The Mali Graphics Debugger has two target components that interact to collect and transmit trace information from your application to the GUI on the host. These two target components are:

Intercept Library: The intercept library intercepts calls made by your application to one of the supported libraries and collects information about each call as it is made on the underlying system. The intercept library needs to be loaded before your application starts.

Daemon: The daemon application collects trace data from all running, intercepted applications and passes this data to the host. All data is transferred using TCP/IP using port 5002.

The method for using these components varies by target platform. Instructions for each supported platform are defined below.

4.2 Linux

4.2.1 Prerequisites

- A running OpenGL ES or OpenCL application.
- A network connection to a host running the MGD GUI.
- The target device should permit TCP/IP communication on port 5002.

4.2.2 Installation

Navigate to the target directory and enter either the arm_fbdev folder (soft float implementation) or armhf_fbdev (hard float implementation) according to the configuration of your system. Inside this folder there should be the following:

- libinterceptor.so
- mgddaemon
- libEGL.so
- libGLESv2.so
- libOpenCL.so

These files need to be copied to the target device. The location of the files does not matter as they should be able to run anywhere as long as the user has sufficient privileges. The execute permission bit needs to be set on the mgddaemon application. This can be done using the following command from the directory on the target to which the files were copied.

```
chmod +x ./mgddaemon
```

4.2.3 Run Instructions

To capture traces into MGD the user needs to do the following:

1) Start the daemon running if not already started.
2) Start a capture from the MGD GUI.
3) Start your application with the intercept libraries enabled.

4.2.4 Start the daemon

The daemon should be started before you run your first trace. In a terminal, run:

```
./mgddaemon &
```

from the directory you which you copied the daemon. The daemon can remain running for the duration that MGD is being used, and will handle applications starting and stopping.

4.2.5 Start MGD GUI

Once the daemon has started connect the MGD GUI to the target by starting a capture.

4.2.6 Intercept the application

To intercept the application correctly the system needs to preload the intercept library libinterceptor.so, in the MGD target distribution. To do you need to define the LD_PRELOAD environment variable to point at this library. For example:

```
LD_PRELOAD=/path/to/intercept/libinterceptor.so ./your_app
```

When the application starts, trace data should start to fill the trace window on the MGD GUI.

If you are unable to use LD_PRELOAD on your system there is an alternative; see Section 8.14 for more information.

4.2.7 Uninstalling

To uninstall simply remove the files which were loaded onto the target.

4.3 Android

4.3.1 Prerequisites

- Android Developer Tools (ADT) installed on a machine that connects to the Android device.
- PATH should include the path to the adb binary.
- The target device should be rooted and allow modification of the /system partition.
- The target device should permit TCP/IP communication on port 5002

4.3.2 Installation Instructions for Android 4.2 and 4.3

Run the following commands from a host command line from the target/arm_android directory located in installation directory of the MGD tool.

```
adb shell su -c mount -o remount /system
adb push libGLES_mgd.so /sdcard/
adb push mgddaemon /sdcard/
adb shell
# The following commands run on the target
su
cd /sdcard/
cp mgddaemon /system/bin/mgddaemon
chmod 777 /system/bin/mgddaemon
cp libGLES_mgd.so /system/lib/egl/libGLES_mgd.so
chmod 777 /system/lib/egl/libGLES_mgd.so
cp /system/lib/egl/egl.cfg /system/lib/egl/egl.cfg.bak
echo "0 0 mgd" > /system/lib/egl/egl.cfg
```

The name of the application that should be traced should have its name written in `/system/lib/egl/processlist.cfg`. It is highly recommended that only a single application is traced at any one time, but the processlist.cfg file may contain a list of process names separated by a newline character. For convenience, the interceptor will print the name of any processes which link against GLES to logcat, so the name of the process can be found in this way. For example the line in logcat will read:

"`Process = com.arm.mali.Timbuktu`", in which case your `processlist.cfg` file should contain a single line: `com.arm.mali.Timbuktu`

Note: If you do not have a processlist.cfg file in the right place on your system, then the interceptor will gather trace data from all running GLES applications. If you have more than one GLES application running in this case then the debugger state presentation will not be reliable.

Once the steps above have been completed all subsequently opened applications will pass all GLES/EGL calls through libGLES_mgd.so. To revert this, run the following on the target:

```
cp /system/lib/egl/egl.cfg.bak /system/lib/egl/egl.cfg
```

Note: If an application is started before the installation instructions above are executed, then the application will not have loaded the interceptor library, and no tracing will occur.

4.3.3 Installation Instructions for Android 4.4 "KitKat"

Android 4.4 uses a different mechanism to load the OpenGL ES and EGL libraries and the configuration file `/system/lib/egl/egl.cfg` is no longer relevant.

To make Android load the MGD intercept library before the system library, the intercept library must be named `/system/lib/egl/libGLES.so`. Usually there will not be any library with that name on the system, so it is sufficient to:

- follow the same instructions in 4.3.2 for installing the MGD deliverables on the target system (modifying `egl.cfg` is not necessary)
- create a symbolic link by running the following on the target:

```
ln -s /system/lib/egl/libGLES_mgd.so /system/lib/egl/libGLES.so
```

Once libGLES.so is installed, the system has to be restarted in order to load the new library.

Note: the `mgddaemon` process should be started after the graphics system has been loaded and just before running the application to debug otherwise all the Android processes will be intercepted by MGD.

4.3.4 Run Instructions

If you wish for MGD to connect to the daemon over USB, then you will need to run the following on the host:

```
adb forward tcp:5002 tcp:5002
```

Next ensure you are running the daemon. In a terminal, run:

```
adb shell
su
mgddaemon
```

Now in MGD you can connect to the IP of the target, or to 127.0.0.1:5002 if using USB, and start you application.

4.3.5 Uninstalling

To uninstall MGD you should do the following:

```
# Restore the old egl.cfg file
cp /system/lib/egl/egl.cfg.bak /system/lib/egl/egl.cfg
rm /system/bin/mgddaemon
rm /system/lib/egl/libGLES_mgd.so
```

The target device should then be rebooted to allow the original libraries to be reloaded.

4.4 Troubleshooting

4.4.1 Target devices with no cp support

On systems that do not have `cp`, you can instead use cat on the target, e.g:

```
 cat /sdcard/libGLES_mgd.so > /system/lib/egl/libGLES_mgd.so
```

4.4.2 No trace visible

The interceptor component on the target reports through logcat on Android. If no trace is found then it is advisable to review the logcat trace. Generally you should:

- [Linux] Ensure that the interceptor library is in your PRELOAD path.
- [Android 4.3 and earlier] Ensure that the egl.cfg file has been correctly modified.
- [Android 4.4 and later] The system has to be fully restarted to load the intercept library.
- Ensure you force close and reopen your application after installing the interceptor, to ensure the interceptor is loaded.
- Ensure the daemon is started before the application.
- Ensure your application is making OpenGL ES or OpenCL calls.

4.4.3 Applications crash after installing MGD on Android 4.3 and below

Certain Android devices require that MGD be installed as multiple libraries. So instead of a single `/system/lib/egl/libGLES_mgd.so` you must have `/system/lib/egl/libGLESv1_CM_mgd.so`, `/system/lib/egl/libGLESv2_mgd.so`, and `/system/lib/egl/libEGL_mgd.so`. If, after following the installation instructions in section 4.3.2, your Android applications start crashing, it's possible that your Android system is looking for several libraries instead of the single MGD library you've installed. To check if this is the case and to resolve the problem, try running the following:

```
adb shell
# The following commands run on the target
su
mount -o remount /system
cd /system/lib/egl
ln -s libGLES_mgd.so libEGL_mgd.so
ln -s libGLES_mgd.so libGLESv2_mgd.so
ln -s libGLES_mgd.so libGLESv1_CM_mgd.so
chmod 777 *
```

This will create the required libraries as links to the main MGD library.

4.4.4 Frame Capture doesn’t work on Android 4.4

If you find that the frame capture feature of MGD is not working on an Android 4.4 device, it may be because the application is manually loading the graphics libraries based on the information in `/system/lib/egl/egl.cfg`. To check if this is the case and to resolve the problem, try to move `/system/lib/egl/egl.cfg` by running the following commands:

```
adb shell
# The following commands run on the target
su
mv /system/lib/egl/egl.cfg /system/lib/egl/egl.cfg.bak
```

5 Getting Started with the Mali Graphics Debugger

5.1 Running the Host GUI

Run the application:

- On Windows by double-clicking the MGD icon.
- On Linux by running `/path/to/installation/gui/mgd &`
- On Mac OS X by double-clicking the MGD icon inside the `gui` directory.

The main window should open.

Load one of the supplied sample traces from `/path/to/installation/samples` using File->Open, or using the toolbar  button. The various application windows should fill with information from the loaded trace that you may examine at will.

5.2 Using the Mali Graphics Debugger on Your Application

Before running your application, ensure that the supplied daemon application is running and that the appropriate interception libraries are in place. Instructions on how to do this can be found in the **Target Installation** section of this manual.

Note that it is not necessary to rebuild your application to enable tracing.

5.2.1 Capturing a Live Trace

Select Debug->Set Target IP… and review the target connection details. Ensure that port 5002 is open to allow the daemon to transfer data to the host application.

With both target and host applications running as before, start a live capture by pressing the toolbar  button. The GUI should show the trace captured dynamically from the target.

When ready, stop the capture by pressing the toolbar  button.

5.2.2 Pausing, stepping frames and resume

The application can be paused by pressing the  button; the application will be halted at the final `eglSwapBuffers()` call to allow you to examine the result. Once paused, individual frames can be rendered on target by stepping with the  button. The application may be resumed by pressing the  button.

Note that only the threads that are calling the graphics API functions will be paused.

5.2.3 Capturing Framebuffer Content

Whilst executing, it is possible to perform an in-depth capture of the output from the graphics system on a draw-by-draw basis. Press the  button to take a snapshot of framebuffer content following each draw call in the next full frame of the application. Note that this involves considerable work in composing and transferring data that will slow the application down considerably.

In order to capture subsequent frames you will need to pause the application with the  button. Once paused, proceed by pressing the  button for each frame that needs capturing.

5.2.4 Analyzing Overdraw

MGD has the ability to show overdraw in a given scene. Whilst capturing a live trace press the button. MGD will now replace the fragment shader in the target application with an almost transparent white colored fragment shader. Each time a pixel is rendered to the framebuffer the alpha value is increased via an additive blend, meaning the whiter the final image appears the more overdraw happens in that area.

Original Image

Image with overdraw feature turned on

An application with low levels of overdraw should appear to be a uniform dull grey.

5.2.5 Analyzing the Shadermap

MGD has the ability to give each shader program in use in a given scene a different solid color. Whilst capturing a live trace, press the button. This allows the shader in use by each object in the scene to be identified, and allows detection of any bugs that may be caused by incorrect shader assignment. An example of this feature is displayed below:

Original Image

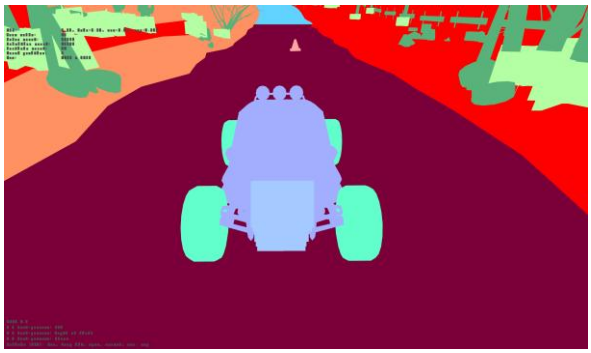
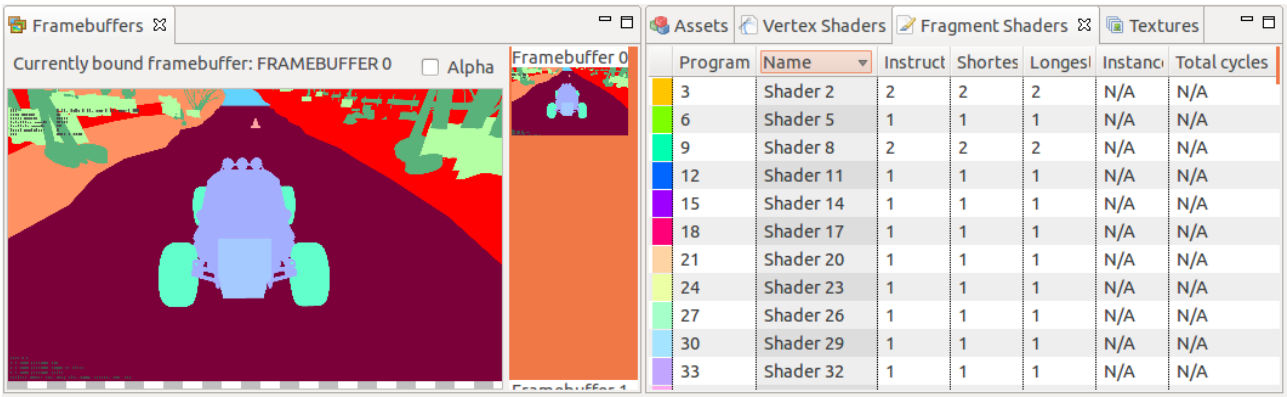


Image with shader map feature turned on

There are 100 unique colors that can be assigned to shader programs, at which point programs will have duplicate colors. The program that corresponds to a color can be identified by matching the color in the scene with the color shown in the shader views, as shown below. Alternatively you may position the cursor over a captured framebuffer image (captured in shadermap mode) and the active shader will be identified above the image.



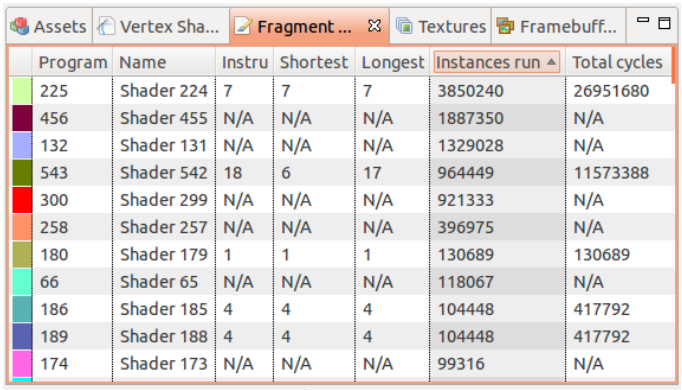
5.2.6 Overdraw and Shadermap limitations

Applying any full screen post processing effects, for example rendering to a texture, will prevent the overdraw map or shadermap from displaying correctly on the device. However, the information can be seen by switching to the correct framebuffer in the UI after capturing a frame while either feature is active.

5.2.7 Analyzing the Fragment Count

MGD has the ability to count the number of fragments processed by a shader per draw call. If depth testing is enabled and a fragment would be excluded as a result, then that fragment will not be included in the count.

To toggle this feature, click the  button. When enabled, each draw call will increment the “Instances run” field of the fragment shader used to draw it. The fragment count represents the number of fragments that have been rendered with the selected shader in the current frame up to, and including the currently selected draw call. An example of this feature is shown below.



The “Total cycles” field is calculated using the average number of cycles for a given shader multiplied by the number of fragments processed.

Note: the two columns ‘Instances run’ and ‘Total cycles’ will only be available for those frames where the fragment count analysis has been requested. These columns will indicate ‘N/A’ (not available) for other frames.

5.2.8 Fragment Count Limitations

To maintain compatibility with older OpenGL ES 2.0 hardware and software, this feature uses a software method to count the number of fragments. As a result, a single draw call can take several

seconds to complete. In addition, the target device screen will show only the final draw call in a frame, and the frame capture feature will not show any usable information.

5.2.9 Replaying a Frame

MGD has the ability to replay certain frames, depending on what calls were in that frame. To see if a frame can be replayed you must pause you application in MGD. Once paused, if a frame can be replayed, the  button will be enabled. Clicking this button will cause MGD to reset the OpenGL ES state of your application back to how it was before the previous frame had been drawn. It will then play back all the function calls in that frame. This feature can be combined with the Overdraw, Shadermap, and Fragment Count features. You can, for example, pause you application in an interesting position, activate the Overdraw mode and then replay the frame. The previous frame will be replayed exactly as before but with the overdraw mode enabled. You can repeat this process with the other modes enabled to get a complete picture for a single frame.

5.2.10 Frame Replay Limitations

Frame replay will be disabled if the frame you want to replay:

- creates or deletes any OpenGL ES/EGL objects,
- changes state that had not previously been changed,
- is not complete (i.e. no eglSwapBuffers call),
- has calls from multiple threads/contexts,
- calls various unsupported functions.

More information about exactly why frame replay is disabled for a particular frame can be found in the Console View in MGD.

6 Exploring Your Application

6.1 API Function Calls

The main editor window shows a table of function calls made by your application as it is running. Use this to examine exactly what your application was requesting of the graphics system and what that system returned.

Each call has the time at which it was made, the list of arguments sent to the call and the value (if any) returned by the underlying system when the function was called. Note that some columns in this table may be initially hidden – right click in the table to enable or disable columns.

The overview window shows a frame-oriented view of the trace. Each frame is delimited by a call to `eglSwapBuffers()`. Selecting an item in the overview will highlight the corresponding item in the main trace.

Double-clicking on an API call will open a browser page showing the documentation for that function (if available).

6.2 Trace Statistics

This window shows a selected summary of the trace as a whole. Use this to gain an overview of the state of your application as it ran.

6.3 Trace Problems

This window shows problems that were detected with one or more API calls as they were made. These problems can include improper use of the API (passing illegal arguments, for example) or issues known to adversely impact performance. Use this view to improve the quality and performance of your application.

Selecting an entry in this view will highlight the offending issue(s) within the trace view. Hover your cursor over the problem report to gain a more detailed view of the problem.

6.4 Trace State

This view shows the state of the underlying system at a time following the function selected in the trace view, and is updated as the trace selection changes. Use this to explore how the system state changes over time and the causes of that change.

The initial state is shown as an entry in normal type. If the relevant API standard defines an initial state then this will be shown, otherwise <*unknown*> will appear instead.

If a state item has changed then its value will be shown in bold type. The function call that made the change can be located by selecting ‘Select Previous Change Location’ from the right click menu on the state item. The function call that next changes a given state item can be located in a similar way.

The state items affected by the currently selected function are highlighted in the view and in the navigation strip to the right of the view.

6.5 Loaded Assets Tab

This view shows those items currently reserved or allocated by calls to the graphics system, and includes textures, shaders, framebuffers and EGL context values. Use this to explore what your application has loaded and what is currently active.

The Assets tab shows a tree of asset items (if any) as loaded by API calls up to and including the currently selected function. Selecting any item within the tree will show a preview of the item if available.

6.5.1 General Operations on Assets

The following operations are available on an asset item wherever it appears in the GUI:

- Asset items shown in normal type are known to the system, but are not currently bound. Assets shown in bold type are those currently bound and in use.
- Double clicking an asset item will show a larger view of the item.
- The right click menu on an asset item allows you to locate where the asset was either created or modified.

6.6 Vertex/Fragment Shader Tabs

These are an alternative tabular view of all currently loaded shaders. For each shader various cycle counts are shown allowing you to identify which shaders are most costly.

Active shaders are shown in bold type as before.

6.7 Textures Tab

This shows an alternative tabular view of all currently loaded textures and includes information on their size and format. Use this to visualize the images that you have loaded into the system.

Loading textures is done using an external program: note that for larger traces the application can take a short time to convert and display all textures. The following texture formats are currently supported:

- GL_COMPRESSED_RGBA8_ETC2_EAC
- GL_COMPRESSED_RGB8_ETC2
- GL_ETC1_RGB8_OES
- GL_LUMINANCE
- GL_ALPHA
- GL_RGBA4
- GL_RGBA with type GL_UNSIGNED_BYTE or GL_UNSIGNED_SHORT_4_4_4_4
- GL_RGB with type GL_UNSIGNED_BYTE
- GL_COMPRESSED_RGBA_ASTC_*_KHR
- GL_COMPRESSED_SRGB8_ALPHA_ASTC_*_KHR

6.8 Framebuffers Tab

This view shows the content of any framebuffers loaded at the currently selected point in the trace but only if a framebuffer capture has been successfully executed on the target. Use this to gain an insight into what the graphics system has produced as a result of your application calls.

The view shows the bound framebuffer as a large image, with a series of smaller images representing the other buffers available to the system. For a captured frame it is possible to step through the sequence of draw calls for that frame one at a time and observe how the final scene is constructed.

6.9 Vertex Attributes Tab

This view shows the values of the vertex attributes that are passed to the vertex shader when a ‘draw’ call happens. Therefore, vertex attributes are visible only when a ‘draw’ call such as `glDrawArrays` or `glDrawElements` is selected in the trace. If `GL_ELEMENT_ARRAY_BUFFER_BINDING` or `GL_ARRAY_BUFFER_BINDING` is set, the corresponding buffer object will be used to provide the values.

7 About the Implementation

The Mali Graphics Debugger works by intercepting each OpenGL ES or OpenCL call made by the application under test. Once intercepted, call arguments are logged before they are passed transparently to the existing OpenGL ES or OpenCL library. The logged data is collected and passed to the host via a daemon running on the system.

7.1 OpenGL ES Conformance

This product is based on a published Khronos Specification. Under normal trace conditions no changes are made to the stream of calls made by the application on the existing OpenGL ES implementation and therefore should not affect the conformance status of that implementation.

8 Known Issues

8.1 OpenGL ES Extensions

Generally, known OpenGL ES extensions will appear in the trace, but will not have an effect on the trace or asset state.

8.2 Shading Language Version

The host application supports syntax-highlighting of shaders from OpenGL ES 3.0 and before. There is support for Open CL kernel source but this is currently limited to a plain text view.

8.3 Shader Compiler

- The system uses a built-in version of the Mali Offline Shader Compiler to determine vertex and fragment shader cycle counts. These cycle counts will only be correct for Mali 400 devices running r2p4 drivers, however, other Mali-400 devices are likely to offer similar counts.
- The shader compiler currently only supports OpenGL ES 2.0 shaders at present. No cycle counts will be displayed for other shader versions.

8.4 Performance

The Mali Graphics Debugger aims to be as unobtrusive as possible. However, there is a performance impact imposed by the gathering and sending of trace data to the host. This is particularly pronounced when you request a snapshot of a frame as this causes pixel read-back calls to be inserted by the interceptor after each draw call.

The interceptor library performance has been improved: the library now has negligible impact on application performance when not tracing.

8.5 API Asset Coverage

- There is currently no support for most API extension functions or enumerations
- Not all asset types are covered at present
- Not all texture types/formats are currently supported

8.6 Tracing Multiple Processes

If multiple applications are traced simultaneously then the trace shown in the GUI will contain function calls from all applications together. The trace state will then be a combination of the state from all applications that is likely to be misleading. Advice on this issue can be found in the **Target Installation** section of this manual.

8.7 Memory

Capturing for long periods of time or attempting to capture many framebuffer and/or other images is very expensive on memory. If a memory shortage is detected an active trace may be terminated to protect the system. See Section 2.2 above for advice.

8.8 Partial support for earlier trace versions

As new features are being added to the Mali Graphics Debugger, the data format of the saved traces is updated. We aim to support opening and visualizing traces captured with an earlier version of the tool but we cannot guarantee full functionality with older traces. The best solution is to update the Mali Graphics Debugger software on both target and host and re-trace the application.

8.9 Maximum number of displayed vertex attributes

The Vertex Attributes view is able to display up to 32 different vertex attributes. If an application is using more than 32 vertex attributes the remaining ones are captured and stored in the trace file but not displayed.

8.10 GTK Warnings when closing MGD (Ubuntu only)

Occasionally on closing the application the system will show errors from the GIMP Toolkit (GTK) similar to the following:

```
LIBDBUSMENU-GTK-CRITICAL **: watch_submenu: assertion
`GTK_IS_MENU_SHELL(menu)' failed

(Mali Graphics Debugger:3989): LIBDBUSMENU-GLIB-WARNING **: Trying to remove
a child that doesn't believe we're it's parent.
```

These are believed to relate to issues within GTK itself: they are widely reported and are believed to be harmless.

8.11 Issues with texture and image output on 64-bit Linux host

Mali Graphics Debugger requires that the 32-bit version of libjpeg62 be available on your system. On certain distributions, this is not there by default. On Ubuntu, this can be installed using the following command:

```
sudo apt-get install libjpeg62:i386
```

8.12 Issues viewing Khronos man pages

Depending on your particular platform, you may or may not be able to correctly view the Khronos man pages when double clicking functions. This is particularly an issue for Windows which uses Internet Explorer. This unfortunately is outside of our control, as it is an incompatibility between the Khronos man page format, and the platform default browser.

8.13 Temporary Hard Disk Space

During normal operation Mali Graphics Debugger uses a large amount of temporary disk storage. If there is not enough storage space available in the system temporary directory many error messages will be displayed and MGD can crash. The temporary directory used for MGD can be modified by adding the following line to the *mgd.ini* text file in the installation directory, after the `-vmargs` entry:

```
-Djava.io.tmpdir=<PathToTempDir>
```

8.14 Intercepting without using LD_PRELOAD

In some cases it may not be possible to use `LD_PRELOAD` (for example, `LD_PRELOAD` is already being used for another purpose). In this case you need to define both `LD_LIBRARY_PATH` and `MGD_LIBRARY_PATH`, as follows:

```
LD_LIBRARY_PATH=/path/to/intercept/dir/:$LD_LIBRARY_PATH
MGD_LIBRARY_PATH=/path/to/original/drivers/dir/
```

In this case, the /path/to/intercept/dir/ should be the directory on the target where the installation files were copied. Typically this contains libinterceptor.so, libGLESv2.so, libEGL.so etc.

The /path/to/original/drivers/dir/ should contain the pre-existing libGLESv2.so, libEGL.so files from the graphics driver installation.

`LD_PRELOAD` need not be defined when using this method.

When a graphics application runs, the MGD intercept libraries are loaded from the `LD_LIBRARY_PATH` first. These intercept libraries dynamically load the original graphics libraries from the `MGD_LIBRARY_PATH` location as required.

9 Changes from Previous Versions

9.1 Changes between version 1.2.2 and 1.3.0

The following summarizes the changes made in this issue.

Issue	Summary
[MGD-504]	The results of glGetError are now show for every call
[MGD-246]	Added “Step” feature to allow stepping through frames on the target
[MGD-896]	Traces are now in a binary format to increase performance
[MGD-282]	Added a feature in the Vertex Attribute View to visualise sparse vertex indices. Also added a warning if the vertex indices are too sparse.
[MGD-1024]	Added support for replaying frames which don’t create or destroy state
[MGD-297]	Shader cycles statistics are now calculated for ‘*Midgard’* based devices
[MGD-263]	Double-clicking an MGD trace file now opens MGD (Windows only)
[MGD-900]	Search function is faster
[MGD-1000]	MGD is more responsive when selecting the last frame in a big trace
[MGD-1001]	MGD no longer runs out of memory after opening and closing several trace files
[MGD-1092]	Fixed Shader View sorting when using “Show create location”
[MGD-241]	String arguments are now shown instead of the pointer value in the Trace View
[MGD-1121]	The Vertex Attribute View is now correct when the minimum vertex index is >0
[MGD-1138]	Fixed Shaders View so it shows shaders correctly before they’ve been linked
[MGD-1155]	Added EGL parameters are in the Assets View
[MGD-146]	Stopped context being lost in the Outline View when selecting a call other than glDrawElements
[MGD-1104]	Fixed shadermaps so they use the same shader number as API calls
[MGD-1096]	In a multi-context trace, the trace problems are now correct
[MGD-1094]	Constants are now correctly displayed for glClear
[MGD-65]	Texture formats for T-Rex HD are now correct
[MGD-1066]	Stopped UI locking up while saving traces
[MGD-831]	Attaching a texture to a channel of an FBO now detaches whatever is currently bound
[MGD-1091]	Added support for BGRA textures
[MGD-1079]	Framebuffer view is now cleared when trace file gets closed
[MGD-1065]	Stopped UI locking up when connecting to a non-existing IP address
[MGD-1015]	“Show create location” / Show last modification now works for Shader Views
[MGD-997]	It is no longer possible to close main application window when Open File dialog is open
[MGD-1071]	Asset view selection is no longer cleared when stepping backwards through the trace

[MGD-1068]	Stepping through draw calls no longer resets the asset table
[MGD-1036]	Fixed a NullPointerException which was thrown after reopening the Assets View
[MGD-903]	Stopped the framebuffer view of other open traces being cleared when you close a trace
[MGD-2]	Cancelling file read no longer results in Stream Closed error
[MGD-888]	Traces can be exported to a text file
[MGD-210]	Trace file highlights can now be removed once set
[MGD-947]	Function arguments now display correct enumeration values
[MGD-935]	Fixed java.util.ConcurrentModificationException thrown while tracing GFXBench

9.2 Changes between version 1.2.2 and 1.2.1

The following summarizes the changes made in this issue.

Issue	Summary
[MGD-1012]	Fixed unique indices count.
[MGD-231]	Support for Android KitKat 4.4.

9.3 Changes between version 1.2.1 and 1.2.0

The following summarizes the changes made in this issue.

Issue	Summary
[MGD-935]	Fixed java.util.ConcurrentModificationException.
[MGD-197]	Show framebuffer pixel information.
[MGD-922]	Eliminate memory-free error on interceptor closedown.
[MGD-921]	Fix for interceptor segfault on GFXBench3 (PBO).
[MGD-907]	Handle Unicode characters in shader sources.

9.4 Changes between version 1.2.0 and 1.1.0

The following summarizes the changes made in this issue.

Issue	Summary
[D905]	Allow binary shaders to be debugged. All apps will fall back to compiled shaders.
[D852]	Added end to end tests for fragment count
[D837]	Handle click on empty framebuffer image. Previously the app would throw a generic warning if an empty framebuffer was double-clicked.
[D887]	Suppress multiple error dialogs. These were produced when trying to read a texture without the appropriate decoder. Only one report is now produced for each failing decoder.
[D463]	Shaders view shows a fragment count for each shader
	All frames now start with eglSwapBuffers. Previously this call was included at the end

	of a frame. This change improves application consistency.
	Add an 'empty message' to the framebuffers view.
[A860]	Fixed exception thrown when calculating shader statistics.
[A876]	Add armhf_fbdev in the installer
[A873]	Fix workbench save/restore with new versions.
[D3]	Fixed vertex and fragment views being empty after shader deletion Shaders are shown next to their bound program in the shader views There may be duplicate shaders, as a shader can be bound to multiple programs After a shader is deleted, the shader is shown greyed out if still attached Vertex shaders in the vertex shader view also now have a colour
	Add framebuffer size in the tooltip
[D335]	README_linux and README_android merged into user guide Added target installation content to the userguide Deleted README_android and README_linux
[D844]	Daemon now reports version during start up
[D852]	Updated user documentation. Also improved the messages that a daemon produces when it starts up. Includes updates to user guide and code to better document the use of port 5002.
[D859]	Adding Android ASTC support
	All mga references become mgd
	Changed test trace file extension to mgd.
	Fix frame and draw call index numbers in stats view. These were one-out.
	Adding ASTC decoding to GUI.
[D854]	Changed Linux installer extension to tgz. This simplifies publishing.
[D160]	Renaming State view 'State' column to 'State Item'
[D836]	Renaming samples to have a .mgd extension
	Show colors in the shaders view.
[D838]	Close process streams after use. These were no being closed, and so were accumulating until the system ran out of descriptors.
	Rename Trace Problems view
[A753]	Clear frame image when model unloads.
[D12]	Show multiple texture formats/types only if they are different.
[D34]	Overdraw map now supports GLES3 shaders (Timbuktu works)
[D63]	Add status line with progress report for background jobs.
[A595]	Fix 'task already scheduled or canceled' when closing and re-opening stats view.
[A801]	Fix exception when cancelling a file open action.
[A788]	Inform the user when the connection to the target is broken
[A793]	change extension to .mgd
[A722]	Better message for broken URLs in help lookup.
	Fix opening a file shows up as dirty.

[A815]	Add title to vertex attribute index column.
	Hide the filmstrip panel if no screenshots are available.
	Display screenshots in the left pane in the GUI.
[A760]	Saving now updates tab. And you can differentiate between save and save as.
	Adding single-step function.
	Fixing interaction between pause and framebuffer requests.
	Improve image drawing, remove unnecessary images.
	Add support for RGB and RGB565 formats for framebuffers.
	Enable O3 optimization in the Android build.
[A794]	Message when texture cannot be displayed externally.
	Implemented overdraw map
[A834]	Fix bug calculating shader cycle average.
[A779]	Vertices per draw call and frame now show Unique vertices as well
[A834]	Add vertices count to shader stats.
[A284]	Selecting frame selects last call in frame. Previously the first call would be selected. Will allow us to more easily present per-frame information.
	Enable all the basic texture formats.
	Add GL_ALPHA texture format as grayscale image.
	Revised error handling. All LOGE or LOGI statements now terminate with \n (previously there was a mix). All exit() calls are now made with a non-zero value if indicating failure.
	Implemented core GLES3 vertex attrib types
[A727]	Updated User Guide. Updated known-issues section to contain information on the Khronos manual page issues.
	Added mgd.ini option to substitute vendor
	Renaming start/stop to connect/disconnect. This better reflects what these commands actually do, and helps towards separating the start/stop controls.
	Added LD_LIBRARY_PATH/MGD_LIBRARY_PATH interception method By naming/symlinking MGD appropriately, MGD can be placed in the LD_LIBRARY_PATH variable, and the library path to forward calls to can then be specified by passing the environment variable MGD_LIBRARY_PATH. This method is safer than LD_PRELOAD, and can be used with other tracers.
	Improved interceptor to support more drivers
	Included updated GLES/glext.h
	Updated size of bitfields in CL definition.
	Add to the trace a timestamp showing the time before/after each function call.
	Stop up-scaling the FB images if they are already smaller than the canvas.
[A762]	Fixed find on a live trace
	Added armhf build to bundle
	Updated emulator to load libGLES from same dir Now loads libGLES* from same

	directory as libEGL, rather than using LD_LIBRARY_PATH, which was causing some trouble previously.
[A758]	Fix null pointer exception when saving. This occurs when a constant value is unrecognised. These are now replaced with 'unrecognised' but this can only be temporary until unknown constants are properly supported.
[A724]	Add User Guide note on GTK warnings.
[A720]	Improving the progress bar on multiple file load. The previous bar was not correctly showing the total progress when opening multiple files, this has been fixed. There remains an issue with the blocking of the UI thread by the openEditor call, but this is unavoidable at the moment.
[A717]	Only permit existing file to be opened. Previously the file->open dialog would allow the user to type a filename that didn't exist, causing problems later in the flow.
[A691]	Search substrings (they don't need to fully match).
	Fix Y coordinate of CUBEMAP.
[A684]	Fix bug. MGD did not show up on Mac with Java 1.6
[D686]	Fixing standard Mac menu items. The 'About MGD' and 'Preferences' options were missing from the Mac implementation.
[A697]	Revising socket close mechanism to eliminate errors. The socket closedown code reported lots of warnings even in the correct case. Code has now been refactored to improve the messaging and to try and eliminate spurious warnings.
	Added EGL plugin to send context on eglMakeCurrent
	GLES3 working on Android, and Nexus10 4.3 booting. Only needed chmodding to work on Android 4.3, so have changed the README to reflect this requirement. Have also removed the GLES2 version of the android interceptor, and will now ship GLES3 as it is public.
[D698]	Fix sequencing on save. Save operation no longer closes an active trace if the user cancels the file selection dialog.

9.5 Changes between version 1.1.0 and 1.0.2

The following summarizes the changes made in this issue.

Issue	Summary
[353]	Added Vertex Attributes view, which shows all the vertices used in a ‘draw’ call
[353]	Indices buffers are captured in the trace
	Added warning for swapping between buffer targets
[653]	Adding statistic for vertices per frame and show vertices count in the Outline View
	Shader statistics are now updated individually
[349]	Added ability to find function calls with text pattern search (CTRL-F)
	Shaders are now sorted numerically
	Improved the vertical bar with markers to point to the correct items when it is clicked
[591]	“Save” now asks before overwriting
	Add reference to the buffers table in GL_ELEMENT_ARRAY_BUFFER_BINDING

[620]	Numbers start from 1 in views.

9.6 Changes between version 1.0.2 and 1.0.1

The following summarizes the changes made in this issue.

Issue	Summary
	Add uniforms support.
	Fix concurrent modification exception.
[550]	Fix bug in Windows installer.
	Moving views; adding right click menu.
	Dimension sorts by width following area.
	Adding shader attributes to program view.
	Update EULA with Apache Commons library.
[543]	Fixing trace load progress counter.
[539]	Texture names now sort on ID
[353]	Added glVertexAttrib*fv family of entry points
[353]	Added glVertexAttrib*f commands to AssetProcessor
	Upgrade everything to Java 1.7
	Small improvements to the UI of the Outline view
	Fix for interceptor vertex array buffer sending
[514]	Adding index to draw call in frame.
[485]	Fix warning 'timer already canceled'.
	Add detection of eglGetError errors.
	Display frames with alternate colors in the trace view.
[518]	Adding table header tool tips.
[517]	Added index column to trace view.
[515]	Attachment temporary files now deleted on exit.
	Small UI improvements
	Fix NullPointerException with buffers.
[489]	Fix trace editor switching.
	Add statistics entry to show the number of API calls per frame.
	Make open file trace faster.
[483]	Improved performance when highlighting the locations of a problem in the trace.
[508]	Fix double-click global action issue.
	Add buffers view.
	Changed Asset view to sort GLES objects alphabetically
[498]	Added preview text and icons for Buffer assets.

	Add a simple binary viewer for buffers.
	Fix precision errors in the progress bar.
[482]	Show MB read in the progress bar to show activity for enormous files.
	Set the size of a texture even if no data is available.
	Display information for textures bound to framebuffers.
[341]	Show number of vertices and draw calls in the Outline view.
[341]	Add per frame and per draw call statistics in the view.
[498]	Added AssetProcessor support for all GLES3 target buffers.
[498]	Updated AssetProcessor to handle glBufferSubData
[498]	Added tracking of buffer creation/deletion/modification to model.
[498]	Added glBufferData test app
	Improve file moving to work cross device

9.7 Changes between version 1.0.1 and 1.0.0

The following table details the changes made in this issue.

Issue	Summary	Notes
[429]	Removed multi-selection on trace problems view.	Since only the first selection is used. Also selection now done on a single-click rather than a double-click.
[473]	Fixed issue when textures with type 565 were sent.	Caused traces with RGB565 images to fail to load.
[427]	Personalised icons on shader editor.	Shader editor pane now shows the icon appropriate to the content.
[472]	Added eglGetProcAddress path for function pointer lookup in interceptor functions.	Previously, the only path available used dlsym, which will not work with extension functions which must look up the function in the underlying driver with eglGetProcAddress. The interceptor originally returned addresses to core API functions, which is counter to the wording of the EGL spec.
[453]	Fixing trace load cancel button.	MGD now stops cleanly when the cancel button is pressed on a large trace load.
[451]	Reducing argument memory usage.	Provide support for saving attachments and framebuffers to disk when the system is short of memory.
[474]	Fix Save dialog (before it was actually a open dialog).	Also add a filter for txt extension on trace files.
	Add type to the image buffers and textures, and display it.	
[418]	Added documentation for all special case functions.	All trace functions can be double-clicked to reveal help page.
[447]	Modified Trace Editor code to	Functions such as glClear which take a bit mask now show the bit mask value expanded into each of the

	handle bitfields.	mask values if possible.
[469]	Fix exception thrown when no markers are selected.	
[398]	Added process filter to Android target.	Now requires a /system/lib/egl/processList.cfg to exist, and have the running process name equal one of the lines of that file, in order for a single process trace to occur. The interceptor will trace all processes by default if processList.cfg is not present.
[435]	Removed shader editor right click menu	The menu items had no effect, and so have been removed.
[436]	Save and restore window layout	The application will now remember where windows were placed in the workbench, and will restore these at the start of the next session.
[448]	Retain connection IP address and port information	If the user enters information in the connection dialog then this is now saved across sessions.
[431]	Removing unused popup menu on stats view.	Removed unnecessary popup menu.

9.8 Changes in version 1.0.0

- This version is the first release of the Mali Graphics Debugger.

10 Support

For further support on this product, please visit the Mali Developer Center.

It should be noted that continuing support of the product is at ARM's discretion unless explicitly included in a current contract between ARM and you.

11 Legal

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