OSP logcat crunch

Debugging and Profiling

Lecture 10

Operating Systems Practical

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Logging

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Keywords

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Keywords

Android logging framework

- Logd daemon
  - From Android 5.0
  - Centralized user-mode logger
  - Can be integrated with SELinux
  - Uses 4 sockets
- Liblog library
- `android.util.Log`
- `logcat`

Android logging framework

- Write log messages:
  1. Log class
  2. Liblog library
  3. `/dev/socket/logdw` socket
- Read log messages:
  1. `logcat`
  2. Liblog library
  3. `/dev/socket/logdr` socket

Message Structure

- Priority - severity
  - Verbose, debug, info, warning, error, fatal
- Tag identifies the component generating the message
  - Logcat can filter log messages based on the tag
- Message: actual log text

Native Logging API

- Exposed through `android/log.h`
- `#include <android/log.h>`
- `Android.mk` dynamically link native code to log library
  - `LOCAL_LDLIBS += -llog`
  - Before `include $(BUILD_SHARED_LIBRARY)`

- `__android_log_write`
  - Generate a simple string message
  - Params: priority, tag, message

```
__android_log_write(ANDROID_LOG_WARN, "my_native_code",
"Warning message!");
```

- `__android_log_print`
  - Generate formatted string (like printf)
  - Params: priority, tag, string format, other params

```
__android_log_print(ANDROID_LOG_ERROR, "my_native_code",
"Errno =%d", errno);
```

- `__android_log_vprint`
  - Additional parameters as `va_list`

```
void log_verbose(const char* format, ...){
        va_list args;
        va_start(args, format);
        __android_log_vprint(ANDROID_LOG_VERBOSE, "my_-
native_code", format, args);
        va_end(args);
}
```

- `__android_log_assert`
  - Assertion failures
  - Priority is not specified, always fatal

```
__android_log_assert("0 != errno", "my_native_code", "Big
error!");
```

  - SIGTRAP to process - debugger inspection

Log control

- Cannot suppress log messages based on priority
- Preprocessor based solution

```
#define MY_LOG_NOOP (void) 0

#define MY_LOG_PRINT(level,fmt,...) \
        __android_log_print(level, MY_LOG_TAG, "(%s:%u)␣%s:␣" fmt
        __FILE__, __LINE__, __PRETTY_FUNCTION__, ##__VA_ARGS__)

#if MY_LOG_LEVEL_WARNING >= MY_LOG_LEVEL
#       define MY_LOG_WARNING(fmt,...) \
        MY_LOG_PRINT(ANDROID_LOG_WARN, fmt, ##__VA_ARGS__)
#else
#       define MY_LOG_WARNING(...) MY_LOG_NOOP
#endif
```

Log Control

- In native code

```
#include "my-log.h"
...
MY_LOG_WARNING("Message!");
```

- In Android.mk

```
MY_LOG_TAG := \"my_native_code\"

ifeq ($(APP_OPTIM),release)
	MY_LOG_LEVEL := MY_LOG_LEVEL_ERROR
else
	MY_LOG_LEVEL := MY_LOG_LEVEL_VERBOSE
endif

LOCAL_CFLAGS += -DMY_LOG_TAG=$(MY_LOG_TAG)
LOCAL_CFLAGS += -DMY_LOG_LEVEL=$(MY_LOG_LEVEL)
```

Log Console Messages

- STDOUT and STDERR not visible by default
- Redirect STDOUT and STDERR to logging system

```
adb shell stop
adb shell setprop log.redirect-stdio true
adb shell start
```

  - Display with `logcat` - tags stdout and stderr
  - Temporary config -> erased when booting device
- Permanent config -> modify `/data/local.prop` on device

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Keywords

- NDK supports debugging using GNU Debugger (GDB)
- `ndk-gdb` script
  - Handles error conditions
  - Outputs error messages
- Requirements
  - Use `ndk-build` -> build system generates files needed for debugging
  - `android:debuggable` in `AndroidManifest.xml`
  - Android version 2.2 or higher

- `ndk-gdb` script sets up the debug session
- Launches the app using Activity Manager through ADB
  - Activity Manager sends the request to Zygote
  - Zygote forks and creates new process
- `ndk-gdb` starts GDB server and attaches to the app
- Configures port forwarding to make GDB server accessible from the host machine (debug port)
- Copies binaries for Zygote and shared libraries to the host
- Starts GDB client
- Debug session is active -> You can start debugging app
  - Commands sent over the debug port

- Go to project directory
- `rm -rf bin obj libs`
- Compile native code using `ndk-build`
- We need `build.xml` -> `android update project -p`
- Compile and package the whole project in debug mode `ant debug`
- Deploy app on device `ant installd`
- `ndk-gdb --start` to start app and the debugging session
- When GDB prompt appears run commands

GDB Commands

- `break`: Breakpoint in a location (function name, file name & line number)
- `clear`: deletes all breakpoints
- `enable/disable/delete`: operations on a certain breakpoint
- `next`: go to the next line in source code
- `continue`: continue execution
- `backtrace`: display call stack
- `backtrace full`: call stack with local variables on frames
- `print`: display variable, expression, memory address, register
- `display`: continue printing value after each step
- `info threads`: list running threads
- `thread`: select a certain thread

Dalvik Debug Monitor Server

- Integrated in Android Studio
- Launch Android Debug Monitor -> DDMS button
- Works with real devices and emulator
- Debugging Android applications
- Port-forwarding, screen capture, thread info, heap info, process state, radio state, incoming call, SMS spoofing, location spoofing, etc.

DDMS - Interaction with Debugger

- When started, DDMS connects to `adb`
- VM monitoring service is created between `adb` and DDMS
- The service notifies DDMS when a VM is started or terminated
- Obtains the pid, opens a connection to the VM's debugger through adbd
- Talks to the VM using a custom wire protocol

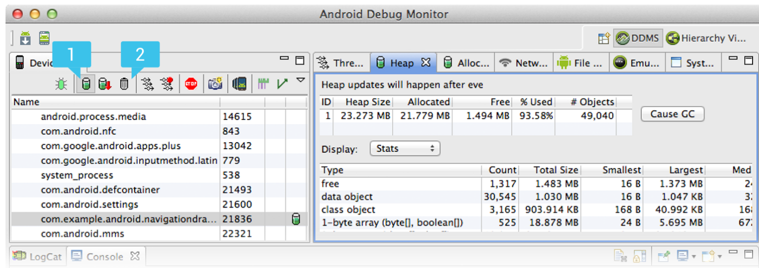
DDMS

Source: http://developer.android.com

DDMS - Heap Update

- View how much heap the process is using
  - Select process in *Devices* tab
  - *Update Heap* to obtain heap info
  - *Cause GC* to invoke Garbage Collection (refresh data)
  - Select object type to view number of allocated objects

DDMS - Heap Update



Source: http://developer.android.com

DDMS - Track Allocations

- Track memory allocation
  - *Start Tracking* in the *Allocation Tracker* tab
  - *Get Allocations* to obtain list of allocated objects
  - Finally *Stop Tracking*
  - Detailed info about the method and line that allocated a certain object
- Examine thread info
  - *Update Threads* to obtain thread info for the selected process

DDMS - Track Allocations

Android Debug Monitor

DDMS | Hierarchy Vi...

Devices

Name	
com.google.android.googlequickse...	2829
com.google.android.gms	1123
cloudtv.hdwidgets	13701
android.process.media	14615
com.android.nfc	843
com.google.android.apps.plus	13042
com.google.android.inputmethod.latin	779
system_process	538
com.android.defcontainer	21493
com.android.settings	21600
com.example.android.navigationdra...	21836
com.google.android.music:main	25356
com.google.android.deskclock	25662
com.google.android.apps.uploader	26180
com.google.android.apps.walletnfcrel	26220
com.google.android.youtube	26236
com.songkick	26280
com.google.android.apps.bazaar	26295

Thre... | Heap | Alloc... | Netw... | File ... | Emu... | Syst...

Stop Tracking | Get Allocations | Filter: | Inc. trace

Alloc Order	Allocation Size	Allocated Class	Thread Id	Allocated in
149	5740832	byte[]	1	android.graphics.BitmapFactory
152	1435220	byte[]	1	android.graphics.BitmapFactory
83	704	com.android.int...	1	java.lang.reflect.Constructor
194	456	android.widget.l...	1	java.lang.reflect.Constructor
159	184	int[]	1	java.lang.Throwable
122	180	char[]	1	java.lang.AbstractStringBuilder

```
at android.graphics.BitmapFactory.nativeDecodeAsset(Native Method)
at android.graphics.BitmapFactory.decodeStream(BitmapFactory.java:503)
at android.graphics.BitmapFactory.decodeResourceStream(BitmapFactory.java:356)
at android.graphics.drawable.Drawable.createFromResourceStream(Drawable.java:800)
at android.content.res.Resources.loadDrawable(Resources.java:2105)
at android.content.res.Resources.getDrawable(Resources.java:695)
at android.widget.ImageView.resolveUri(ImageView.java:636)
at android.widget.ImageView.setImageResource(ImageView.java:365)
at com.example.android.navigationdrawerexample.MainActivity$PlanetFragment.onCreate...
```

LogCat | Console

Source: http://developer.android.com

Outline

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Keywords

- Use troubleshooting tools and techniques to identify the cause of a problem
- Observe the stack trace when an app crashes with `logcat`
  - Lines starting with # represent stack calls
  - Line #00 is the crash point
  - After #00 the address is specified (pc)

Stack Trace

- `ndk-stack`
  - To add file names and line numbers to the stack trace
  - `adb logcat | ndk-stack -sym obj/local/armeabi`
  - Run command in the project directory
  - Obtain exact file name and line number where it crashed

CheckJNI

- Extended series of checks before calling JNI functions
- Enable CheckJNI on a device
  - Rooted device

```
adb shell stop
adb shell setprop dalvik.vm.checkjni true
adb shell start
```

    - Logcat: `D AndroidRuntime: CheckJNI is ON`
  - Regular device

```
adb shell setprop debug.checkjni 1
```

    - Logcat: D Late-enabling CheckJNI
- Error detected by CheckJNI

```
W JNI WARNING: method declared to return
'Ljava/lang/String;' returned '[B'
W failed in LJniTest;.exampleJniBug
```

Libc Debug Mode

- Troubleshoot memory issues
- Enable libc debug mode

```
adb shell setprop libc.debug.malloc 1
adb shell stop
adb shell start
```

- Libc debug mode values
  - 1 - detects memory leaks
  - 5 - detects overruns by filling allocated memory
  - 10 - detects overruns by filling memory and adding sentinel

```
...  testapp using MALLOC_DEBUG = 10 (sentinels, fill)
...  *** FREE CHECK buffer 0xa5218, size=1024, corrupted 1
bytes after allocation
```

Valgrind

- Advanced memory analysis
- Open-source tool for memory debugging, memory leaks detection and profiling
- Support for Android
- Build from sources
  - Binaries and components in `Inst` directory
  - `adb push Inst /data/local/`
  - Give execution permissions
- Helper script

```
#!/system/bin/sh
export TMPDIR=/sdcard
exec /data/local/Inst/bin/valgrind --error-limit=no $*
```

- Push in /data/local/Inst/bin and set execution permissions

- To run app under Valgrind, inject the script into the startup sequence

```
adb shell setprop wrap.com.example.testapp  "logwrapper
/data/local/Inst/bin/valgrind_wrapper.sh"
```

- Property wrap.packagename
- Execute app
- Logcat displays Valgrind output

Strace

- Intercepts system calls and signals
- System call name, arguments and return value
- Useful for analyzing closed-source applications
- Included in Android emulator
- Run the application and obtain pid

```
adb shell ps | grep com.example.testapp
```

- Attach `strace` to running app

```
adb shell strace -v -p <PID>
```

Tombstones

- Tombstone - generated when a process crashes
- `/data/tombstones/tombstone_*`
- A file containing information about the crashed process
  - Build fingerprint
  - Crashed process, PID, TIDs
  - Signal and fault address
  - CPU registers
  - Call stack
  - Stack content of each call
- Use with `ndk-stack` and `addr2line` to obtain the file and line where the process has crashed

Tombstones

```
Build fingerprint: 'Android/aosp_hammerhead/hammerhead:4.4.2/
KOT49H/eng.upb.20140407.130154:userdebug/test-keys'
Revision: '11'
pid: 27836, tid: 27836, name: test.nativeapp4  >>>
com.test.nativeapp4 <<<
signal 11 (SIGSEGV), code 1 (SEGV_MAPERR), fault addr 00000000
    r0 00000000  r1 00000000  r2 6f8b70e4  r3 6f8b8328
[..]
backtrace:
    #00  pc 00008bbc  /system/lib/libandroid.so (AAsset_close+3)
    #01  pc 00000d47  /data/app-lib/com.test.nativeapp4-2/
libNativeApp4.so (displayAsset(ANativeActivity*)+18)
    #02  pc 00000db1  /data/app-lib/com.test.nativeapp4-2/
libNativeApp4.so (ANativeActivity_onCreate+96)
[..]
stack:
    bea91430  00000000
    bea91434  401a7315  /system/lib/libutils.so
(android::SharedBuffer::release(unsigned int) const+28)
    bea91438  bea91450  [stack]
    bea9143c  00000000
    bea91440  00000000
    bea91444  402ad59b  /system/lib/libandroidfw.so
    bea91448  6f8b70e0  [anon:libc_malloc]
```

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GNU Profiler (Gprof)

- Unix-based profiling tool
- Compute absolute execution time spent in each function
  - Instrumentation with `gcc` when using `-pg` at compile time
  - Sampling data stored at run-time in `gmon.out`
  - gprof uses `gmon.out` to produce profiling reports
- Android NDK includes gprof tool
  - Android NDK toolchain lacks the implementation of `__gnu_mcount_nc` used for timing
- Open-source project Android NDK Profiler

- Install module
  - Download zip, extract in `$NDK_HOME/sources`, rename directory to `android-ndk-profiler`
- Enable profiler
  - Update `Android.mk` to statically link profiling library
  - Include `prof.h` in the native code

```
#ifdef MY_ANDROID_NDK_PROFILER_ENABLED
#include <prof.h>
#endif
```

  - Start collecting profiling data

```
#ifdef MY_ANDROID_NDK_PROFILER_ENABLED
      monstartup("libModule.so");
#endif
```

  - Stop collecting data

```
#ifdef MY_ANDROID_NDK_PROFILER_ENABLED
      moncleanup();
#endif
```

Generate Reports

- The collected data is stored in `/sdcard/gmon.out`
- App needs permission to write on the SD card

```
<uses-permission android:name="android.permission.WRITE_-
EXTERNAL_STORAGE" />
```

- Pull `gmon.out` from the SD card
- Run gprof

```
$NDK_HOME/toolchains/arm-linux-androideabi-4.4.3/prebuilt/
linux-x86/bin/arm-linux-androideabi-gprof
obj/local/armeabi-v7a/libModule.so gmon.out
```

  - Gprof analyses data and generates a report
  - Two sections: flat profile and call graph
  - Duration of each function

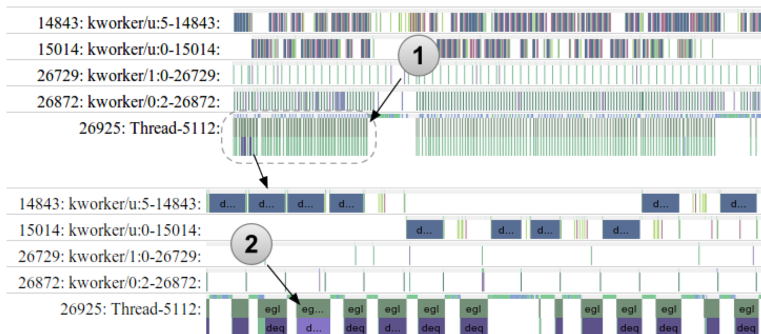
Systrace

- Gather code execution data -> Identify execution problems and improve performance
- Show all processes on a common timeline
- Execution times, CPU frequency, CPU load, disk activity, threads
- Android 4.1 or higher, root access, developer debugging enabled
- GUI and CLI

```
$ cd android-sdk/platform-tools/systrace
$ python systrace.py --time=10 -o mynewtrace.html sched gfx
view wm
```

- Open trace in a web browser

- Thicker bars (tasks that take longer than others) can indicate a performance problem



Source: http://developer.android.com

Systrace - Application Level Tracing

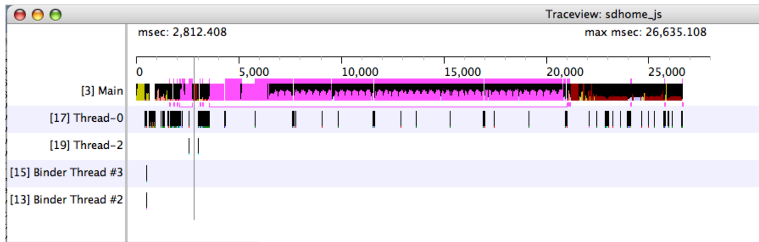
- From Android 4.3 use `Trace` class to add instrumentation to the application code
- Trace calls can be nested
- Traces must begin and end in the same thread

```
Trace.beginSection("Start␣trace");
try {
        // executing tasks
} finally {
        Trace.endSection(); // end trace
}
```

- Graphical viewer for execution logs (generated with `Debug` class)
- Timeline panel - displays each thread and method started/stopped
- Profile panel - summary of all time spent in a method
- Two methods to generate trace logs:
  - Use methods of the `Debug` class to start and stop tracing
  - Use method profiling feature of DDMS (no precise log timing)

```
Debug.startMethodTracing("data"); // start tracing to
                                  // "/sdcard/data.trace"
// execute tasks
Debug.stopMethodTracing(); // stop tracing
```

- Displays the execution of each thread in a separate row
- Each method - a different color
- Thin line below - extent of all calls to the selected method



Source: http://developer.android.com

Traceview - Profile Panel

- All time spent in a method (inclusive and exclusive times)
- Exclusive time = time spent in a method
- Inclusive time = time spent in a method + time spent in any called functions
- Last column - number of calls to this method + number of recursive calls

Name	Incl %	Inclusive	Excl %	Exclusive	Calls+Rec
▼ 4 android/webkit/LoadListener.nativeFinished ()V	66.6%	17734.382	53.2%	14161.950	14+0
3 android/webkit/LoadListener.tearDown ()V	100.0%	17734.382			14/14
6 android/view/View.invalidate (IIII)V	19.8%	3516.410			2413/2853
57 android/webkit/BrowserFrame.startLoadingResource (ILjava	0.3%	44.636			3/15
53 java/util/HashMap.put (Ljava/lang/Object;Ljava/lang/Objec	0.0%	6.223			6/326
20 android/webkit/JWebCoreJavaBridge.setSharedTimer (J)V	0.0%	2.593			2/730
378 android/view/ViewGroup.requestLayout ()V	0.0%	1.139			2/54
315 java/util/HashMap.<init> (I)V	0.0%	0.879			3/41
629 android/webkit/BrowserFrame.loadCompleted ()V	0.0%	0.285			1/1
598 android/webkit/WebView.didFirstLayout ()V	0.0%	0.231			1/2
703 android/webkit/BrowserFrame.windowObjectCleared (I)V	0.0%	0.036			1/2
▶ 5 android/webkit/JWebCoreJavaBridge$TimerHandler.handleMessa	16.3%	4342.697	0.5%	132.018	730+0
▶ 6 android/view/View.invalidate (IIII)V	15.6%	4161.341	1.2%	319.164	2853+0
▶ 7 android/webkit/JWebCoreJavaBridge.access$300 (Landroid/webk	15.1%	4025.658	0.1%	26.727	729+0

Source: http://developer.android.com

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