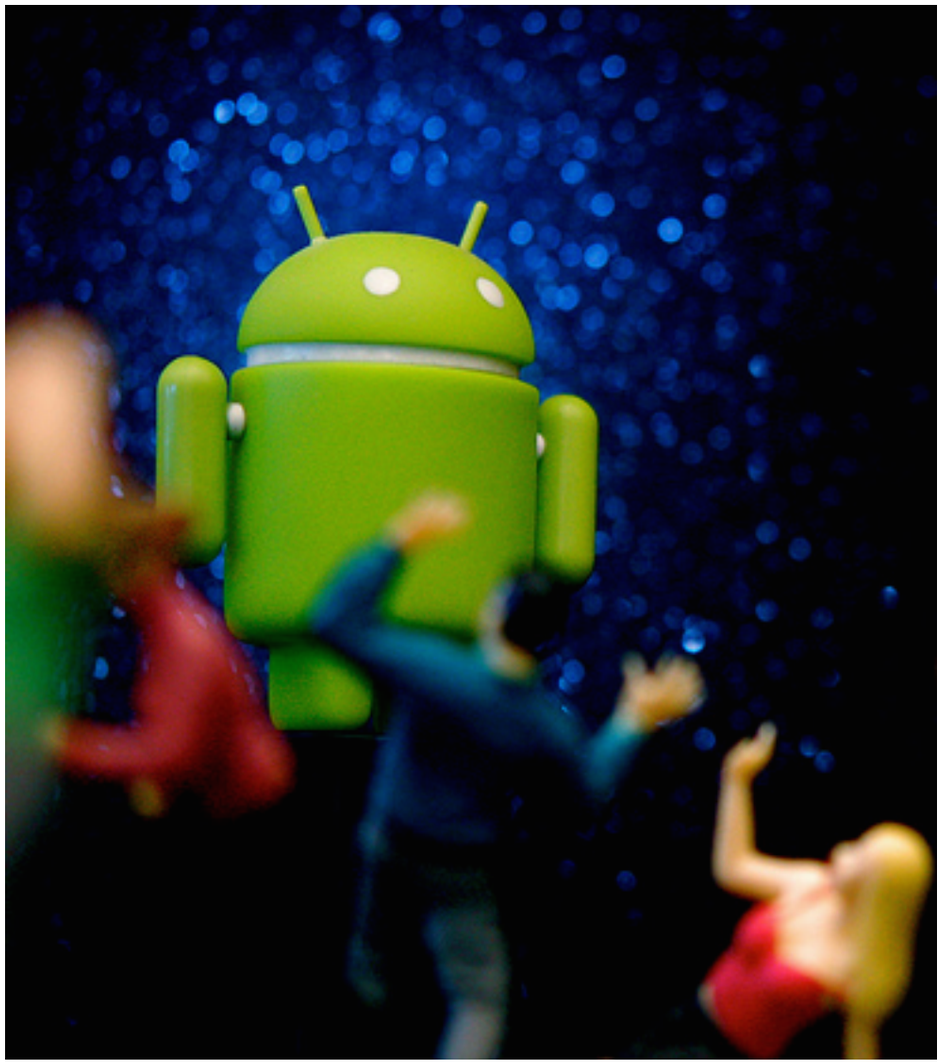

JD Hancock: Reign of The Android. http://bit.ly/1GN8vmg

Tips and Tricks for Building High-Performance Android Apps using Native Code

Kenneth Geisshirt
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Realm Inc.
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http://github.com/Realm/
http://realm.io/

Today's Goal

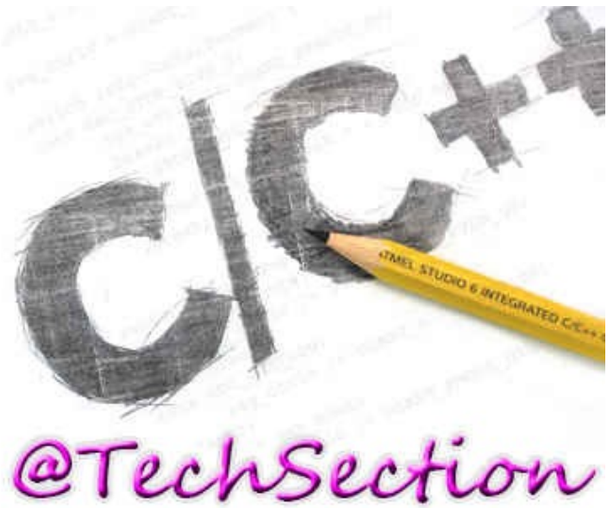
- Android development is not just Java

Swen-Peter Ekkebus: Goal! http://bit.ly/1x1suYm

- C and C++ can speed apps up - and reuse old legacy code

- Learn a few tricks when working with Java Native Interface

- Hands-on exercises



Avinash Sharma: http://bit.ly/1aRorcH

Agenda

Exploratorium. After Dark: Time http://bit.ly/1aSQxo0

- Setting up your environment
- Java Native Interface
- Threading
- Using non-NDK libraries[1]
- Benchmarking
- Debugging

[1]NDK = Native Development Kit

Advantages

- Use C or C++ in your apps → no JIT needed as always machine instructions
- Access to system calls (like `mmap()`)
- Almost no limits on memory usage
- OpenGL programming
- Sharing code across platforms
- Reusing legacy libraries

Alan Bates. Good Times http://bit.ly/1BXX7FN

Disadvantages

Rocher: That_Sux http://bit.ly/1BdGNhJ

- C and C++ memory management → easy to crash your app
- And debugging across languages is hard
- Bionic C library isn't the GNU C library
- Doing a native call is expensive (in time)
- Cumbersome to use non-NDK libraries

Use Cases

- AndEngine (2D Game Engine)

  http://www.andengine.org

- ImageMagick for Android

  https://github.com/paulasiimwe/Android-ImageMagick

- LevelDB for Android

  https://github.com/litl/android-leveldb

- Support Vector Machine for Android

  https://github.com/cnbuff410/Libsvm-androidjni

See-ming Lee; Rainbow Teddy shows BBF Stitch how to use the Canon EOS M; http://bit.ly/1O3yA43

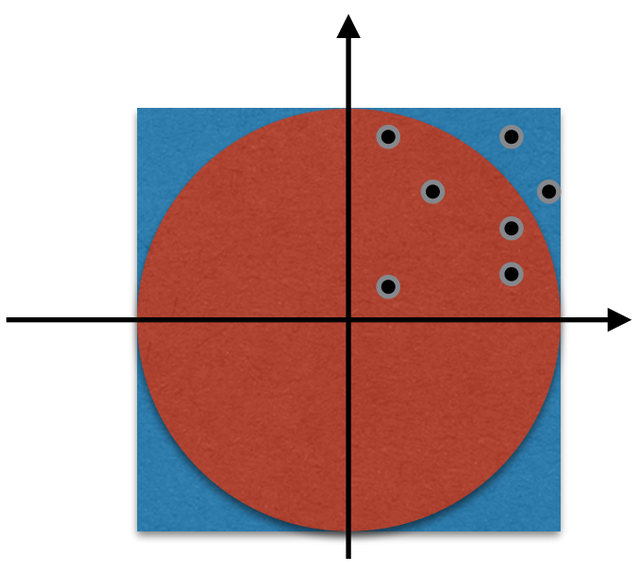
Playing with C++

Example: estimating π

Estimating π using dart

- Throw arrows at random
- $N_{hit}/N = A/4$ (quarter of a circle)
- $A = \pi \cdot r^2$ (area of a circle)
- $\pi = 4 \cdot N_{hit}/N$ (with $r = 1$)

Bogdan Suditu: Darts. http://bit.ly/18jCExj



```
for i = 1,..,N
    x = random(0, 1)
    y = random(0, 1)
    if (sqrt(x·x+y·y) < 1)
        Nhit = Nhit +1
π = 4·Nhit/N
```

Example: the classes

jeramiah.andrick. My random number generator http://bit.ly/1wbTbP2

Random number generator

- Constructor with seed
- Method `uniform()` to return random number between 0.0 and 1.0

π estimator

- Constructor with number of iteration
- Method `estimate()` to calculate the value of π

Quinn Dombrowski: Pi http://bit.ly/1Kz55cp

Exercise 1

- Implement two C++ classes
    1. RNG - a random number generator
        - `uniform()` returns a number in [0, 1[
    2. pi - a π estimator using MC algorithm
        - `estimate()` returns π
- Write simple test program
- Compile using `clang++` or `g++`
- Go to https://github.com/kneth/AndroidCalcPi if lazy 😄
    - Branch: initial

The environment

- Android Studio 1.3.0 (July 28, 2015)
- Java 1.8 JDK
  - or set version (▶ Build ▶ Build types)
- Android SDK 24.3.3
  - Android NDK can now be bundled
- Gradle 2.5
  - `gradle-wrapper.properties`
- A rooted device is nice to have
- Always use Intel HAXM for the emulator

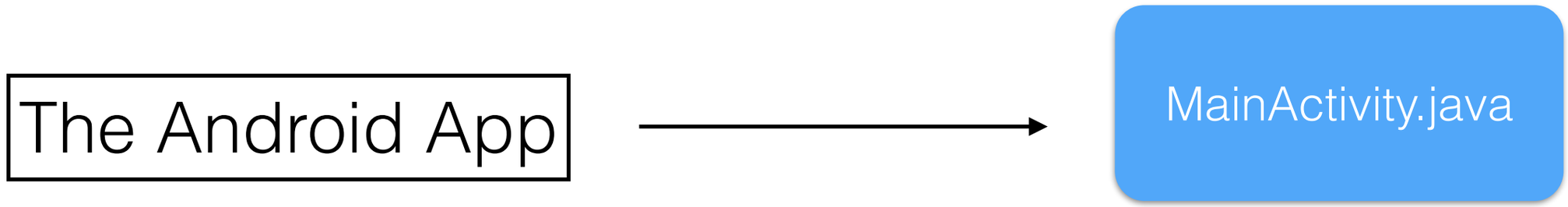
Dave Gingrich;http://bit.ly/1HxRJWj

`local.properties`

```
ndk.dir=/usr/local/Cellar/android-sdk/24.3.3/ndk-bundle
sdk.dir=/usr/local/Cellar/android-sdk/23.0.2
```

Java Native Interface

Architecture



Organize your files

- Use the experimental Android plugin for Gradle
- Place C/C++ files in `app/src/main/jni/`
- Add `ndk.dir` to `local.properties`
- Add an `ndk` section to your app's `build.gradle`

```
android.ndk {
    moduleName = "calcPi"
    cppFlags += ["-fexceptions"]
    stl = "gnustl_shared" // for exceptions
}
```

Building and Loading your native code

- Automatically build for all supported architectures (ARM, ARMv7, ARM64, MIPS, MIPS64, x86, x86-64)

- Android only installs the relevant architecture

- Load native code early (main activity's `onCreate`)

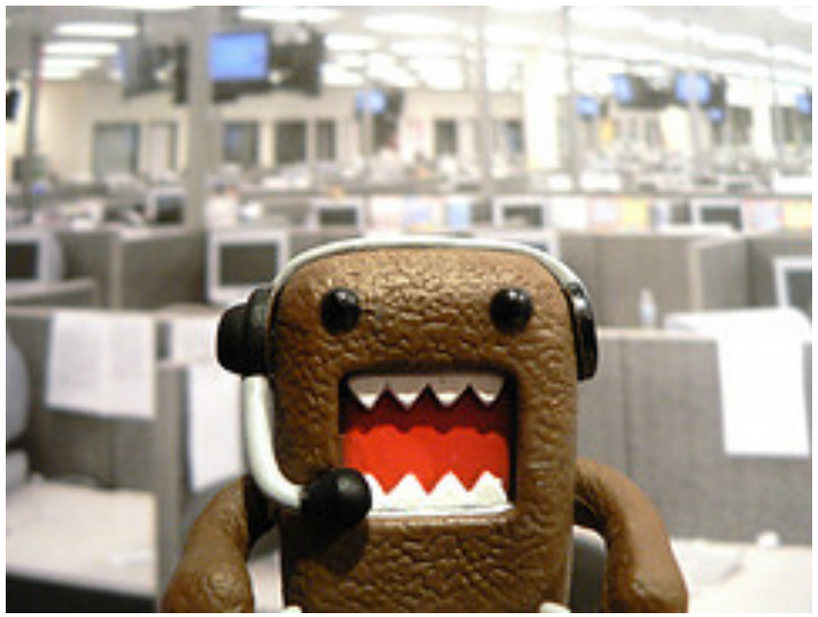
Thomas Hawk: Loading Zone http://bit.ly/1MoBk9S

```
System.loadLibrary("calcPi");
```

The module name (from `build.gradle`)

Calling a C++ function

- Use Java's `native` keyword in the signature
- Implement the function in C++
- Use a `long` to store the C++ pointer when you creates an object



lamont_cranston: call center http://bit.ly/1A4JlK5

Returns a pointer (a C++ object)

Operates on a C++ object

Tell the Java compiler it's a native function

```
native long nativeCreate(long iterations);
native double nativeEstimate(long nativePtr);
```

Generate header files

Paul: Generator Room Door http://bit.ly/1C3SSs7

- `.class` files contain information about native calls
- `javah` can extract signatures and generate C/C++ header files

Add path to jar files you depend on

Classes to extract from

```
!/bin/bash
# Setting up
CLASSDIR="$(pwd)/../app/build/intermediates/classes/debug"
JNIDIR="$(pwd)"

# Generate the headers
(cd "$CLASSDIR" && javah -jni -classpath "$CLASSDIR" -d "$JNIDIR"
net.zigzak.androidcalcpi.NativePi net.zigzak.androidcalcpi.NativeRNG)

# Remove "empty" header files (they have 13 lines)
wc -l "$JNIDIR"/*.h | grep " 13 " | awk '{print $2}' | xargs rm -f
```

Java types in C/C++

- Java types are mapped to C/C++ types
- Convert `Date` to `long` before call
- Pass pointers over as `long`/`jlong`

Java	C/C++
`long`	`jlong`
`String`	`jstring`
`long[]`	`jlongArray`
`Object`	`jObject`
`float`	`jfloat`

The pointer

Generated function name

cast to a proper C++ pointer

```
JNIEXPORT jdouble JNICALL Java_net_zigzak_androidcalcpi_NativePi_nativeEstimate
  (JNIEnv *, jobject, jlong nativePtr)
{
    Pi *pi = reinterpret_cast<Pi *>(nativePtr);
    double estimate = pi->estimate();
    return estimate;
}
```

Define as a macro if used often:

```
#define P(x) reinterpret_cast<Pi *>(x)
```

Working with arrays

- Copy values from JVM memory to C/C++ memory

```
jsize arr_len = env->GetArrayLength(columnIndexes);
jlong *arr = env->GetLongArrayElements(columnIndexes, NULL);
// use the elements of arr
env->ReleaseLongArrayElements(columnIndexes, arr, 0);
```

- Remember to free C/C++ memory → avoid memory leaks

```
jArray = env->NewByteArray(jlen);
if (jArray)
  // Copy data to Byte[]
  env->SetByteArrayRegion(jArray, 0, jlen,
      reinterpret_cast<const jbyte*>(bufPtr));
free(bufPtr);
return jArray;
```

- Create a new Java array
- Copy C/C++ array to Java array

Strings as trouble-makers

- Java strings are in modified UTF-8
  - null character encoded as 0xC0 0x80 (not valid UTF-8)
  - Many C/C++ libraries assume plain UTF-8

Create a new Java string

```
jchar stack_buf[stack_buf_size];
// adding characters to stack_bf
jchar* out_begin = stack_buf;
if (int_cast_with_overflow_detect(out_curr - out_begin, out_size))
    throw runtime_error("String size overflow");
return env->NewString(out_begin, out_size);
```

- Copy Java string to C/C++ array
- Remember to deallocate C array

```
jstring s;  // typical a JNI function parameter
jchar *c = e->GetStringChars(s, 0);
// use c
env->ReleaseStringChars(s, c);
```

Exercise 2

- Create a simple Android app
  - Implement Java classes RNG and Pi
  - Generate header files
  - Implement intermediate C++ function and call original C++ code
  - Go to https://github.com/kneth/AndroidCalcPi if lazy 😄
    - branch wrapping

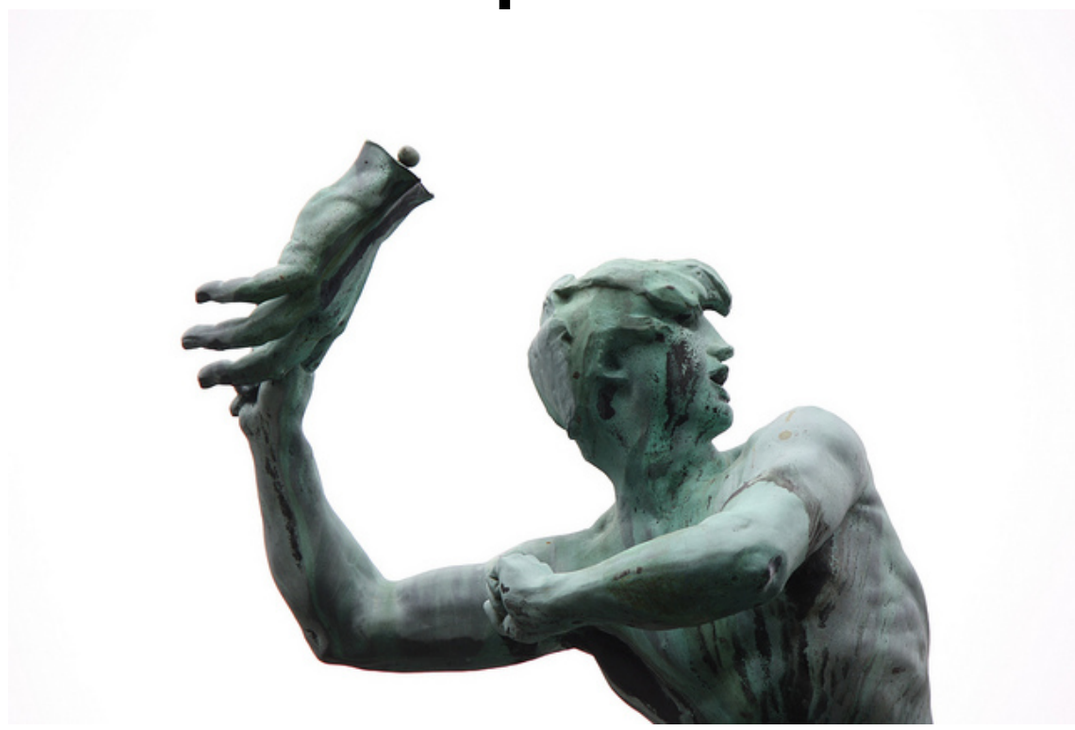
C++ exceptions

- C++ code can throw exceptions
  - `new` can throw `bad_alloc`,etc.
- If uncaught the app crashes with hard-to-understand messages in the log
- Better solution:
  - catch and rethrow as Java exception

```
Build fingerprint: 'generic_x86/sdk_x86/generic_x86:4.4.2/KK/999428:eng/test-keys'
Revision: '0'
pid: 1890, tid: 1890, name: t.zigzak.calcpi  >>> net.zigzak.calcpi <<<
signal 6 (SIGABRT), code -6 (SI_TKILL), fault addr --------
eax 00000000  ebx 00000762  ecx 00000762  edx 00000006
esi 00000762  edi 0000000b
xcs 00000073  xds 0000007b  xes 0000007b  xfs 00000000  xss 0000007b
eip b7707c96  ebp b776cce0  esp bfa22090  flags 00200203
backtrace:
#00  pc 0003bc96  /system/lib/libc.so (tgkill+22)
#01  pc 00000005  <unknown>
stack:
bfa22050  00000001
bfa22054  b899c6d0  [heap]
bfa22058  00000015
bfa2205c  b76d9ef9  /system/lib/libc.so (pthread_mutex_unlock+25)
bfa22060  a73bfd19  /data/app-lib/net.zigzak.calcpi-1/libgnustl_shared.so
bfa22064  b7767fcc  /system/lib/libc.so
```

Throwing a Java exception

- You don't throw an exception
- You set the "exception" state in JVM
- Return from C/C++ function



followtheinstructrions: hand werpen http://bit.ly/1Bo3gZx

1 Get a reference to the exception

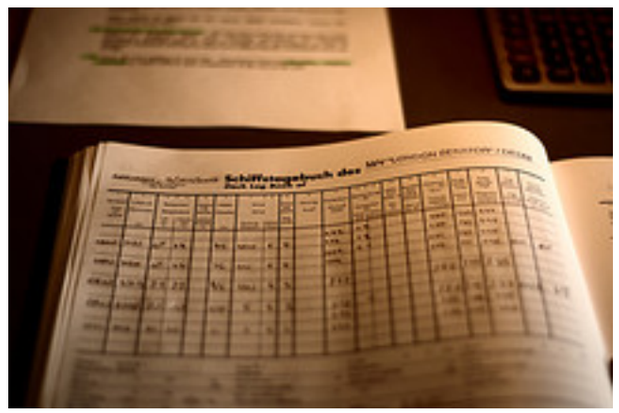
2 Set the "exception" state

3 Clean up

```
try {
    Pi *pi = new Pi(static_cast<long>(iterations));
    return reinterpret_cast<jlong>(pi);
}
catch (std::exception& e) {
    jclass jExceptionClass =
       env->FindClass("java/lang/RuntimeException");
    std::ostringstream message;
    message << "Allocating native class Pi failed: " << e.what();
    env->ThrowNew(jExceptionClass, message.str().c_str());
    env->DeleteLocalRef(jExceptionClass);
}
return 0;
```

Logging

- JNI provides access to the Android log
- `__android_log_print` is a simple variadic log function



vitelone: Deck Log Book http://bit.ly/1AXKZ0j

- Linking with `liblog` is required
- `size_t` depends on bit width → cast to `int64_t` before logging

Link flag

```
android.ndk {
    moduleName = "calcPi"
    cppFlags += ["-fexceptions"]
    ldLibs += ["log"]
    stl = "gnustl_shared" // for exceptions
}
```

Macro to simplify logging

```
#define LOG(...) __android_log_print(ANDROID_LOG_DEBUG, "calcPi", __VA_ARGS__);
```

Tracing JNI calls

- It is useful the trace calls
  - Define `ENTER`, `ENTER_PTR`, and `LEAVE` macros
    - Logging native pointer as `jlong` often produce negative numbers - don’t worry

```
1955-1955/net.zigzak.calcpi D/calcPi: Enter Java_net_zigzak_calcpi_NativePi_nativeCreate
1955-1955/net.zigzak.calcpi D/calcPi: iterations: 10000
1955-1955/net.zigzak.calcpi D/calcPi: Enter Java_net_zigzak_calcpi_NativePi_nativeEstimate
-1202665872
1955-1955/net.zigzak.calcpi D/calcPi: estimate = 3.128400e+00
```

Exercise 3

- Catch common C++ exceptions (`bad_alloc`)
- Rethrow as a Java exception
- Adding logging/tracing of JNI calls
- Go to https://github.com/kneth/AndroidCalcPi if lazy 😄
  - branch exceptions-and-logging

Tricks to compiling and linking

Reduce size

- Compiler can optimise for size (`-Os`)
- Link Time Optimizations (LTO) can reduce size of native code
- Eliminate unused code (`-ffunction-sections -fdata-sections`) and unused ELF symbols (`-fvisibility=hidden`)

```
android.ndk {
    moduleName = "calcPi"
    cppFlags += ["-Os", "-fexceptions", "-fvisibility=hidden"
       "-ffunction-sections", "-fdata-sections",
       "-Wl,--gc-sections", "-flto"]
    ldLibs += "log"
    stl = "gnustl_shared" // for exceptions
    ldFlags += ["-Wl,--gc-sections", "-flto"] // reduce size
}
```

http://realm.io/news/reducing-apk-size-native-libraries/

Threading

POSIX threads

- Android's Bionic C library supports POSIX threads
  - except cancellation
  - Threading can utilize your device's cores
  - If you utilize all cores for longer times, you get

```
W/art :  Suspending all threads took: 40.036ms


I/Choreographer :  Skipped 18858 frames!  The application may be doing
too much work on its main thread.
```

Exercise 4

- Add a π estimator using POSIX threads
  - reuse the `estimate` method
- Go to https://github.com/kneth/AndroidCalcPi if lazy 😄
  - branch posix-threads

Using non-NDK libraries

Libraries

- NDK has some libraries
  - Basic ones: standard C, logging, etc.
    - Linked during build
- Android has many other libraries
  - `/system/lib` is their home
  - OpenSSL, XML2, SQLite, ICU

How to use?

- Android has dynamic linking
  - Add `dl` to `ldFlags`
  - Include `dlfcn.h` in your C/C++ files
  - You might have to declare relevant structs and types

Find symbol in .so file

Function pointer

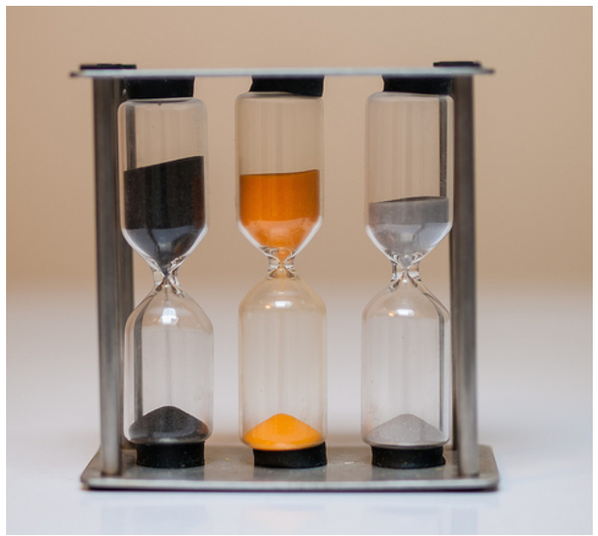
```
SHA256_CTX ctx;
int (*SHA224_Init)(SHA256_CTX *);
SHA224_Init =
  reinterpret_cast<int (*)(SHA256_CTX*)>
  (dlsym(RTLD_DEFAULT, "SHA224_Init"));
SHA224_Init(&ctx);
```

Exercise 5

- Add method to a class
  - Load one or two libcrypto functions
  - and call them
- Go to https://github.com/kneth/AndroidCalcPi if lazy 😄
  - branch non-ndk-libraries

Benchmarking

What makes benchmarking hard?



William Warby, Triple Timer; http://bit.ly/1TwetP4

- Android devices do many things
  - checking for updates, synchronising accounts, garbage collection, etc.
- Android timers are not reliable
- Just-in-Time compilation

Measuring timer resolution

- Use `Debug.threadCpuTimeNanos()`
- But resolution depends on device
- Microbenchmark must be longer than resolution
- Resolution is used to validate benchmark
- Go to https://github.com/kneth/AndroidCalcPi
  - branch benchmarking

```
long diff = 50000;
for (int i = 0; i < 100; i++) {
  long end;
  long start =
      Debug.threadCpuTimeNanos();
  while (true) {
    end = Debug.threadCpuTimeNanos();
    if (end != start) {
      if (diff > (end - start)) {
        diff = end - start;
      }
      break;
    }
  }
}
```

Debugging

Android Debug Bridge

- Android Debug Bridge (adb) has some useful subcommands
  - `shell`: plain command-line shell
  - `pull`: copy file from device
  - `push`: copy file to device

M. O'Thompsonski, http://bit.ly/1Da0o0h

Get stack trace

- Android apps are processes
  - Dump stack traces using `kill`

```
mkdir -p /data/anr
ps # find your app
kill -3 <pid>
cat /data/anr/traces.txt
```

- Log every native call

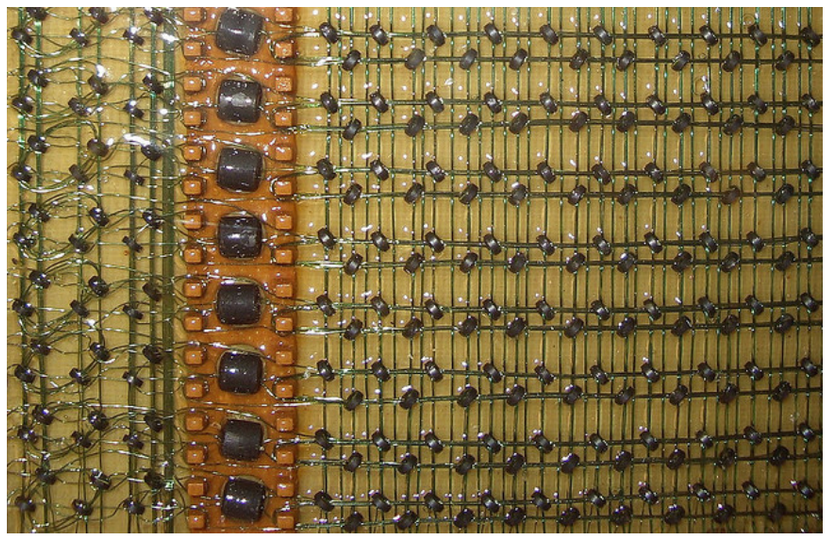
```
#define ENTER_PTR(ptr)
 __android_log_print(ANDROID_LOG_DEBUG,"calcPi", "Enter %s %" PRId64,
 __FUNCTION__, static_cast<int64_t>(ptr));
```

Forces 64 bit value!

The name of the function

Checking native memory

- The emulator can help checking malloc
- C/C++ makes it easy to do memory management wrong
- Set the debug level to 20



Steve Jurvetson, Primitive Memories; http://bit.ly/1HY80sf

```
adb shell setprop libc.debug.malloc 20
adb shell stop
adb shell start
```

Native debugging

- Android Studio 1.3 supports native debugging
  - gdb or lldb
  - Add a run configuration (native)

App's `build.grade`

```
android.buildTypes {
    debug {
        isJniDebuggable = true
        isDebuggable = true
    }
}
```

References

- *High Performance Android Apps* by Doug Sillars. O'Reilly Media, 2015.

- *Essential JNI* by Rob Gordon. Prentice Hall, 1998.

- *The Java Native Interface* by Sheng Liang. Addison-Wesley, 1999.

- *Android NDK* by Sylvian Rataboil. Packt Publishing, 2012.

AnDevCon

The Android Developer Conference

Please take a moment to fill out the class feedback form via the app. Paper feedback forms are also available in the back of the room.

eventmobi.com/adcboston