How to bring compute intensive C++ based apps to Android

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Outline

1. Let's get started
   • Motivation – Why native code on Android?
   • Introduction – About the TiGL App for aircraft design at DLR

2. Hacking
   • Preparing Native App Development
   • Compiling and patching 3rd party libraries
   • Using JNI to communicate between Java and C/C++

3. Building
   • Integrate NDK build into Gradle

4. Testing / Running
   • Using the Android Emulator efficiently
   • Debugging with ndk-gdb and Eclipse
Motivation – Why native code?

• Rewrite of large and tested codebase to Java not reasonable
  • Introduces new errors
  • Code depends on other 3rd party libraries without Java counterpart
  • Too time consuming

• Many numerical algorithms implemented in C or Fortran

• C and Fortran compilers produce highly optimized machine code

• On the other hand:
  • Native code is harder to debug
  • Must be ported (may contain platform specific code)
About the TiGL project at DLR

- Central **geometry** viewer and library used by many simulation tools in DLR for **aircraft design**

- Written in C++, large tested code base

- Uses other Open Source Software:
  - CAD kernel OpenCASCADE
  - 3D engine OpenSceneGraph

- Multiplatform – Win, Linux, OS X, and **Android**

- Open Source ![logo](link), Apache 2.0
Aircraft design at DLR

- Aero/CFD Simulations
- Modeling with CAD Systems
- Rendering, Visualization
- 3D Printing
The TiGL Geometry Viewer
Why Android?

Because we can!

And it’s fun 😊
What you’ll need

- Android SDK
- Android Native Development Kit (NDK):
  - gcc cross compiler toolchains
  - ndk-build: The android build system for native code
  - ndk-gdb to debug native apps
  - Android specific libraries
- CMake / Autotools to cross-compile dependencies
Steps to the Native Android App

1. Install Android SDK + NDK

2. Cross-Compile and patch 3rd party libraries with NDK toolchain

3. Define a Java Interface class for the communication with your native code

4. Write JNI glue code that calls native code and translates Java objects

5. Create a shared library containing your native code

6. Design Java based Android UI that talks to your JNI wrapper

7. Build the App: Compile native code + standard build steps
Using 3rd party native libraries

- Many open source libraries are already adapted to be used as Android modules
  - Use these if available!!
  - Can be found e.g. on https://github.com/android

- Or, port the library to Android and either
  a. Cross-compile using the default build system of the library (e.g. CMake, Autotools, Scons…) + create pre-built module
  b. Or, override build system with new Android.mk Makefile
Cross-compiling CMake based 3rd party libs

1. Install standalone cross compiling toolchain

   
   \$NDK/build/tools/make-standalone-toolchain.sh --platform=android-9
   --install-dir=/opt/

2. Create AndroidToolchain.cmake

   ```
   SET(CMAKE_SYSTEM_NAME Linux)
   SET( TOOLCHAIN /opt/arm-linux-androideabi-4.6/)
   
   SET( CMAKE_FIND_ROOT_PATH $<TOOLCHAIN> )
   SET( CMAKE_C_COMPILER "$<TOOLCHAIN>/bin/arm-linux-androideabi-gcc")
   SET( CMAKE_CXX_COMPILER "$<TOOLCHAIN>/bin/arm-linux-androideabi-g++")
   
   SET( CMAKE_FIND_ROOT_PATH_MODE_PROGRAM NEVER )
   SET( CMAKE_FIND_ROOT_PATH_MODE_LIBRARY ONLY )
   SET( CMAKE_FIND_ROOT_PATH_MODE_INCLUDE ONLY )
   ```

3. Configure CMake project with toolchain argument

   ```
   cmake -DCMAKE_TOOLCHAIN_FILE=AndroidToolchain.cmake ...
   ```
Writing prebuilt module Android.mk

- The cross-compiled libs must be packaged as an Android module for further use

```bash
LOCAL_PATH := $(call my-dir)

include $(CLEAR_VARS)

# define module name and library #
LOCAL_MODULE := PTKernel
LOCAL_SRC_FILES := $(LOCAL_PATH)/obj/local/$(TARGET_ARCH_ABI)/libPTKernel.a

# set include directories #
LOCAL_EXPORT_C_INCLUDES := $(LOCAL_PATH)/include/oce

include $(PREBUILT_STATIC_LIBRARY)
```

- Copy Android.mk to root install directory of library
Or - override build system with custom Android.mk

```
LOCAL_PATH := $(call my-dir)
include $(CLEAR_VARS)

# build TIXI_static library #
LOCAL_MODULE := TIXI_static

TIXI_INCLUDES := $(LOCAL_PATH)/src
LOCAL_C_INCLUDES := $(TIXI_INCLUDES)
LOCAL_EXPORT_C_INCLUDES := $(TIXI_INCLUDES)

# Add all *.c files from src directory #
FILE_LIST := $(wildcard $(LOCAL_PATH)/src/*.c)
LOCAL_SRC_FILES := $(FILE_LIST:$(LOCAL_PATH)=%=%)

# link with other Android modules #
LOCAL_STATIC_LIBRARIES := libxslt libxml2 curl

include $(BUILD_STATIC_LIBRARY)
$(call import-module,libxml2)
$(call import-module,libxslt)
$(call import-module,curl)
```
Patching OpenCASCADE (and other 3rd parties) code

- Differences in Android’s Bionic C library
  - No timezone function
  - No pw_gecos member in passwd struct
  - Missing System V IPC calls, i.e. provide workarounds to
    shmat, shmget, semctl, semop, semget ...

- Use #ifdef __ANDROID__ for android specific code paths
- Deactivate X-Server based code paths

OpenCASCADE rendering engine must be replaced
(it uses X library calls, fixed function OpenGL pipeline …)
Use JNI to wrap native code

- **Java Native Interface** enables communication with native (C++) code

- Realized, by calling functions from a shared library (*.dll or *.so)

- Provides:
  - Loading shared library via `System.loadLibrary("mylib")`
  - Functions to convert between Java and C data types
  - Mechanism to call Java methods from C/C++

- BUT! - Java to C glue code has to be written by hand

- Header file of JNI Wrapper class should be created with `javah` (assures correct function names, including package names)
JNI – write native interface (Java)

• Define interface class in Java

```java
package de.dlr.sc.jnitutorial;

public class NativeInterface {
    static {
        // load tutorial-native.so from libs
        System.loadLibrary("tutorial-native");
    }

    // Declare a native methods
    public native void initNative();
    public native String getName();
    public native void setName(String s);
}
```

• Create JNI header file with javah

```bash
javah de.dlr.sc.jnitutorial.NativeInterface
```
JNI – automatically generated header file

/* DO NOT EDIT THIS FILE – it is machine generated */
#include <jni.h>
/* Header for class de_dlr_sc_jnitutorial_NativeInterface */

ifndef _Included_de_dlr_sc_jnitutorial_NativeInterface
#define _Included_de_dlr_sc_jnitutorial_NativeInterface
ifndef __cplusplus
extern "C" {
#endif

JNIEXPORT void JNICALL Java_de_dlr_sc_jnitutorial_NativeInterface_initNative
    (JNIEnv *, jobject);

JNIEXPORT jstring JNICALL Java_de_dlr_sc_jnitutorial_NativeInterface_getName
    (JNIEnv *, jobject);

JNIEXPORT void JNICALL Java_de_dlr_sc_jnitutorial_NativeInterface_setName
    (JNIEnv *, jobject, jstring);

#endif
#endif
JNI – handwritten C++ glue code

```c
#include "de_dlr_sc_jnitutorial_NativeInterface.h"
#include "tutorial.h"

JNIEXPORT void JNICALL Java_de_dlr_sc_jnitutorial_NativeInterface_initNative (JNIEnv * env, jobject)
{
    init_native();
}

JNIEXPORT jstring JNICALL Java_de_dlr_sc_jnitutorial_NativeInterface_getName (JNIEnv * env, jobject)
{
    // create java string from std::string
    return env->NewStringUTF(get_name().c_str());
}

JNIEXPORT void JNICALL Java_de_dlr_sc_jnitutorial_NativeInterface_setName (JNIEnv * env, jobject, jstring name)
{
    // convert to c-string
    const char * cname = env->GetStringUTFChars(name, NULL);
    // call library function
    set_name(cname);
    // free allocated memory for string
    env->ReleaseStringUTFChars(name, cname);
}
```
Life cycle of native code

- With hybrid Java/C++ Apps, no automatic life cycle management for native code
- Compared to Java code, no need to store and restore state on suspend/resume

Native library resides in memory

- Provide initialization and shutdown routines for native library
Compiling + Packaging
Automate build with Gradle and NDK

• Gradle?
  • The new build system for Android
  • Replaces Apache Ant
  • Used by Android Studio

• NDK integration into Gradle just recently added by Google
• Problem: Gradle creates Makefiles files which mostly don’t work
• Workaround:
  • Disable automatic creation of Android.mk Makefiles
  • Write your own Android.mk files
  • Define a custom build task to call ndk-build
Automate build with Gradle and NDK

1. Register libs folder to the APK and disable automatic Android.mk creation

```groovy
jniLibs.srcDir 'libs'
jni.srcDirs = []
```

2. Define custom task to build native code

```groovy
task ndkBuild(type: Exec) {
    def ndkBuild;
    if (System.properties['os.name'].toLowerCase().contains('windows')) {
        ndkBuild = new File(System.env.ANDROID_NDK_HOME, 'ndk-build.cmd')
    } else {
        ndkBuild = new File(System.env.ANDROID_NDK_HOME, 'ndk-build')
    }
    commandLine ndkBuild, '-j', Runtime.runtime.availableProcessors()
}
```

3. Add task to build dependencies

```groovy
tasks.withType(Compile) {
    compileTask -> compileTask.dependsOn ndkBuild
}
```
Running + Testing
Using the emulator efficiently

- Standard Android Virtual Device emulates ARM instructions using QEMU

- Use a x86 based emulator with GPU acceleration

- Install Intel HAXM acceleration driver (part of Android SDK)

- All 3rd party libraries must be recompiled with an x86 based NDK toolchain

- Add `x86` to `APP_ABI` in `Application.mk` to compile for x86 platform
Using the emulator efficiently
The Genymotion Android emulator

- X86 based very fast Android emulator
- Uses VirtualBox under the hood
- Comes with many pre-configured devices
- Just works
Debugging native apps

- NDK ships debugger ndk-gdb

- Using ndk-gdb from Eclipse is tricky:
  - Set `APP_OPTIM := debug` in jni/Application.mk
  - Add `NDK_DEBUG=1` option to `ndk-build` command (IMPORTANT!)
  - Workaround an Eclipse Bug by running once

        ndk-gdb --nowait

        from project directory while the app is already launched

- Note: Debugging with Genymotion Emulator needs a patch:
TiGL Viewer in Play Store

TiGL Viewer is a small app to display aircraft geometries based on the CPACS file format. It uses the OpenCASCADE CAD engine to create the geometries and GoodFreeView for the 3D display. This is the Android port of the desktop version of TiGL Viewer.
Questions

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https://github.com/rainman110/droidcon_jni
OpenMP Thread parallelism on Android

• Apps crashing when using OpenMP directives outside the main thread
• Reason are differences in Thread Local Storage (TLS) on Android compared to Desktop
• BUT:
  • The NDK can be patched, to enable OpenMP:

http://recursify.com/blog/2013/08/09/openmp-on-android-tls-workaround