NDK
native API crunch

Native Applications

Lecture 9

Android Native Development Kit

29 April 2014

Outline

Native applications

- Native activities
- From Android API level 9 (2.3 Gingerbread)
- Only native code, no Java
- App still runs on Dalvik VM
- API to access Android resources
  - Windows, assets, device configuration
- Missing functionality
- Used mainly for multimedia apps

Outline

Low-level Native Activity - Example

- Application named `NativeApp`
- Android Tools -> Add Native Support
- `AndroidManifest.xml`
  - Min API level 9
  - Specify activity name

```
<activity android:name="android.app.NativeActivity">
```

  - Specify property `android.app.lib_name`
    - Native module name without lib prefix and .so suffix

```
<meta-data android:name="android.app.lib_name"
android:value="NativeApp" />
```

  - `android:hasCode` must be false
    - No Java code

```
<application android:hasCode="false">
```

Native Activity Source Code

```
#include <jni.h>
#include <android/native_activity.h>
#include <android/log.h>
static void onStart(ANativeActivity* activity){
        __android_log_print(ANDROID_LOG_INFO, "NativeApp",
"Start: %p\n", activity);
}
[..]
void ANativeActivity_onCreate(ANativeActivity* activity,
                    void* savedState, size_t savedStateSize) {
        printInfo(activity);
        activity->callbacks->onStart = onStart;
        activity->callbacks->onResume = onResume;
        activity->callbacks->onPause = onPause;
        activity->callbacks->onStop = onStop;
        activity->callbacks->onDestroy = onDestroy;
        [..]
        activity->instance = NULL;
}
```

Native Activity Source Code

- `NativeApp.cpp` in `jni/`
- `ANativeActivity_onCreate()` is an entry point
- `ANativeActivity` structure defined in `native_activity.h`
- `savedState`: previously saved state of the activity
- `savedStateSize`: size in bytes of the saved state
- Implement callbacks to handle lifecycle events and user inputs

Building and Running App

- Android.mk

```
LOCAL_PATH := $(call my-dir)
include $(CLEAR_VARS)
LOCAL_MODULE := NativeApp
LOCAL_SRC_FILES := NativeApp.cpp
LOCAL_LDLIBS := -landroid -llog
include $(BUILD_SHARED_LIBRARY)
```

- Build app and run

```
04-26 15:51:41.535: I/NativeApp(6474): Internal data path:
/data/data/com.test.nativeapp/files
04-26 15:51:41.535: I/NativeApp(6474): External data path:
/storage/emulated/0/Android/data/com.test.nativeapp/files
04-26 15:51:41.535: I/NativeApp(6474): SDK version code: 19
04-26 15:51:41.535: I/NativeApp(6474): Start: 0x750539a8
04-26 15:51:41.535: I/NativeApp(6474): Resume: 0x750539a8
```

NativeActivity class

- Android framework provides `android.app.NativeActivity.java`
  - Helps the creation of a native activity
  - Subclass of `android.app.Activity`
  - Wrapper that hides the Java world from the native code
  - Exposes native interfaces defined in `native_activity.h`
  - Instance is created when you launch the native activity
  - Its `onCreate` calls `ANativeActivity_onCreate` through JNI
  - Invokes the callbacks when the corresponding events occur

ANativeActivity Structure

```
typedef struct ANativeActivity {
        struct ANativeActivityCallbacks* callbacks;
        JavaVM* vm;
        JNIEnv* env;
        jobject clazz;
        const char* internalDataPath;
        const char* externalDataPath;
        int32_t sdkVersion;
        void* instance;
        AAssetManager* assetManager;
} ANativeActivity;
```

ANativeActivity Structure

- `callbacks`: array of pointers to callback functions
  - You can set the pointers to your own callbacks
  - Called by the Android framework
- `vm`: global Java VM handle
- `env`: JNIEnv interface pointer
- `clazz`: reference to `android.app.NativeActivity` object
  - Used to access fields and methods
- `internalDataPath`, `externalDataPath`, `sdkVersion`
- `instance`: use it to store user-defined data
- `assetManager`: accessing binary assets in the apk

Outline

High-level Native Applications

- `native_activity.h` provides a simple single thread callback mechanism
- Long callback functions -> app becomes unresponsive to user actions
- Solution: use multiple threads
- Static library `android_native_app_glue`
  - Built on top of `native_activity.h`
  - Execute callbacks and handle user input in separate threads

High-level Native App Source Code

```
#include <jni.h>
#include <android_native_app_glue.h>
void handle_activity_lifecycle_events(struct android_app* app,
int32_t cmd) {
        __android_log_print(ANDROID_LOG_INFO, "NativeApp",
"%d: received data %d", cmd, *((int*)(app->userData)));
}
void android_main(struct android_app* app) {
        app_dummy();
        int data = 1234;
        app->userData = &data;
        app->onAppCmd = handle_activity_lifecycle_events;
        while (1) {
                int ident, events;
                struct android_poll_source* source;
                if ((ident=ALooper_pollAll(-1, NULL, &events,
(void**)&source)) >= 0) {
                        source->process(app, source);
                }
        }
}
```

Implementation Details

- Implement function `android_main`
  - Implement event loop which polls for events
  - Runs in a background thread
- Two event queues attached to the background thread (by default)
  - Activity lifecycle event queue and input event queue
  - Identify the event by ID
    - `LOOPER_ID_MAIN` or `LOOPER_ID_INPUT`
  - Additional event queues can be attached
- `android_app->userData` - transmit data to the processing function

- When event is received
  - Pointer to `android_poll_source` structure
    - Event ID, `android_app` structure, `process` function
  - Call `source->process` function
    - Calls `android_app->onAppCmd` for lifecycle events
    - Calls `android_app->onInputEvent` for input events
  - Implement our own processing functions
  - Set the function pointers to these functions
- In the example
  - Function called when lifecycle events occur
  - Prints cmd and transmitted data
  - Cmd is an enum defined in `android_native_app_glue.h`
  - APP_CMD_START = 10, APP_CMD_RESUME = 11, etc.

Building and Running App

- Android.mk

```
LOCAL_PATH := $(call my-dir)
include $(CLEAR_VARS)
LOCAL_MODULE := NativeApp2
LOCAL_SRC_FILES := NativeApp2.cpp
LOCAL_LDLIBS := -llog -landroid
LOCAL_STATIC_LIBRARIES := android_native_app_glue
include $(BUILD_SHARED_LIBRARY)
$(call import-module,android/native_app_glue)
```

- Build app and run

```
04-26 17:30:13.145: I/NativeApp2(32570): 10: received data
1234
04-26 17:30:13.145: I/NativeApp2(32570): 11: received data
1234
04-26 17:30:13.155: I/NativeApp2(32570): 0: received data
1234
04-26 17:30:13.175: I/NativeApp2(32570): 1: received data
1234
```

- Implements `ANativeActivity_onCreate`
  - Registers callbacks and calls `android_app_create` function

```
activity->instance = android_app_create(activity,
savedState, savedStateSize);
```

- `android_app_create`
  - Initializes an instance of `android_app` structure
  - Creates an unidirectional pipe for inter-thread communication
  - Creates the background thread to run `android_app_entry`
  - The pipe is used between main and background thread
- `android_app_entry`
  - Looper is created
  - The two event queues are attached to the looper
  - Calls `android_main` (our implementation)

Outline

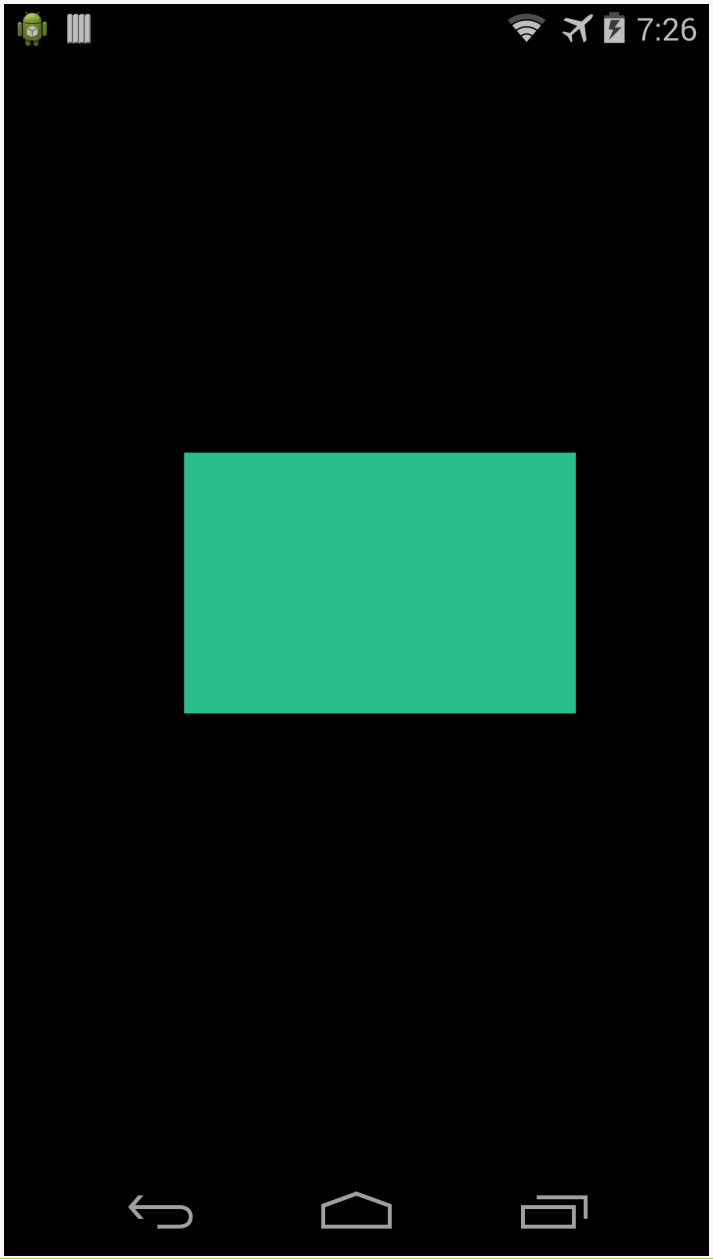
Managing Native Windows - Example

```
void drawSomething(struct android_app* app) {
        ANativeWindow_Buffer lWindowBuffer;
        ANativeWindow* lWindow = app->window;
        ANativeWindow_setBuffersGeometry(lWindow, 0, 0,
WINDOW_FORMAT_RGBA_8888);
        if (ANativeWindow_lock(lWindow, &lWindowBuffer,
                        NULL) < 0) {
                return;
        }
        memset(lWindowBuffer.bits, 0, lWindowBuffer.
stride*lWindowBuffer.height*sizeof(uint32_t));
        int sqh = 400, sqw = 600;
        int wst = lWindowBuffer.stride/2 - sqw/2;
        int wed = wst + sqw;
        int hst = lWindowBuffer.height/2 - sqh/2;
        int hed = hst + sqh;
        for (int i = hst; i < hed; ++i) {
                for (int j = wst; j < wed; ++j) {
                        ((char*)(lWindowBuffer.bits))
[(i*lWindowBuffer.stride + j)*sizeof(uint32_t)] = (char)40;
```

Managing Native Windows - Example

```
                                ((char*)(lWindowBuffer.bits))
[(i*lWindowBuffer.stride + j)*sizeof(uint32_t) + 1] = (char)191;
                                ((char*)(lWindowBuffer.bits))
[(i*lWindowBuffer.stride + j)*sizeof(uint32_t) + 2] = (char)140;
                                ((char*)(lWindowBuffer.bits))
[(i*lWindowBuffer.stride + j)*sizeof(uint32_t) + 3] = (char)255;
                        }
                }
                ANativeWindow_unlockAndPost(lWindow);
}
void handle_activity_lifecycle_events(struct android_app* app,
                                int32_t cmd) {
                __android_log_print(ANDROID_LOG_INFO, "NativeApp",
"%d: dummy data %d", cmd, *((int*)(app->userData)));
                switch (cmd) {
                        case APP_CMD_INIT_WINDOW:
                                drawSomething(app);
                                break;
                }
}
```

Result



Native Window Management Steps

- `native_window.h`
- Set window buffer format and size
  - `ANativeWindow_setBuffersGeometry`
  - Native window `ANativeWindow`
  - Window size - width and height
  - Format: `WINDOW_FORMAT_RGBA_8888`, `WINDOW_FORMAT_ RGBX_8888`, `WINDOW_FORMAT_RGB_565`
- Lock the next drawing surface of the window
  - `ANativeWindow_lock`
  - Returns the window buffer as argument
  - `ANativeWindow_Buffer`

Native Window Management Steps

- Clear buffer
  - May need to override only some part of the window
  - Otherwise set all data to 0
- Draw in the buffer
  - Set width and height
  - Compute start and end for width/height
  - Set red, green, blue, alpha bytes
- Unlock surface and post buffer to display
  - `ANativeWindow_unlockAndPost`

Outline

Handling Input Events - Example

```
int32_t handle_input_events(struct android_app* app,
                            AInputEvent* event) {
        int etype = AInputEvent_getType(event);
        switch (etype) {
        case AINPUT_EVENT_TYPE_KEY:
                __android_log_print(ANDROID_LOG_INFO,
"NativeApp","Input event");
                break;
        case AINPUT_EVENT_TYPE_MOTION:
                __android_log_print(ANDROID_LOG_INFO,
"NativeApp","Motion event");
                int32_t action, posX, pointer_index;
                action = AMotionEvent_getAction(event);
                pointer_index = (action&
AMOTION_EVENT_ACTION_POINTER_INDEX_MASK) >>
AMOTION_EVENT_ACTION_POINTER_INDEX_SHIFT;
                posX = AMotionEvent_getX(event, pointer_index);
```

Handling Input Events - Example

```
                    if (action == AMOTION_EVENT_ACTION_MOVE) {
                            int xMove = posX - mPreviousX;
                            USERDATA* userData = (USERDATA*)app->
userData;
                            userData->xMove = xMove;
                            app->redrawNeeded = 1;
                    }
                    mPreviousX = posX;
                    break;
            }
}
void android_main(struct android_app* app) {
            [..]
            app->onInputEvent = handle_input_events;
            [..]
}
```

Handling Input Events

- Assign a handler for input events

```
app->onInputEvent = handle_input_events
```

- In handler, get event type

```
int etype = AInputEvent_getType(event);
```

- Two types of events defined in `android/input.h`
  - `AINPUT_EVENT_TYPE_KEY` - key event
  - `AINPUT_EVENT_TYPE_MOTION` - motion event
- `AInputEvent_getDeviceId`: id of the device that generated the input (keyboard, touchscreen, mouse, touchpad, etc.)

Key Events API

- `AKeyEvent_getAction`: action code
  - Down, up, multiple
- `AKeyEvent_getFlags`: key event flags
  - Soft keyboard, from system, long press, etc.
- `AKeyEvent_getKeyCode`: key code
  - The physical key that was pressed
- `AKeyEvent_getRepeatCount`: repeat count of the event
  - Key down and up events
- `AKeyEvent_getEventTime`: event time

Motion Events API

- `AMotionEvent_getAction`: combined action code and pointer index
  - Action: down, up, move, cancel, etc.
  - Get pointer index
- `AMotionEvent_getFlags`: event flags
- `AMotionEvent_getX`: current X coordinate for a given pointer index
  - Whole numbers are pixels, fraction subpixels
  - Similar `AMotionEvent_getY`
- `AMotionEvent_getPressure`: event pressure for a given pointer index

Outline

Managing Assets - Example

```
void displayAsset(ANativeActivity* activity){
        AAssetManager* mgr = activity->assetManager;
        AAssetDir* dir = AAssetManager_openDir(
activity->assetManager, "");
        const char* fname = AAssetDir_getNextFileName(dir);
        AAsset* asset = AAssetManager_open(
activity->assetManager, fname, AASSET_MODE_BUFFER);
        if (NULL == asset) {
                __android_log_print(ANDROID_LOG_ERROR,
"NativeApp", "_ASSET_NOT_FOUND_");
                return;
        }
        long size = AAsset_getLength(asset);
        char* buffer = (char*) malloc (sizeof(char)*size);
        AAsset_read (asset,buffer,size);
        __android_log_print(ANDROID_LOG_INFO, "NativeApp",
"Message from file: %s", buffer);
        AAsset_close(asset);
        AAssetDir_close(dir);
}
```

Managing Assets API

- Access text, images, audio, video
- Get native AASetManager object
  - From Java: `AAssetManager_fromJava`
  - In the fully native app: `activity->assetManager`
- Open asset directory
  - `AAssetManager_openDir`
  - To open `assets` directory set `dirName` to ""
  - For subdirectories of `assets` specify directory name
- Get asset file name
  - `AAssetDir_getNextFileName`
  - Iterate over the files in the directory
  - Returns NULL - all files have been returned / no file in the directory

Managing Assets API

- Open file
  - `AAssetManager_open`
  - Mode:
    - AASSET_MODE_UNKNOWN: access method unknown
    - AASSET_MODE_RANDOM: read chunks, move forward and backward
    - AASSET_MODE_STREAMING: read sequentially, move forward
    - AASSET_MODE_BUFFER: load contents into memory, fast small reads
- Read file
  - `AAsset_read`
  - Put contents in a buffer, similar to `read`
- Close file
  - `AAsset_close`
- Close asset directory
  - `AAssetDir_close`

Outline

Bibliography

- Android Native Development Kit Cookbook, Chapter 5
- Android Recipes, A Problem - Solution Approach, Chapter 8
- Android NDK Beginner's Guide, Chapter 5
- `http://mobilepearls.com/labs/native-android-api/`

Outline

NDK
native API crunch

- Native activity
- Callbacks
- Looper
- Input events
- Lifecycle events
- Native window
- Drawing surface
- Key events
- Motion events
- Asset manager