CHAPTER 12

NDK and C/C++ Optimization

The previous chapter introduced the basic principles of performance optimization, optimization methods, and related tools for Android application development. Because Java is the recommended application development language for Android developers, the optimization tools presented in Chapter 11 were mainly for Java. However, C/C++ development shouldn't be excluded from Android app development. This chapter introduce the Android NDK for C/C++ application development along with related optimization methods and optimization tools.

Introduction to JNI

Java applications do not run directly on the hardware—they run in a virtual machine. The source code of an application is not compiled to get hardware instructions, but is instead compiled to allow a virtual machine interpret and execute code. For example, Android applications run in the Dalvik virtual machine (DVM); its compiled code is executable code for the DVM in `.dex` format. This feature means Java runs on the virtual machine and ensures its cross-platform capability: that is, its "compile once, run anywhere" feature. Dalvik has a just-in-time (JIT) compiler and is optimized to have a low memory requirement.

Everything has pros and cons. Java's cross-platform capability causes it to be less connected to and limits its interaction with the local machine's internal components, making it difficult to use local machine instructions to take advantage of the machine's performance potential. It is difficult to use locally based instructions to run a huge existing software library, and this limits its functionality and performance. Starting in Android 4.4 (KitKat), Google introduced Android Runtime (ART), which is an application runtime environment that replaces Dalvik. ART transforms the application's bytecode into native instructions that are later executed by the device's runtime environment. ART introduces ahead-of-time (AOT) compilation by performing it when an application is installed.

Is there a way to make Java code and native code software collaborate and share resources? The answer is yes, using the Java Native Interface (JNI), which is an implementation method for a Java local operation. JNI is a Java platform defined by the Java standard to interact with the code on the local platform, generally known as the *host platform*. But this chapter is about the mobile platform; and in order to distinguish it from the mobile cross-development host, we call it the *local platform*. The interaction between Java Code and native application includes two directions: Java code calling native functions (methods), and local application calls to the Java code. Relatively speaking, the former method is used more in Android application development. So this chapter's emphasis is on the approach in which Java code calls native functions.

Java calls native functions through JNI by having the local method stored in the form of library files. For example, on a Windows platform, the files are in `.dll` file format, and on Unix/Linux machines, the files are in `.so` file format. An internal method of calling the local library file enables Java to establish close contact with the local machine: this is called the *system-level* approach for various interfaces.

JNI usually has two usage scenarios: first, to be able to use legacy code (for example, prior to use C/C++, Delphi and other development tools); second, in order to better, more directly interact with the hardware for better performance.

JNI's general workflow is as follows: Java initiates calls so that the local function's side code (such as a function written in C/C++) runs. This time the object is passed over from the Java side and run a local function Then the result value is returned to the Java code. Here JNI is an adapter, completing mapping between the variables and functions (Java method) between the Java language and native compiled languages (such as C/C++). Java and C/C++ are very different in terms of function prototype definitions and variable types. In order to make the two match, JNI provides a `jni.h` file to complete the mapping between them. This process is shown in Figure 12-1.

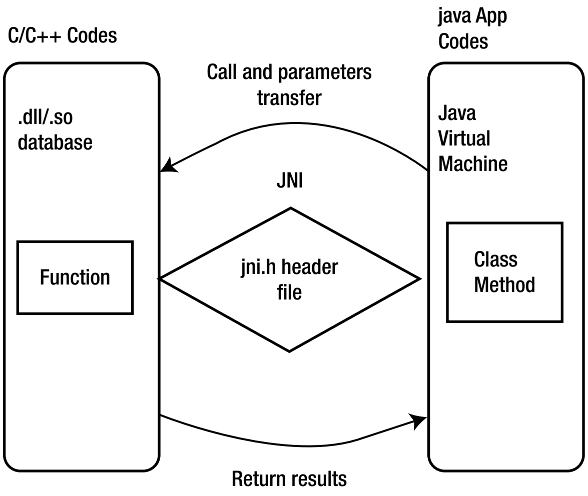


Figure 12-1. *JNI general workflow*

The general framework of a C/C++ function call via JNI and a Java program (in particular, an Android application) is as follows:

1. A method of compiling native declared in a Java class (C/C++ function).
2. The `.java` source code file containing the native method is compiled.

3. The `javah` command generates a `.h` file, including a function prototype for implementing the native method based on the `.class` files.
4. C/C++ is used to implement the local method.
5. The recommended method for this step is to first copy the function prototypes in the `.h` file and then modify the function prototypes and add the function body. In this process, the following points should be noted:
    - The JNI function call must use the C function. If it is a C++ function, do not forget to add the `extern` C keyword.
    - Method names should use the following template:

      `Java_package_class_method`*, or* `Java_ package name _ class name _ function method name`.
6. The C/C++ file is compiled into a dynamic library (under Windows, a `.dll` file; under Unix/Linux, a `.so` file).

Use the `System.loadLibrary()` or `System.load()` method in Java to load the dynamic library that is generated. These two functions are slightly different:

`System.loadLibrary()` loads the default directory under the local link library.

`System.load()` requires an absolute path, depending on the local directory to add a cross-link library.

In the first step, Java calls the native C/C++ function; the format is not the same for both C and C++. For example, for Java methods such as non-passing parameters and returning a `String` class, C and C++ code for the function differ in the following ways:

- C code:

```
Call function:(*env) -> <jni function> (env, <parameters>)
Return jstring:return (*env)->NewStringUTF(env, "XXX");
```

- C++ code:

```
Call function:env -> <jni function> (<parameters>)
Return jstring:return env->NewStringUTF("XXX");
```

`NewStringUTF` is the Java `String` object's function generated in C/C++, provided by JNI.

Java Methods and C Function Prototype Java

Earlier you saw that in the code framework for Java programs to call a C/C++ function, you can use the javah command, which generates the corresponding .h file for native methods based on the .class files. The .h file is generated in accordance with certain rules, to make the correct Java code to find the corresponding C function to execute. Another good solution is to use env->RegisterNatives function to manually do the mapping and avoid using javah.

For example, suppose you have the following Java code for Android:

```
   public class HelloJni extends Activity
1. {
2.     public void onCreate(Bundle savedInstanceState)
3.     {
4.         TextView tv.setText(stringFromJNI() );  // Use C function Code
5.     }
6.     public native String  stringFromJNI();
7. }
```

For the C functions stringFromJNI() used on line 4, the function prototype in the .h file generated by javah is

```
JNIEXPORT jstring JNICALL Java_com_example_hellojni_HelloJni_stringFromJNI
  (JNIEnv *, jobject);
```

The C source code files to define the function code are roughly as follows:

```
/*
......
Signature: ()Ljava/lang/String;
*/
jstring Java_com_example_hellojni_HelloJni_stringFromJNI
(JNIEnv* env,  jobject thiz )
  {
    ......
    return (*env)->NewStringUTF(env, "......");
}
```

From this code, you can see that the function name is quite long but still regular, in full accordance with the naming convention java_package_class_method. That is, the stringFromJNI() method in Hello.java corresponds to the Java_com_example_hellojni_HelloJni_stringFromJNI() method in C/C++.

Notice the comment for Signature: ()Ljava/lang/String;. Here the () in ()Ljava/lang/String; indicates the function parameter is empty, which means, other than the two parameters JNIEnv * and jobject, there are no other parameters. JNIEnv * and jobject are two parameters that all JNI functions must have for the JNI environment and corresponding Java class (or object), respectively. Ljava/lang/String; indicates that the function's return value is a Java String object.

Java and C Data Type Mapping

As mentioned, Java and C/C++ have very different variable types. In order to make the two match, JNI provides a mechanism to complete the mapping between Java and C/C++. The relationships of the main types are shown in Table 12-1.

Table 12-1. *The Correspondence between Java Types and Local (C/C++) Types*

Java Type	Native Type	Description
`boolean`	`jboolean`	C/C++ 8-bit integer
`byte`	`jbyte`	C/C++ unsigned 8-bit integer
`char`	`jchar`	C/C++ unsigned 16-bit integer
`short`	`jshort`	C/C++ signed 16-bit integer
`int`	`jint`	C/C++ signed 32-bit integer
`long`	`jlong`	C/C++ unsigned 64-bit integer
`float`	`jfloat`	C/C++ 32-bit floating point
`double`	`jdouble`	C/C++ 64-bit floating point
`void`	`void`	N/A
`Object`	`jobject`	Any Java object, or does not correspond to an object of Java type
`Class`	`jclass`	Class object
`String`	`jstring`	String object
`Object[]`	`jobjectArray`	Array of any object
`boolean[]`	`jbooleanArray`	Boolean array
`byte[]`	`jbyteArray`	Array of bits
`char[]`	`jcharArray`	Character array
`short[]`	`jshortArray`	Short integer array
`int[]`	`jintArray`	Integer array
`long[]`	`jlongArray`	Long integer array
`float[]`	`jfloatArray`	Floating-point array
`double[]`	`jdoubleArray`	Double floating-point array

When a Java parameter is passed, you can use C code as follows:

- *Basic types can be used directly*: For example, double and jdouble are interchangeable. Basic types are those from boolean through void in Table 12-1. In such a type, if the user passes a boolean parameter into the method, then there is a local method jboolean corresponding to the boolean type. Similarly, if the local methods return a jint, then an int is returned in Java.
- *Java object usage*: An Object object has String objects and a generic object. The two objects are handled a little differently:
    - String *object*: The String object passed by Java programs is the corresponding jstring type in the local method. The jstring type and char * in C are different. So if you just use it as a char *, an error will occur. Therefore, jstring nust be converted into a char * in C/C++ prior to use. Here you use the JNIEnv method for conversion.
    - Object *object*: Use the following code to get the object handler for the class:

```
jclass objectClass = (env)->FindClass("com/ostrichmyself/jni/Structure");
```

- Use the following code to get the required domain handler for the class:

```
jfieldID str = (env)->GetFieldID(objectClass,"nameString","Ljava/lang/String;");
jfieldID ival = (env)->GetFieldID(objectClass,"number","I");
```

- Then use the following similar code to assign values to the incoming fields of the jobject object:

```
(env)->SetObjectField(theObjet,str,(env)->NewStringUTF("my name is D:"));
(env)->SetShortField(theObjet,ival,10);
```

- If there is no incoming object, then C code can use the following code to generate a new object:

```
jobject myNewObjet = env->AllocObject(objectClass);
```

■ **Note** NewObject() needs to be called instead if you want the object constructor to be called.

Java Array Processing

For an array type, JNI provides some operaable functions. For example, `GetObjectArrayElement` can take the incoming array and use `NewObjectArray` to create an array structure.

Resource Release

The principle of resource release is as follows:

- Objects of C/C++ new or object of malloc need to use the C/C++ to release.
- If the new object of the `JNIEnv` method is not used by Java, it must be released.
- To convert a string object from Java to UTF using `GetStringUTFChars`, you need to open the memory, and you must use `ReleaseStringUTFChars` method to release the memory after you are finished using `char *`.

These are brief descriptions of the basic ideas of type mapping when Java exchanges data with C/C++. For more information about Java and C/C++ data types, please refer to related Java and JNI books, documentation, and examples.

Introduction to NDK

You now know that the Java code can access local functions (such as C/C++) using JNI. To achieve this, you need development tools. As stated earlier, an entire set of development tools based on the core Android SDK are available that you can use to cross-compile Java applications to applications that can run on the target Android device. Similarly, you need cross-development tools to compile C/C++ code into applications that can run on an Android device. This tool is the Android Native Development Kit (NDK), which you can download from `http://developer.android.com`.

Prior to the NDK, third-party applications on the Android platform were developed on a special Java-based DVM. The announcement of the native SDK allows developers to directly access Android system resources and to implement parts of apps using native-code languages such as C and C++. The application package file (`.apk`) can be directly embedded into the local library. In short, with the NDK, Android applications originally run on the DVM can use native languages like C/C++ for program execution. This brings the following benefits:

- Performance improvements from using native code to develop parts of programs that require high performance, and by directly accessing the CPU and hardware
- The ability to reuse existing native code

Of course, compared to the DVM, using native SDK programming also has some disadvantages, such as added program complexity, difficulty in guaranteeing compatibility, the inability to access the Framework API, more difficult debugging, decreased flexibility, and so on. In addition, access to JNI requires additional performance overhead.

In short, NDK application development has pros and cons. You need to use NDK at your own discretion. The best strategy is to use NDK to develop parts of the application for which native code will improve performance.

NDK includes the following major components:

- Tools and build file needed to generate native code libraries from C/C++ sources. These include a series of NDK commands, including `javah` (use the `.class` files to generate the corresponding `.h` files) and `gcc` (described later)
- A consistent local library embedded in the application package (`.apk` files) that can be deployed in Android devices
- Support for some native system header files and libraries for all future Android platforms
- Documentation, samples, and tutorials

The process framework of NDK application development is shown in Figure 12-2. An Android application consists of three parts: Android application files, Java native library files, and dynamic libraries. These three parts are generated from different sources through the respective generation path. For an ordinary Android application, the Android SDK generates Android applications files and Java native library files. The Android NDK generates the dynamic library files (the file with the `.so` extension) using native code (typically C source code files). Finally, Android application files, Java native library files, and dynamic libraries are installed on the target machine, and complete collaborative applications run.

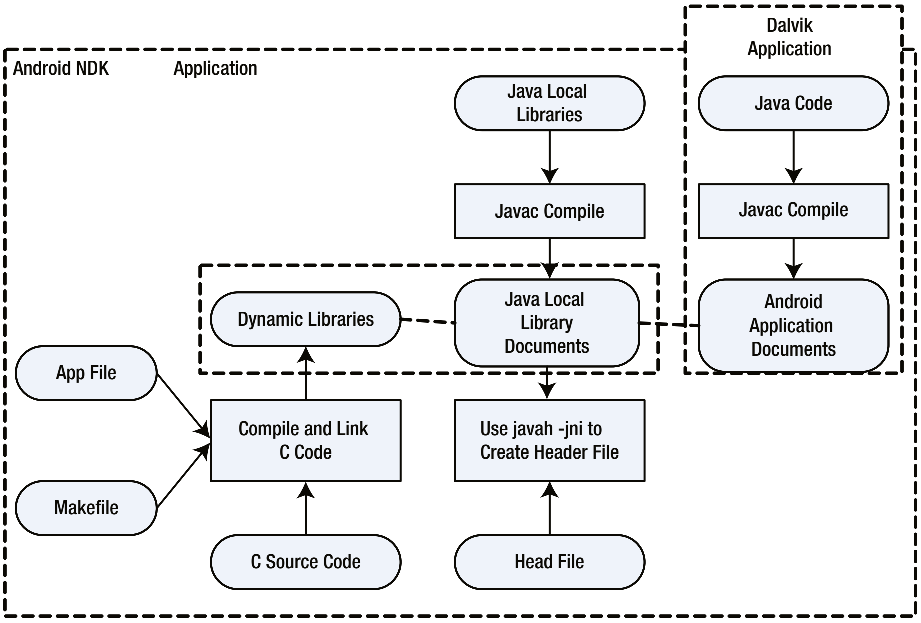


Figure 12-2. *Flowchart of Android NDK application development*

Application projects developed with NDK (referred to as *NDK application projects*) have the components shown in Figure 12-3. Unlike typical applications developed using the Android SDK, in addition to the Dalvik class code, manifest files, and resources, NDK application projects also include JNI and a shared library generated by NDK.

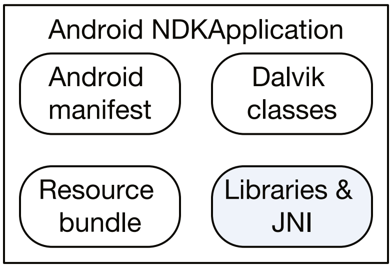


Figure 12-3. *Application components for an Android NDK application*

Android adds NDK support in its key API version. Each version includes some new NDK features, simple C/C++, a compatible Standard Template Library (STL), hardware expansion, and so on. These features make Android more open and more powerful. The mapping of the Android API and its corresponding relationship with the NDK are shown in Table 12-2.

Table 12-2. *Relationship between the Main Android API and NDK Versions*

API Version	Supported NDK Version
API Level 3	Android 1.5 NDK 1
API Level 4	Android 1.6 NDK 2
API Level 7	Android 2.1 NDK 3
API Level 8	Android 2.2 NDK 4
API Level 9	Android 2.3 NDK 5
API Level 12	Android 3.1 NDK 6
API Level 14	Android 4.0.1 NDK 7
API Level 15	Android 4.0.3 NDK 8
API Level 16	Android 4.1 NDK 8b
API Level 16	Android 4.2 NDK 8d
API Level 17	Android 4.2 NDK 9
API Level 18	Android 4.3 NDK 9d
API Level 19	Android 4.4 NDK 10

TIP: THE MEANING OF APPLICATION BINARY INTERFACE (ABI)

Each piece of native code generated using the Android NDK is given a matching application binary interface (ABI). The ABI precisely defines how the application and its code interact with the system at runtime. An ABI is roughly like instruction set architecture (ISA) in computer architecture.

A typical ABI usually contains the following information:

- Machine code the CPU instruction set should use
- Runtime memory access ranking
- The format of executable binary files (dynamic libraries, programs, and so on) as well as what type of content is allowed and supported
- Different conventions used in passing data between the application code and systems (for example, when the function call registers and/or how to use the stack, alignment restrictions, and so on)
- Alignment and size limits of enumerated types, structure fields, and array
- A unique name; the available list of function symbols for application machine code at runtime usually comes from a very specific set of libraries

Android currently supports the following ABI types:

- *armeabi*: ABI name for the ARM CPU, which supports at least the ARMv5TE instruction set.
- *armeabi-v7a*: Another ABI name for ARM-based CPUs; it extends the armeabi CPU instruction set extensions, such as Thumb-2 instruction set extensions and floating-point processing unit directives for vector floating-point hardware.
- *x86*: ABI name generally known for supporting the x86 or IA-32 instruction set of the CPU. More specifically, its target is often referred to in the following sections as the i686 or Pentium Pro instruction set. Intel Atom processors belong to this ABI type.

- *MIPS*: ABI for MIPS-based CPUs that support the MIPS32r1 instruction set. The ABI includes the following features: MIPS32 revision 1 ISA, little-endian, O32, hard-float, and no DSP applicationThese types have different compatibilities. x86 is incompatible with armeabi and armeabi-v7a. The armeabi-v7a machine is compatible with armeabi, which means the armeabi framework instruction set can run on an armeabi-v7a machine, but not necessarily the other way around, because some ARMv5 and ARMv6 machines do not support armeabi-v7a code. Therefore, when you build the application, users should be chosen carefully based on their corresponding ABI machine type.

Installing NDK and Setting Up the Environment

The NDK is included in Intel Beacon Mountain for Linux, Intel Beacon Mountain for OS X and Intel Integrated Native Developer Experience (INDE) for Windows host system, and is installed when you install one of those Intel tools. The installation is detailed in Chapter 3. An environment setup program is also included in Intel INDE; you can download it and run the setup automatically.

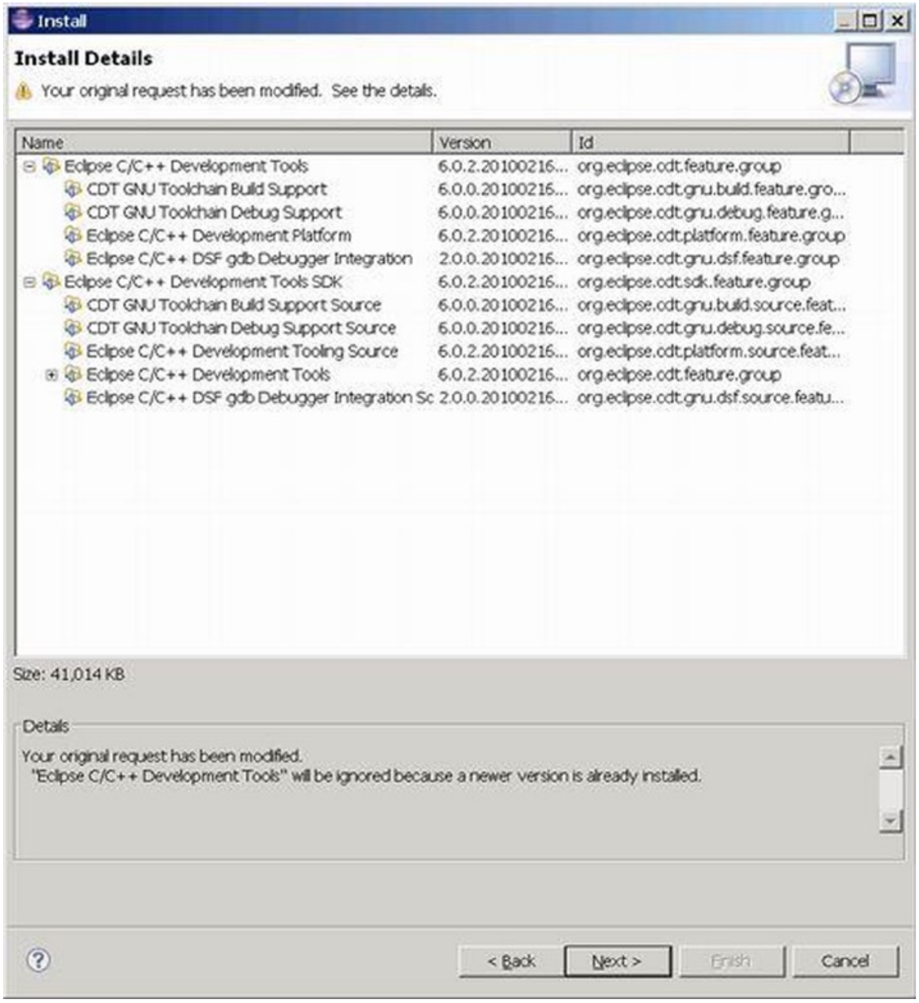
Installing CDT

CDT is an Eclipse plug-in that compiles C code into `.so` shared libraries. After installing the Cygwin and NDK module, you already can compile C code into `.so` shared libraries at the command line, which means the core component of Windows NDK is already installed. If you prefer to use the Eclipse IDE rather than a command-line compiler to compile the local library, you need to install the CDT module.

If you need to install it, follow these steps.

1. Visit the official Eclipse web site (`www.eclipse.org/cdt/downloads.php`) and download the latest CDT package.
2. Start Eclipse. Select Help ➤ Install New Software ➤ Start to install CDT.
3. In the pop-up Install dialog box, click Add.
4. In the pop-up Add Repository dialog box, enter a name.
5. For Location, you can enter the local address or the Internet address. If you use an Internet address, Eclipse goes to the Internet to download and install the package; a local address directs Eclipse to install the software from the local package. In this case, enter the local address; then click the Archive button in the pop-up dialog box and enter the directory and file name for the CDT file you downloaded. If you downloaded it from the Internet, the address is `http://download.eclipse.org/tools/cdt/releases/galileo/`.

6. After returning to the Install dialog box, click to select the software components that need to be installed. In this example, CDT Main Feature is the required component you need to select. A list of detailed information about CDT components to install is displayed, as shown in Figure 12-4.



Name	Version	Id
Eclipse C/C++ Development Tools	6.0.2.20100216...	org.eclipse.cdt.feature.group
CDT GNU Toolchain Build Support	6.0.0.20100216...	org.eclipse.cdt.gnu.build.feature.gro...
CDT GNU Toolchain Debug Support	6.0.0.20100216...	org.eclipse.cdt.gnu.debug.feature.g...
Eclipse C/C++ Development Platform	6.0.2.20100216...	org.eclipse.cdt.platform.feature.group
Eclipse C/C++ DSF gdb Debugger Integration	2.0.0.20100216...	org.eclipse.cdt.gnu.dsf.feature.group
Eclipse C/C++ Development Tools SDK	6.0.2.20100216...	org.eclipse.cdt.sdk.feature.group
CDT GNU Toolchain Build Support Source	6.0.0.20100216...	org.eclipse.cdt.gnu.build.source.feat...
CDT GNU Toolchain Debug Support Source	6.0.0.20100216...	org.eclipse.cdt.gnu.debug.source.fe...
Eclipse C/C++ Development Tooling Source	6.0.2.20100216...	org.eclipse.cdt.platform.source.feat...
Eclipse C/C++ Development Tools	6.0.2.20100216...	org.eclipse.cdt.feature.group
Eclipse C/C++ DSF gdb Debugger Integration Sc	2.0.0.20100216...	org.eclipse.cdt.gnu.dsf.source.featu...

Size: 41,014 KB

Details

Your original request has been modified.
"Eclipse C/C++ Development Tools" will be ignored because a newer version is already installed.

Figure 12-4. *Detailed information for the CDT component installation*

7. Review the License dialog box, and click "I accept the terms of the license agreement" to continue.

8. The installation process starts. When it is finished, restart Eclipse to complete the installation.

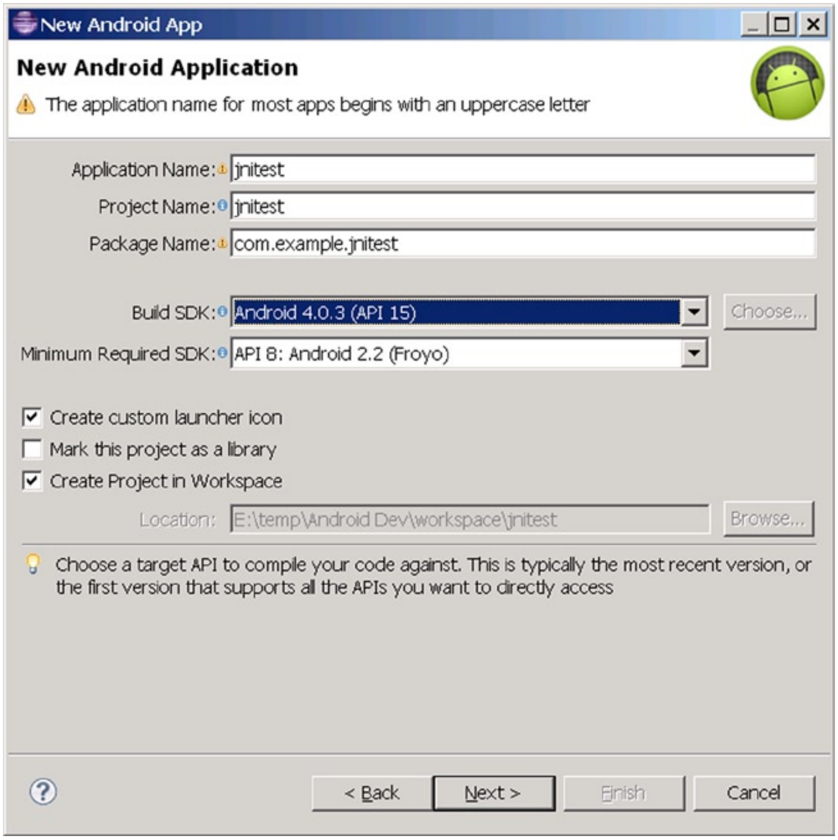
NDK Examples

This section provides an example to illustrate the use of JNI and NDK. As described previously, NDK can be run from both the command line and in the Eclipse IDE. The example uses both methods to generate the same NDK application.

Using the Command Line to Generate a Library File

The app name in this example is `jnitest`. It is a simple example to demo the JNI code framework. The steps are as follows:

1. Create an Android app project, compile the code, and generate the `.apk` package. You first create a project in Eclipse, and name the project `jnitest`. Choose Build SDK to support the x86 version of the API, as shown in Figure 12-5. For the other options, use the default values. Then generate the project.



The application name for most apps begins with an uppercase letter

Application Name: jnitest
Project Name: jnitest
Package Name: com.example.jnitest

Build SDK: Android 4.0.3 (API 15)
Minimum Required SDK: API 8: Android 2.2 (Froyo)

[✓] Create custom launcher icon
[ ] Mark this project as a library
[✓] Create Project in Workspace
Location: E:\temp\Android Dev\workspace\jnitest

Choose a target API to compile your code against. This is typically the most recent version, or the first version that supports all the APIs you want to directly access

Figure 12-5. *Setting up the `jnitest` project parameters*

After the project has been generated, the file structure is created as shown in Figure 12-6. Note the directory where the library file (in this case, `android.jar`) is located, because later steps use this parameter.

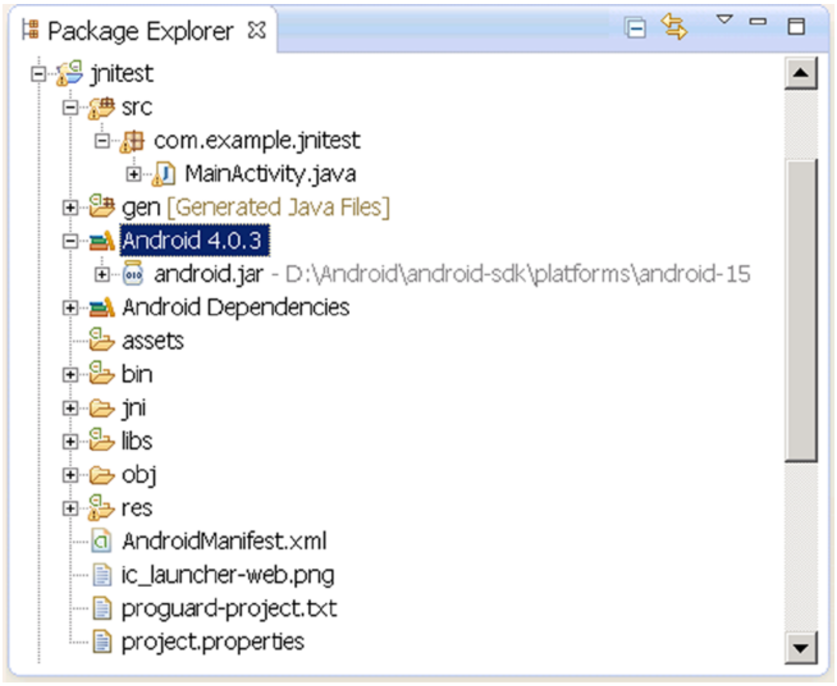


Figure 12-6. *File structure of the `jnitest` project*

a. Modify the Java files to create code using a C function. In this case, the only Java file is `MainActivity.java`; modify its code as follows:

```
package com.example.jnitest;
import android.app.Activity;
import android.widget.TextView;
import android.os.Bundle;
public class MainActivity extends Activity
{
    @Override
    public void onCreate(Bundle savedInstanceState)
    {
        super.onCreate(savedInstanceState);
        TextView tv = new TextView(this);
        tv.setText(stringFromJNI() );  // stringFromJNIas a  C function
        setContentView(tv);
    }
15.     public native String stringFromJNI();
16.
17.     static {
18.         System.loadLibrary("jnitestmysharelib");
19.     }
20.  }
```

The code is very simple. In lines 11–13, you use a `TextView` to display a string returned from the `stringFromJNI()` function. But unlike in the Android application discussed earlier, nowhere in the entire project can you find the implementation code for this function. So where does the function implementation occur? Line 15 declares that the function is not a function written in Java, but is instead written by the local (native) libraries, which means the function is outside of Java. Because it is implemented in the local library, the question is, what libraries? The answers are described in lines 17–20. The parameter of the static function `LoadLibrary` of the `System` class describes the name of the library: the library is one of shared libraries in Linux named `libjnitestmysharelib.so`. The application code declared in the static area will be executed before `Activity.onCreate`. The library will be loaded into memory at the first use.

Interestingly, when the `loadLibrary` function loads the library name, it automatically adds the `lib` prefix before the parameters and the `.so` suffix at the end. Of course, if the name of the library file specified by parameter starts with `lib`, the function does not add the `lib` prefix.

b. Generate the project in Eclipse. Only build it—do not run it. This compiles the project, but the `.apk` file is not deployed to the target machine.

When this step is completed, the corresponding `.class` files are generated in the project directory `bin\classes\com\example\jnitest`. This step must be completed before the next step, because the next step needs to use the appropriate `.class` files.

2. Create a `jni` subdirectory in the project root directory. For example, if the project root directory is `E:\temp\AndroidDev\workspace\jnitest`, then you can use the `md` command to create the `jni` subdirectory:

```
E:\temp\Android Dev\workspace\jnitest>mkdir jni
```

Test whether the directory has been built:

```
E:\temp\Android Dev\workspace\jnitest>dir
......
2013-02-01  00:45    <DIR>          jni
```

3. Create a C interface file. This is the C function prototype that works with the local (external) function. Specific to this case are the C function prototypes of the `stringFromJNI` function. You declare in Java that you need to use the prototype of the external function; but it is in the Java format, so you need to change it to C format, which means building a C JNI interface file. This step can be done with the `javah` command:

```
$ javah -classpath <directory of jar and .class documents> -d <directory of
.h documents>  <the package + class name of class>
```

The command parameters are as follows:

`-classpath`: The class path

`-d`*:* The storage directory for the generated header file

`<class name>`: The complete `.class` class name of a native function being used, which consists of "the package + class name of class" component.

For this example, follow these steps:

a. Enter the root directory using the command line (for this example, `E:\temp\Android Dev\workspace\jnitest`).

b. Run the following command:

```
E:> javah -classpath "D:\Android\android-sdk\platforms\android-15\android.jar";
bin/classes  com.example.jnitest.MainActivity
```

In this example, the class of the native function `stringFromJNI`'s used is `MainActivity`; and the resulting file after compiling this class is `MainActivity.class`, which is located in the root directory of the project `bin\classes\com\example` directory. The first line of the source code file of its class `MainActivity.java` shows where the package of the class is:

```
package com.example.jnitest;
```

Therefore, this is the command: "class name = package name.Class name" (be careful not to use the `.class` suffix).

`-classpath` first needs to explain the Java library path of the entire package (in this case, the library file is `android.jar`; its location is at `D:\Android\android-sdk\platforms\android-15\android.jar`). Second, it needs to define the target class (`MainActivity.class`) directory. In this case, it is `bin\classes` under `bin\classes\com\example\MainActivity.class`, both separated by semicolons (C).

c. Now the `.h` file is generated in the current directory (the project root directory). The file defines the C language function interface. You can test the output:

```
E:\temp\Android Dev\workspace\jnitest>dir
......
2013-01-31  22:00         3,556 com_example_jnitest_MainActivity.h
```

It is apparent that a new `.h` file has been generated. The document reads as follows:

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

#ifndef _Included_com_example_jnitest_MainActivity
#define _Included_com_example_jnitest_MainActivity
#ifdef __cplusplus
extern "C" {
#endif
#undef com_example_jnitest_MainActivity_MODE_PRIVATE
#define com_example_jnitest_MainActivity_MODE_PRIVATE 0L
#undef com_example_jnitest_MainActivity_MODE_WORLD_READABLE
#define com_example_jnitest_MainActivity_MODE_WORLD_READABLE 1L
#undef com_example_jnitest_MainActivity_MODE_WORLD_WRITEABLE
#define com_example_jnitest_MainActivity_MODE_WORLD_WRITEABLE 2L
#undef com_example_jnitest_MainActivity_MODE_APPEND
#define com_example_jnitest_MainActivity_MODE_APPEND 32768L
#undef com_example_jnitest_MainActivity_MODE_MULTI_PROCESS
#define com_example_jnitest_MainActivity_MODE_MULTI_PROCESS 4L
#undef com_example_jnitest_MainActivity_BIND_AUTO_CREATE
#define com_example_jnitest_MainActivity_BIND_AUTO_CREATE 1L
#undef com_example_jnitest_MainActivity_BIND_DEBUG_UNBIND
#define com_example_jnitest_MainActivity_BIND_DEBUG_UNBIND 2L
#undef com_example_jnitest_MainActivity_BIND_NOT_FOREGROUND
#define com_example_jnitest_MainActivity_BIND_NOT_FOREGROUND 4L
#undef com_example_jnitest_MainActivity_BIND_ABOVE_CLIENT
#define com_example_jnitest_MainActivity_BIND_ABOVE_CLIENT 8L
#undef com_example_jnitest_MainActivity_BIND_ALLOW_OOM_MANAGEMENT
#define com_example_jnitest_MainActivity_BIND_ALLOW_OOM_MANAGEMENT 16L
#undef com_example_jnitest_MainActivity_BIND_WAIVE_PRIORITY
#define com_example_jnitest_MainActivity_BIND_WAIVE_PRIORITY 32L
#undef com_example_jnitest_MainActivity_BIND_IMPORTANT
#define com_example_jnitest_MainActivity_BIND_IMPORTANT 64L
#undef com_example_jnitest_MainActivity_BIND_ADJUST_WITH_ACTIVITY
#define com_example_jnitest_MainActivity_BIND_ADJUST_WITH_ACTIVITY 128L
#undef com_example_jnitest_MainActivity_CONTEXT_INCLUDE_CODE
#define com_example_jnitest_MainActivity_CONTEXT_INCLUDE_CODE 1L
38. #undef com_example_jnitest_MainActivity_CONTEXT_IGNORE_SECURITY
39. #define com_example_jnitest_MainActivity_CONTEXT_IGNORE_SECURITY 2L
40. #undef com_example_jnitest_MainActivity_CONTEXT_RESTRICTED
41. #define com_example_jnitest_MainActivity_CONTEXT_RESTRICTED 4L
42. #undef com_example_jnitest_MainActivity_RESULT_CANCELED
43. #define com_example_jnitest_MainActivity_RESULT_CANCELED 0L
44. #undef com_example_jnitest_MainActivity_RESULT_OK
45. #define com_example_jnitest_MainActivity_RESULT_OK -1L
46. #undef com_example_jnitest_MainActivity_RESULT_FIRST_USER
47. #define com_example_jnitest_MainActivity_RESULT_FIRST_USER 1L
48. #undef com_example_jnitest_MainActivity_DEFAULT_KEYS_DISABLE
49. #define com_example_jnitest_MainActivity_DEFAULT_KEYS_DISABLE 0L
50. #undef com_example_jnitest_MainActivity_DEFAULT_KEYS_DIALER
51. #define com_example_jnitest_MainActivity_DEFAULT_KEYS_DIALER 1L
52. #undef com_example_jnitest_MainActivity_DEFAULT_KEYS_SHORTCUT
53. #define com_example_jnitest_MainActivity_DEFAULT_KEYS_SHORTCUT 2L
54. #undef com_example_jnitest_MainActivity_DEFAULT_KEYS_SEARCH_LOCAL
55. #define com_example_jnitest_MainActivity_DEFAULT_KEYS_SEARCH_LOCAL 3L
56. #undef com_example_jnitest_MainActivity_DEFAULT_KEYS_SEARCH_GLOBAL
57. #define com_example_jnitest_MainActivity_DEFAULT_KEYS_SEARCH_GLOBAL 4L
58. /*
59.  * Class:     com_example_jnitest_MainActivity
60.  * Method:    stringFromJNI
61.  * Signature: ()Ljava/lang/String;
62. */
63. JNIEXPORT jstring JNICALL Java_com_example_jnitest_MainActivity_
    stringFromJNI
64. (JNIEnv *, jobject);
65.
66. #ifdef __cplusplus
67. }
68. #endif
69. #endif
```

In this code, pay special attention to lines 63–64, which are C function prototypes of a local function `stringFromJNI`.

4. Compile the corresponding C file. This is the true realization of a local function (`stringFromJNI`). The source code file is obtained by modifying the `.h` file based on the previous steps.

Create a new `.c` file under the `jni` subdirectory in the project. The file name can be anything; in this case, it is `jnitestccode.c`. The contents are as follows:

```
#include <string.h>
#include <jni.h>
jstring Java_com_example_hellojni_HelloJni_stringFromJNI( JNIEnv* env,
jobject thiz )
```

```
4. {
5.     return (*env)->NewStringUTF(env, "Hello from JNI !");  // Newly added
       code
6. }
```

The code that defines the function implementation is very simple. Line 3 is the Java code used in the prototype definition of the function `stringFromJNI`; it is basically a copy of the corresponding contents of the `.h` file obtained from lines 63–64 of `com_example_jnitest_MainActivity.h`), slightly modified to make the point. The prototype formats of this function are fixed; `JNIEnv* env` and `jobject thiz` are inherent parameters of JNI. Because the parameter of the `stringFromJNI` function is empty, there are only two parameters in the generated C function. The role of the code in the fifth line is to return the string "Hello from JNI!" as the return value.

The code in line 2 is the header file that contains the JNI function, which is required for any functions that use JNI. As it relates to the string function, line 1 contains the corresponding header file in this case. After completing these steps, the `.h` file has no use and can be deleted.

5. Create the NDK makefile file in the `jni` directory. These documents are mainly `Android.mk` and `Application.mk`: `Android.mk` is required, but if you use the default application configuration, you do not need `Application.mk`. The specific steps are as follows:

    a. Create a new `Android.mk` text file under the `jni` directory in the project. This file is used to tell the compiler about some requirements, such as which C files to compile, what file name to use for compiled code, and so on. Enter the following:

    ```
    1. LOCAL_PATH      := $(call my-dir)
    2. include $(CLEAR_VARS)
    3. LOCAL_MODULE    := jnitestmysharelib
    4. LOCAL_SRC_FILES := jnitestccode.c
    5. include $(BUILD_SHARED_LIBRARY)
    ```

Line 3 represents the generated `.so` file name (identifying each module described in your `Android.mk` file). It must be consistent with parameter values of the `System.loadLibrary` function in the Java code. This name must be unique and may not contain any spaces.

■ **Note** The build system automatically generates the appropriate prefix and suffix; in other words, if one is the shared library module named `jnitestmysharelib`, then a `libjnitestmysharelib.so` file is generated. If you name the library `libhello-jni`, the compiler does not add a `lib` prefix and generates `libhello-jni.so` too.

The LOCAL_SRC_FILES variable on line 4 must contain the C or C++ source code files to be compiled and packaged into modules. The previous steps create a C file name.

■ **Note** You do not have to list the header files and include files here, because the compiler automatically identifies the dependent files for you—just list source code files that are directly passed to the compiler. In addition, the default extension name of C++ source files is .cpp. It is possible to specify a different extension name, as long as you define the LOCAL_DEFAULT_CPP_EXTENSION variable. Don't forget the period character at the start (.cxx, rather than cxx).

The previous code in lines 3 and 4 is very important and must be modified for each NDK application based on its configuration. The contents of the other lines can be copied from the example.

b. Create an Application.mk text file under the jni directory in the project. This file is used to tell the compiler the specific settings for this application. Enter the following:

```
APP_ABI := x86
```

This file is very simple; the object code generated by the application instructions is for 86 architecture, so you can run the application on Intel Atom machines. For APP_ABI parameters, you can use any architecture (x86, armeabi, armeabi-v7a or MIPS) that you want to support.

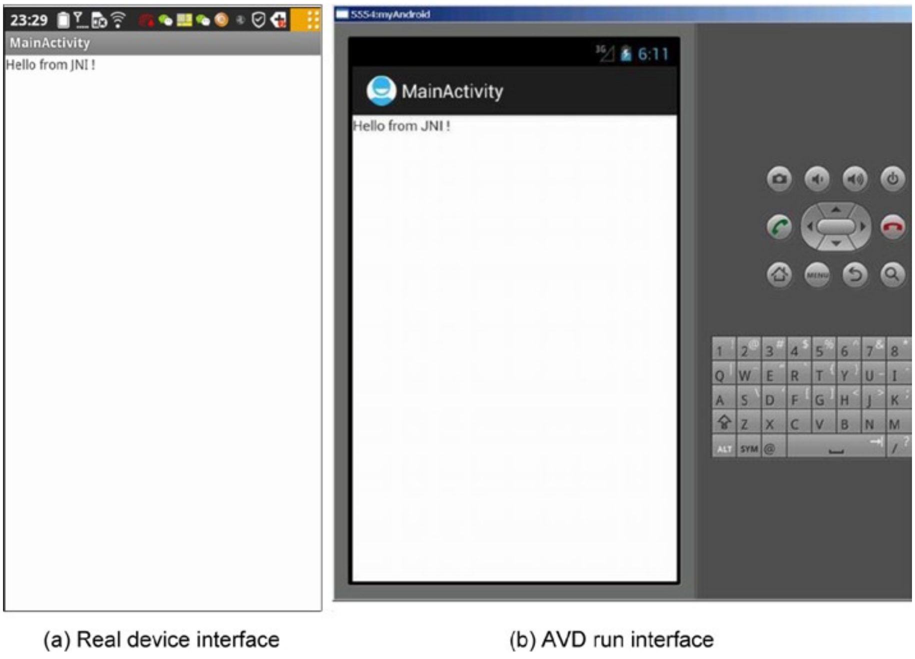
6. Compile the .c file to the .so shared library file. Go to the project root directory (where AndroidManifest.xml is located) and run the ndk-build command:

```
E:\temp\Android Dev\workspace\jnitest>ndk-build
D:/Android/android-ndk-r8d/build/core/add-application.mk:128: Android NDK:
WARNING: APP_PLATFORM android-14 is larger than android:minSdkVersion 8 in
./AndroidM
anifest.xml
"Compile x86  : jnitestmysharelib <= jnitestccode.c
SharedLibrary : libjnitestmysharelib.so
Install       : libjnitestmysharelib.so => libs/x86/libjnitestmysharelib.so
```

This command adds two subdirectories (libs and obj) in the project folder and creates a .so file (command execution information prompt file named libjnitestmysharelib.so) under the obj directory.

If these steps do not define the specified ABI in the Application.mk file, the ndk-build command generates object code for the ARM architecture (armeabi). If you want to generate the x86 architecture instructions, you can do so using the `ndk-build APP_ABI = x86` command to remedy the situation. The architecture of the object code generated by this command is still x86.

7. Run the project. Figure 12-7 shows the application running on the target device.



Hello from JNI !

Hello from JNI !

Figure 12-7. *`jnitest` application interface*

Generating a Library File in the IDE

The previous section described the process of compiling C files into dynamic library `.so` files that can be run on the Android target device. To do this, you run the `ndk-build` command in the command line. You can also complete this step in the Eclipse IDE.

Eclipse supports direct NDK integration. You can install CDT into Eclipse, create an Android project to which you want to add C/C++ code, create a `jni/` directory in your project directory, place your C/C++ sources file in the same directory, and put the `Android.mk` file into it—this is a makefile that tells the Android build-system how to build your files.

If for some reason, you need to manually build the code, you can use the following process to generate the library files in the IDE. The code in steps 1–7 is exactly the same as in the previous section, except that in step 6, you compile `.c` files into `.so` shared library files. This is explained in detail in a moment:

1. Compile the `.c` file into the `.so` shared library file. Right-click the project name, select Build Path ➤ Config Build Path, and, in the pop-up dialog box, select the Builders branch. Click the New button in the dialog box, and then; double-click Program in the prompt dialog box. This process is shown in Figure 12-8.

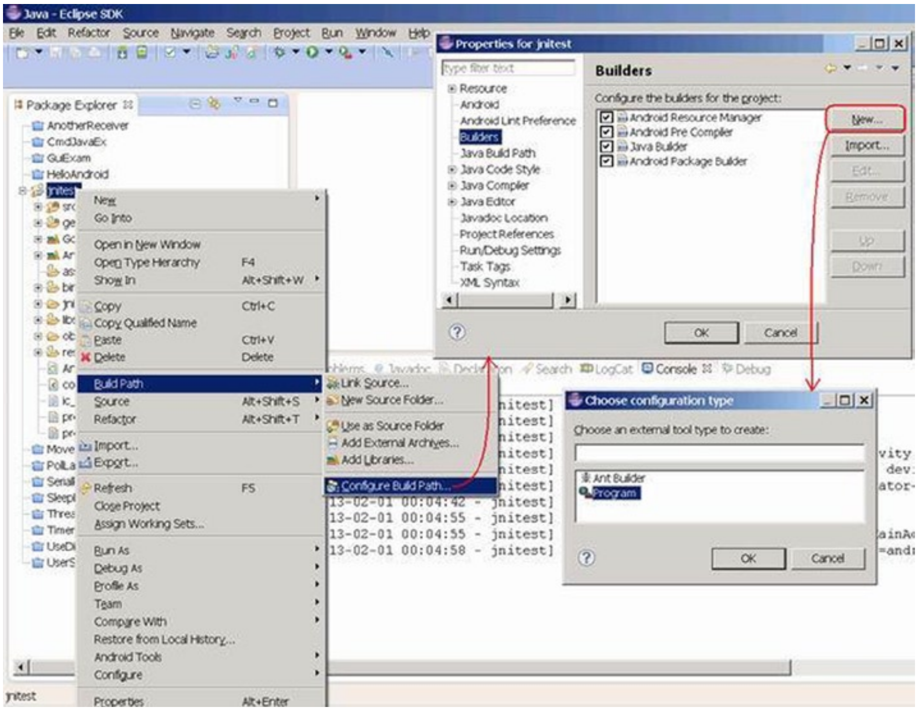


Figure 12-8. Entering parameters settings for the interface to compile C code in Eclipse

2. In the pop-up Edit Configuration dialog box, for the Main tab settings, enter the following:

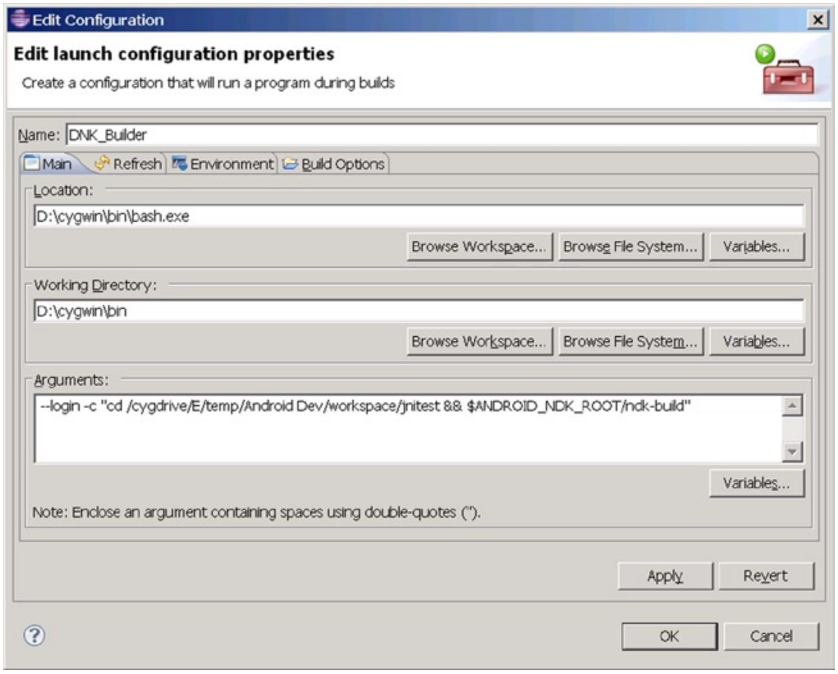
   Location: The path to the Cygwin `bash.exe`

   Working Directory: The `bin` directory of Cygwin

Arguments:

```
--login -c "cd '/cygdrive/E/temp/Android
Dev/workspace/jnitest' && $ANDROID_NDK_ROOT/ndk-build"
```

`E/temp/Android Dev/workspace/jnitest` is the drive letter and path for the project. The settings are shown in Figure 12-9.



Edit Configuration

Edit launch configuration properties

Create a configuration that will run a program during builds

Name: DNK_Builder

Location:
D:\cygwin\bin\bash.exe

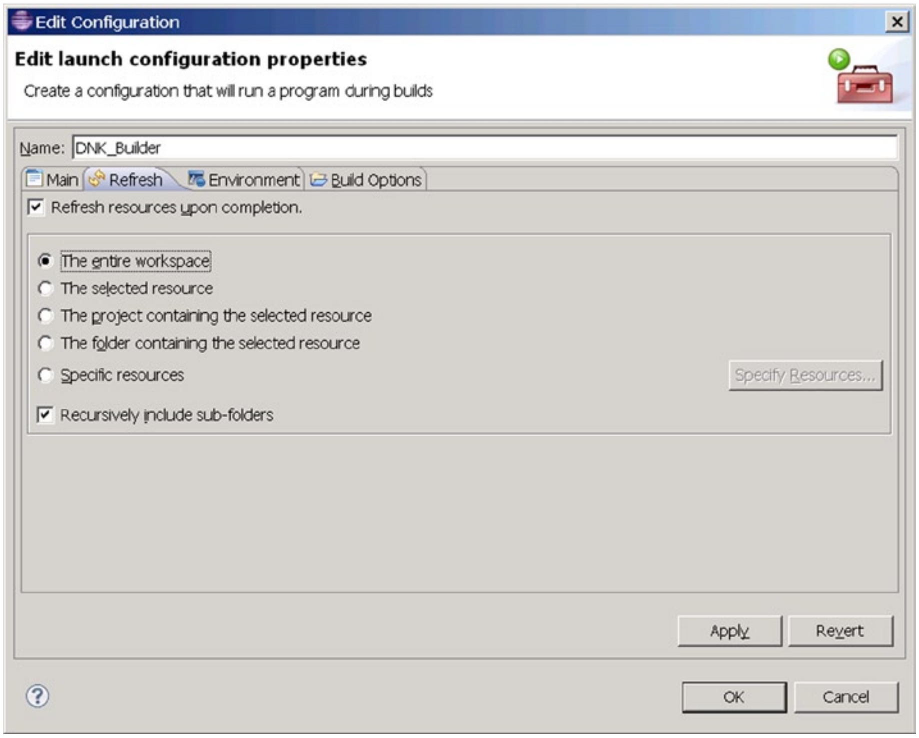
Working Directory:
D:\cygwin\bin

Arguments:
```
--login -c "cd /cygdrive/E/temp/Android Dev/workspace/jnitest && $ANDROID_NDK_ROOT/ndk-build"
```

Note: Enclose an argument containing spaces using double-quotes (").

Figure 12-9. *Main tab setting in the Edit Configuration dialog box*

3. Configure the Refresh tab, ensuring that the The Entire Workspace and Recursively Include Sub-folders items are selected, as shown in Figure 12-10.


Edit Configuration

Edit launch configuration properties

Create a configuration that will run a program during builds

Name: DNK_Builder

Main | Refresh | Environment | Build Options

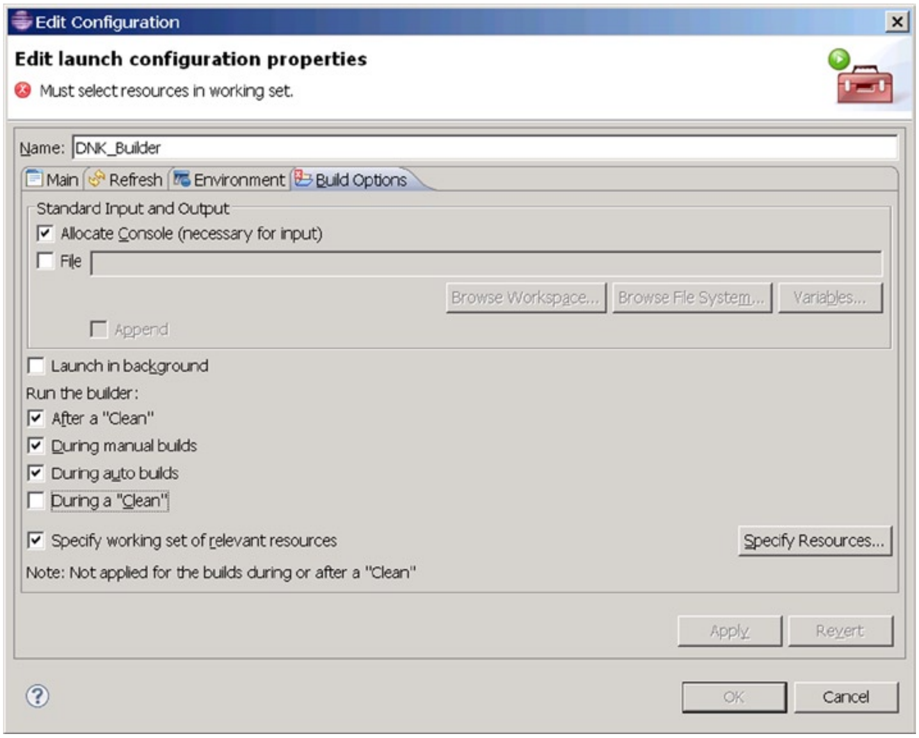
☑ Refresh resources upon completion.

● The entire workspace
○ The selected resource
○ The project containing the selected resource
○ The folder containing the selected resource
○ Specific resources

☑ Recursively include sub-folders

Figure 12-10. *Edit Configuration dialog box Refresh tab settings*

4. Reconfigure the Build Options tab. Select During Auto Builds and Specify Working Set of Relevant Resources, as shown in Figure 12-11.



Edit Configuration

Edit launch configuration properties

Must select resources in working set.

Name: DNK_Builder

Main | Refresh | Environment | Build Options

Standard Input and Output

- [✓] Allocate Console (necessary for input)
- [ ] File
- [ ] Append

- [ ] Launch in background

Run the builder:

- [✓] After a "Clean"
- [✓] During manual builds
- [✓] During auto builds
- [ ] During a "Clean"

- [✓] Specify working set of relevant resources

Note: Not applied for the builds during or after a "Clean"

Figure 12-11. *Edit Configuration dialog box Build Options tab settings*

5. Click the Specify Resources button. In the Edit Working Set dialog box, select the `jni` directory, as shown in Figure 12-12.

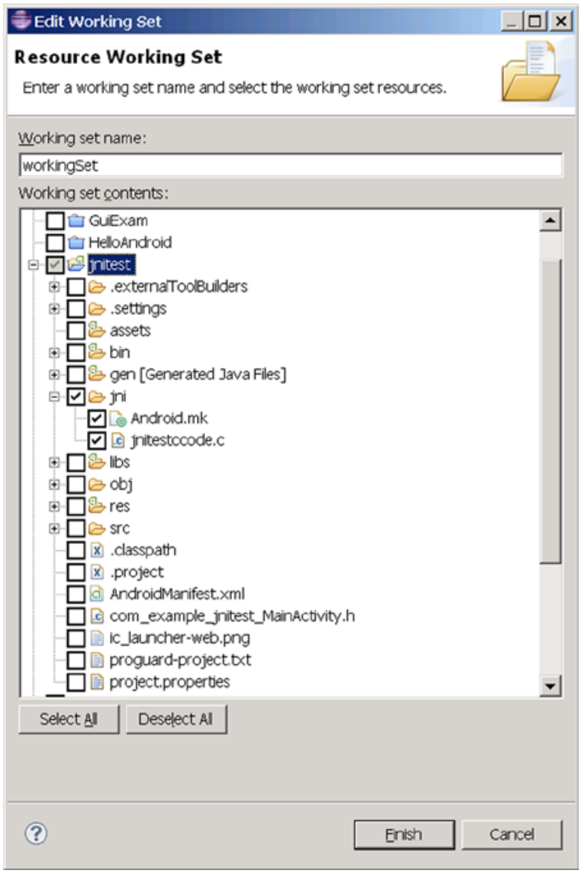


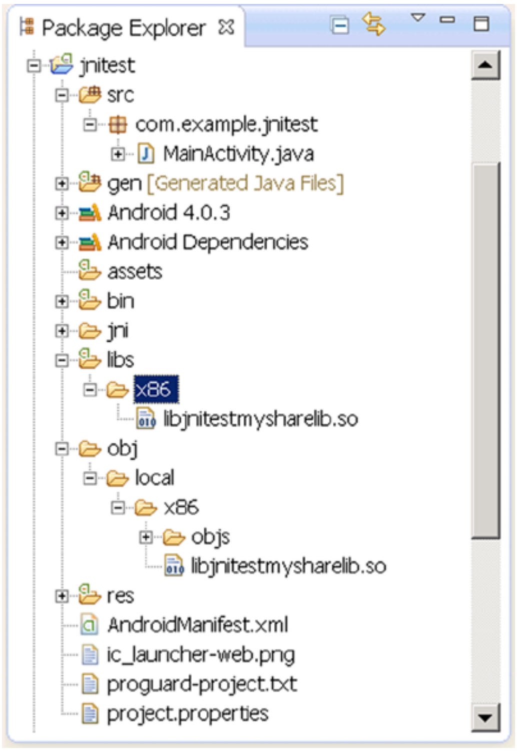
Figure 12-12. *Select source code and directories where related files are located*

6. Save the configuration. It will automatically compile C-related code under the `jni` directory and output the corresponding `.so` library files to the project's `libs` directory. The `libs` directory is created automatically. In the Console window, you can see the output of the build is as follows:

```
/cygdrive/d/Android/android-ndk-r8d/build/core/add-application.mk:128:
Android NDK: WARNING: APP_PLATFORM android-14 is larger than
android:minSdkVersion 8 in ./AndroidManifest.xml
Cygwin        : Generating dependency file converter script
Compile x86   : jnitestmysharelib <= jnitestccode.c
SharedLibrary : libjnitestmysharelib.so
Install       : libjnitestmysharelib.so => libs/x86/libjnitestmysharelib.so
```

Workflow Analysis for NDK Application Development

The process of generating an NDK project as described works naturally to achieve C library integration with Java. You compile `.c` files into `.so` shared library files. The intermediate version of the libraries is put into the `obj` directory, and the final version is put into the `libs` directory. When this is completed, the project file structure is created as shown in Figure 12-13.

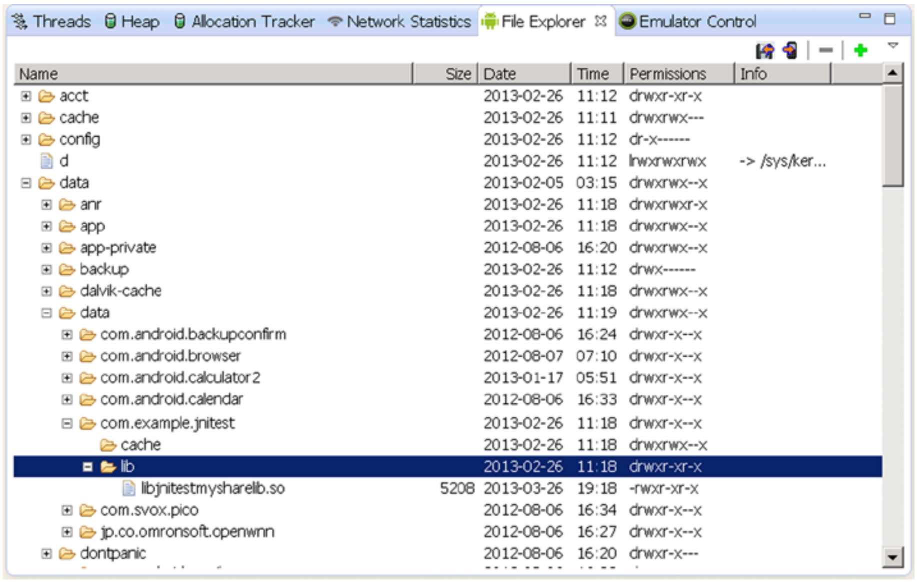


```
Package Explorer
jnitest
  src
    com.example.jnitest
      MainActivity.java
  gen [Generated Java Files]
  Android 4.0.3
  Android Dependencies
  assets
  bin
  jni
  libs
    x86
      libjnitestmysharelib.so
  obj
    local
      x86
        objs
        libjnitestmysharelib.so
  res
  AndroidManifest.xml
  ic_launcher-web.png
  proguard-project.txt
  project.properties
```

Figure 12-13. *The `jnitest` project structure after NDK library files are generated*

When you run the project, the shared library `.so` files are in the project directory on the host machine and are packed in a generated `.apk` file. The `.apk` file is essentially a compressed file; you can use compression software like WinRAR to view its contents. For this example, you can find the `.apk` file in the `bin` subdirectory of the project directory; open it with WinRAR to show the file structure. The content of the `lib` subdirectory of the `.apk` is a clone of the content of the project's `lib` subdirectory.

When the `.apk` is deployed to the target machine, it is unpacked. The `.so` files are placed in the `/data/dat/XXX/lib` directory, where `XXX` is the application package name. For this example, the directory is `/data/data/com.example.jnitest/lib`. You can view the file structure of the target machine under the Eclipse DDMS; the file structure for the example is shown in Figure 12-14. If you are interested, you can try it on the command line, using the adb shell command to view the corresponding contents in the target file directory.



Name	Size	Date	Time	Permissions	Info
acct		2013-02-26	11:12	drwxr-xr-x	
cache		2013-02-26	11:11	drwxrwx---	
config		2013-02-26	11:12	dr-x------	
d		2013-02-26	11:12	lrwxrwxrwx	-> /sys/ker...
data		2013-02-05	03:15	drwxrwx--x	
anr		2013-02-26	11:18	drwxrwxr-x	
app		2013-02-26	11:18	drwxrwx--x	
app-private		2012-08-06	16:20	drwxrwx--x	
backup		2013-02-26	11:12	drwx------	
dalvik-cache		2013-02-26	11:18	drwxrwx--x	
data		2013-02-26	11:19	drwxrwx--x	
com.android.backupconfirm		2012-08-06	16:24	drwxr-x--x	
com.android.browser		2012-08-07	07:10	drwxr-x--x	
com.android.calculator2		2013-01-17	05:51	drwxr-x--x	
com.android.calendar		2012-08-06	16:33	drwxr-x--x	
com.example.jnitest		2013-02-26	11:18	drwxr-x--x	
cache		2013-02-26	11:18	drwxrwx--x	
lib		2013-02-26	11:18	drwxr-xr-x	
libjnitestmysharelib.so	5208	2013-03-26	19:18	-rwxr-xr-x	
com.svox.pico		2012-08-06	16:34	drwxr-x--x	
jp.co.omronsoft.openwnn		2012-08-06	16:27	drwxr-x--x	
dontpanic		2012-08-06	16:20	drwxr-x---	

Figure 12-14. *`jnitest` application deployment target file structure*

In addition, if you run the `jnitest` application in an emulator (in this case, the target machine is a virtual machine), you can see the following output in the Eclipse Logcat window:

```
1. 07-10 05:43:08.579: E/Trace(6263): error opening trace file: No such file
or directory (2)
2. 07-10 05:43:08.729: D/dalvikvm(6263): Trying to load lib
/data/data/com.example.jnitest/lib/libjnitestmysharelib.so 0x411e8b30
3. 07-10 05:43:08.838: D/dalvikvm(6263): Added shared lib
/data/data/com.example.jnitest/lib/libjnitestmysharelib.so 0x411e8b30
4. 07-10 05:43:08.838: D/dalvikvm(6263): No JNI_OnLoad found in
/data/data/com.example.jnitest/lib/libjnitestmysharelib.so 0x411e8b30,
skipping init
5. 07-10 05:43:11.773: I/Choreographer(6263): Skipped 143 frames!  The
application may be doing too much work on its main thread.
6. 07-10 05:43:12.097: D/gralloc_goldfish(6263): Emulator without GPU
emulation detected.
```

Lines 2–3 are reminders of the `.so` shared library loaded in the application.

NDK Compiler Optimization

From the example, you can see that the NDK tool's core role is to compile source code into a `.so` library file that can run on an Android machine. The `.so` library file is put into the `lib` subdirectory of the project directory, so that when you use Eclipse to deploy applications, you can deploy the library files to the appropriate location on a target device, and the application can using the library function.

■ **Note** The nature of the NDK application is to establish a code framework that complies with the JNI standard, to let Java applications use a local function beyond the scope of the virtual machine.

The key NDK command to compile the source code into a `.so` library file is `ndk-build`. This command is not actually a separate command, but an executable script. It calls the `make` command in the GNU cross-development tools to compile a project; and `make` calls, for example, the `gcc` compiler to compile the source code to complete the process, as shown in Figure 12-15. Of course, you can also directly use `.so` shared libraries developed by third parties that are already in Android applications, thus avoiding the need to write your own library (function code).

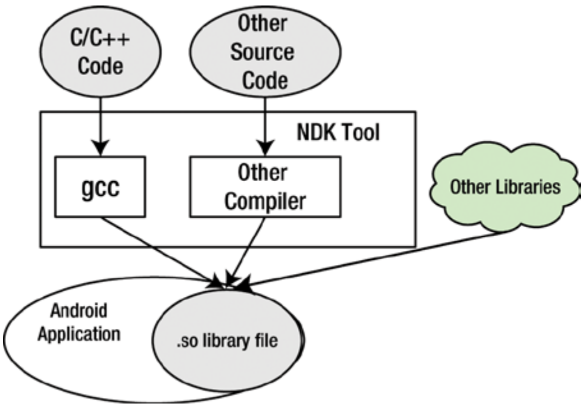


Figure 12-15. *The working mechanism of NDK tools*

As Figure 12-15 shows, the GNU compiler `gcc` is the core tool in NDK to complete C/C++ source code compilation. `gcc` is the standard Linux compiler, which can compile and link C, C++, Object-C, FORTRAN, and other source code on the local machine. Not only can the `gcc` compiler do local compiling, but it can also do cross-compiling. This feature has been used by Android NDK and other embedded development tools. In compiler usage, `gcc` cross-compiling is compatible with native compiling; that is, command parameters and switches of locally compiled code can essentially be ported without modification to cross-compiling code. Therefore, the gcc compiling method described next is generic for both local and cross-compiling.

Chapter 11 mentioned that some optimizations can be done automatically by the compiler, which is referred to as *compiler optimization*. For systems based on Intel x86 architecture processors, in addition to the GNU gcc compiler, the Intel C/C++ compiler is also good. Relatively speaking, because the Intel C/C ++ compiler fully utilizes the features of Intel processors, the code-optimization results are better. For Android NDK, both the Intel C/C++ compiler and gcc can complete the C/C++ code compilation. Currently, the Intel C/C ++ compiler provides the appropriate usage mechanisms. Ordinary users need a professional license, whereas gcc is open source, free software and is more readily available. So, this section uses gcc as an experimental tool to explain how to perform C/C++ module compiler optimization for Android applications.

The gcc optimization is controlled by options in the compiler switches. Some of these options are machine independent, and some are associated with the machine. This section discusses some important options. Machine-related options are described only if relevant to Intel processors.

Machine-Independent Compiler Switch Options

The machine-independent options for gcc compiler switches are the -Ox options, which correspond to different optimization levels. Following are the details.

-O or -O1

Level 1 optimization, which is the default level, uses the -O option; the compiler tries to reduce code size and execution time. For large functions, it needs to spend more compiling time and use a large amount of memory resources for optimizing compiling.

When the -O option is not used, the compiler's goal is to reduce the overhead of compiling so that results can be debugged. In this compilation mode, the statement is independent. By inserting a breakpoint interrupt program run between the two statements, you can reassign variables or modify the program counter to jump to other currently executing statements, so you can precisely control the running process and the user can get results when they want to debug. In addition, if the -O option is not used, only declared register variables can have a register allocation.

If you specify the -O option, the -fthread-jumps and -fdefer-pop options are turned on. On a machine with a delay slot, the -fdelayed-branch option is turned on. Even for machines that support debugging without a frame pointer, the -fomit-frame-pointer option is turned on. Some machines may also open other options.

-O2

This option optimizes even more. gcc performs nearly all supported optimizations that do not involve a space-speed tradeoff. As compared to -O, this option increases both compilation time and the performance of the generated code.

-O3

This option optimizes still more. It turns on all optimizations specified by `-O2` and also turns on the `-finline-functions`, `-funswitch-loops`, `-fpredictive-commoning`, `-fgcse-after-reload`, `-ftree-vectorize`, `-fvect-cost-model`, `-ftree-partial-pre`, and `-fipa-cp-clone` options.

-O0

This option reduces compilation time and makes debugging produce the expected results. This is the default.

An automatic `inline` function is often used as a function-optimization measure. C99 (C language ISO standard developed in 1999) and C++ both support the `inline` keyword. The `inline` function uses inline space in exchange for time. The compiler does not compile an inline-described function into a function, but directly expands the code for the function body, thereby eliminating the function call For example, consider the following function:

```
inline long factorial (int i)
{
    return factorial_table[i];
}
```

Here all occurrences of all the code in the `factorial()` call are replaced with the `factorial_table []` array references.

In the optimizing state, some compilers treat that function as an inline function even if the function does not use inline instructions, if appropriate in the circumstances (such as if the body of the function code is relatively short and the definition is in the header file), in exchange for execution time.

Loop unrolling is a classic speed-optimization method and is used by many compilers as the automatic optimization strategy. For example, the following code needs to loop 100 cycles:

```
for (i = 0; i < 100; i++)
{
    do_stuff(i);
}
```

At the end of each cycle, the cycle conditions have to be checked to do a comparative judgment. By using a loop-unrolling strategy, the code can be transformed as follows:

```
for (i = 0; i < 100; )
{
    do_stuff(i); i++;
    do_stuff(i); i++;
    do_stuff(i); i++;
    do_stuff(i); i++;
    do_stuff(i); i++;
    do_stuff(i); i++;
    do_stuff(i); i++;
    do_stuff(i); i++;
    do_stuff(i); i++;
    do_stuff(i); i++;
}
```

The new code reduces the comparison instruction from 100 to 10 times, and the time used to compare conditions can be reduced by 90%.

Both methods described here improve the code efficiency and accomplish the optimization of the object code. This is a typical way of optimizing the object code to make it more time efficient

Intel Processor-Related Compiler Switch Options

The `m` option of `gcc` is defined for the Intel i386 and x86-64 processor family. The main command options and their effects are shown in Table 12-3.

Table 12-3. *Intel Processor-Related `gcc` Switch Options*

Switch Option	Notes	Description

`-march=cpu-type`
`-mtune=cpu-type`
		Generates code for the specified type of CPU. `cpu-type` can be i386, i486, i586, Pentium, i686, Pentium 4, and so on.

`-msse`		Compiler automatic vectorization: use or do not use MMX, SSE, and SSE2 instructions. For example, `-msse` means programming into the instruction, and `-mno-sse` means not programmed into the SSE instruction.
`-msse2`		
`-msse3`		
`-mssse3`	gcc-4.3 new addition	
`-msse4.1`	gcc-4.3 new addition	
`-msse4.2`	gcc-4.3 new addition	
`-msse4`	Include 4.1 and .2, gcc-4.3 new addition	
`-mmmx`		
`-mno-sse`		
`-mno-sse2`		
`-mno-mmx`		
`-m32` `-m64`		Generate 32/64 machine code.

In Table 12-3, `-march` is the CPU type of the machine, and `-mtune` is the CPU type that the compiler wants to optimize; by default it is the same as for `-march`. The `-march` option is a *tight constraint*, and `-mtune` is a *loose constraint*. The `-mtune` option can provide backward compatibility.

For example, a compiler with the options `-march = i686`, `-mtune = pentium4` is optimized for the Pentium 4 processor but can be run on any i686 as well. And for `-mtune = pentium-mmx` compiled procedures, the Pentium 4 processor can be run.

The following option generates `cpu-type` instructions that specify the type of machine:

```
-march=cpu-type
```

The `-mtune = cpu-type` option is only available if you are optimizing code generated for `cpu-type`. By contrast, `-march = cpu-type` generates code not run on non-`gcc` for the specified type of processor, which means `-march = cpu-type` implies the `-mtune = cpu-type` option.

The `cpu-type` option values related to Intel processors are listed in Table 12-4.

***Table 12-4.** The Main Option Values of `gcc -march` Parameters for `cpu-type`*

cpu-type Value	Description
native	Selects the CPU to generate code at compilation time by determining the processor type of the compiling machine. Using `-march=native` enables all instruction subsets supported by the local machine (hence the result might not run on different machines). Using `-mtune=native` produces code optimized for the local machine under the constraints of the selected instruction set.
i386	Original Intel i386 CPU.
i486	Intel i486 CPU. (No scheduling is implemented for this chip.)
i586	Intel Pentium CPU with no MMX support.
Pentium	
pentium-mmx	Intel Pentium MMX CPU, based on a Pentium core with MMX instruction set support.
pentiumpro	Intel Pentium Pro CPU.
i686	When used with `-march`, the Pentium Pro instruction set is used, so the code runs on all i686 family chips. When used with `-mtune`, it has the same meaning as generic.
pentium2	Intel Pentium II CPU, based on a Pentium Pro core with MMX instruction set support.
pentium3 pentium3m	Intel Pentium III CPU, based on a Pentium Pro core with MMX and SSE instruction set support.

(*continued*)

Table 12-4. (*continued*)

cpu-type Value	Description
pentium-m	Intel Pentium M; low-power version of the Intel Pentium III CPU with MMX, SSE, and SSE2 instruction set support. Used by Intel Centrino-based notebooks.
pentium4 pentium4m	Intel Pentium 4 CPU with MMX, SSE, and SSE2 instruction set support.
prescott	Improved version of Intel Pentium 4 CPU with MMX, SSE, SSE2, and SSE3 instruction set support.
nocona	Improved version of Intel Pentium 4 CPU with 64-bit extensions and MMX, SSE, SSE2, and SSE3 instruction set support.
core2	Intel Core 2 CPU with 64-bit extension and MMX, SSE, SSE2, SSE3, and SSSE3 instruction set support.
corei7	Intel Core i7 CPU with 64-bit extensions and MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, and SSE4.2 instruction set support.
corei7-avx	Intel Core i7 CPU with 64-bit extensions and MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, AVX, AES, and PCLMUL instruction set support.
core-avx-i	Intel Core CPU with 64-bit extensions and MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, AVX, AES, PCLMUL, FSGSBASE, RDRND, and F16C instruction set support.
atom	Intel Atom CPU with 64-bit extensions and MMX, SSE, SSE2, SSE3, and SSSE3 instruction set and Atom Silvermont (SLM) architecture support.

Traditional `gcc` is a local compiler. These command options can be added to `gcc` to control `gcc` compiler options. For example, suppose you have an `int_sin.c` file:

```
$ gcc int_sin.c
```

This command uses the `O1` optimization level (default level) and compiles `int_sin.c` into an executable file named by default `a.out`.

This command uses `O1` optimization (default level) to compile `int_sin.c` into an executable file; the executable file name is specified as `sinnorm`:

```
$ gcc int_sin.c -o sinnorm
```

This command uses O1 optimization (default level) to compile int_cos.c into a shared library file coslib.so. Unlike source code files compiled into an executable program, this command requires that the source code file int_cos.c does not contain the main function:

```
$ gcc int_cos.c -fPIC -shared -o coslib.so
```

This command compiles int_sin.c into the executable file with the default file name. The compiler does not perform any optimization:

```
$ gcc -O0 int_sin.c
```

This command uses the highest optimization level O3 to compile the int_sin.c file to the executable file with the default file name:

```
$ gcc -O3 int_sin.c
```

This command compiles int_sin.c into an executable file using SSE instructions:

```
$ gcc -msse int_sin.c
```

This command compiles int_sin.c into an executable file without any SSE instructions:

```
$ gcc -mno-sse int_sin.c
```

This command compiles int_sin.c into an executable file that can use Intel Atom processor instructions:

```
$ gcc -mtune=atom int_sin.c
```

From the example compiled by gcc locally, you have some experience using the compiler switch options for gcc compiler optimizations. For the gcc native compiler, the gcc command can be used directly in the switch options to achieve compiler optimization. However, from the previous example, you know that the NDK does not directly use the gcc command. Then how do you set the gcc compiler switch option to achieve NDK optimization?

Recall that in the NDK example, you used the ndk-build command to compile C/C++ source code; the command first needed to read the makefile Android.Mk. This file contains the gcc command options. Android.mk uses LOCAL_CFLAGS to control and complete the gcc command options. The ndk-build command passes LOCAL_CFLAGS runtime values to gcc as its command option to run the gcc command. LOCAL_CFLAGS passes the values to gcc and uses them as the command option to run gcc commands:

For example, in section 3, you amended Android.mk as follows:

```
1. LOCAL_PATH      := $(call my-dir)
2. include $(CLEAR_VARS)
3. LOCAL_MODULE    := jnitestmysharelib
4. LOCAL_SRC_FILES := jnitestccode.c
5. LOCAL_CFLAGS    := -O3
6. include $(BUILD_SHARED_LIBRARY)
```

Line 5 is new: it sets the LOCAL_CFLAGS variable script.

When you execute the ndk-build command, which is equivalent to adding a gcc -O3 command option, it instructs gcc to compile the C source code at the highest optimization level, O3. Similarly, if you edit the line 5 to

```
LOCAL_CFLAGS      := -msse3
```

you instruct gcc to compile C source code into object code using SSE3 instructions that Intel Atom supports.

You can set LOCAL_CFLAGS to a different value and compare the target library file size and content differences. Note that this example jnitest C code is very simple and does not involve complex tasks. As a result, the size and content of the library files are not very different when compiled from different LOCAL_CFLAGS values.

Is there an example where there is a significant difference in the size or content of the library file? Yes, as you will see in the following sections.

Optimization with Intel Integrated Performance Primitives (Intel IPP)

Figure 12-15 shows that Android applications can bypass NDK development tools and use existing .so shared libraries developed by third parties directly, including third-party shared libraries provided by Intel Integrated Performance Primitives (Intel IPP). Intel IPP is a powerful function library for Intel processors and chipsets, and it covers math, signal processing, multimedia, image and graphics processing, vector computing, and other areas. A prominent feature of Intel IPP is that its code has been extensively optimized based on the features of the Intel processor, using a variety of methods. It is a highly optimized, high-performance service library. Intel IPP has cross-platform features; it provides a set of cross-platform and OS general APIs, which can be used for Windows, Linux, and other operating systems; and it supports embedded, desktop, server, and other processor-scale systems.

Intel IPP is really a set of libraries, each with different function areas within the corresponding library, and it differs slightly according to the number of functions supported in different processor architectures. For example, Intel IPP 5.X image-processing functions can support 2,570 functions in Intel architecture, whereas it supports only 1,574 functions in the IXP processor architecture.

The services provided by a variety of high-performance libraries, including Intel IPP, are multifaceted and multilayered. Applications can use Intel IPP directly or indirectly. It can provide support not only for applications, but also for other components and libraries.

Applications using Intel IPP can use its function interface directly or use sample code to indirectly use Intel IPP. In addition, using the OpenCV library (a cross-platform Open Source Computer Vision Library) is equivalent to indirectly using the Intel IPP library. Both the Intel IPP and Intel MKL libraries run on high-performance Intel processors on various architectures.

Taking into account the power of Intel IPP, and in accordance with the characteristics of optimized features of the Intel processor, you can use the Intel IPP library to replace some key source code that runs more often and consumes time. This way, you can obtain much higher performance acceleration than with general code. This is simply a “standing on the shoulders of giants” practical optimization method: you can achieve optimization without manually writing code in critical areas.

Intel recently released the Intel Integrated Native Development Experience (INDE), which provides both Intel IPP and Intel Threaded Building Blocks (Intel TBB) for Android application developers. You can easily use Intel IPP, Intel TBB, Intel GPA, and other tools for Android application development.

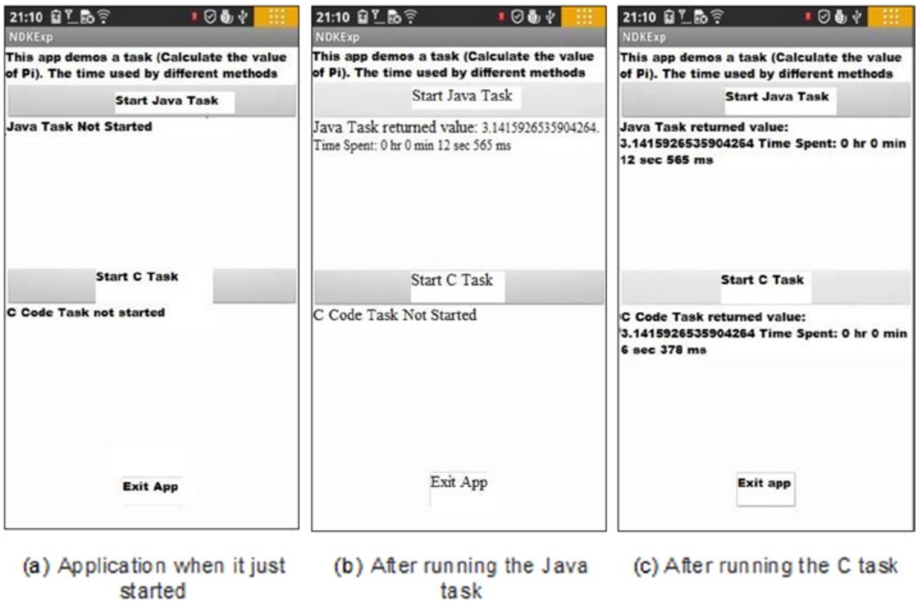
NDK Integrated Optimization Examples

This section uses a case study to demonstrate comprehensive optimization techniques by integrating NDK with C/C++. The case is divided into two steps. The first step is to compile a local function from C/C++ code to accelerate the computing tasks in a traditional Java-based program; the second step demonstrates using NDK compiler optimizations to achieve C/C++ optimization. Each step is introduced in its own section; the two sections are closely linked.

C/C++: Accelerating the Original Application

The previous chapter introduced a Java code example (`SerialPi`) that calculates π. In this section, you change the computing tasks from Java to C code, using NDK to turn it into a local library. You then compare it with the original Java code tasks and get some firsthand experience with using C/C++ native library functions to achieve traditional Java-based task acceleration.

The application used for this case study is named `NdkExp`; see Figure 12-16.


21:10 NDKExp

This app demos a task (Calculate the value of Pi). The time used by different methods

Start Java Task

Java Task Not Started

Start C Task

C Code Task not started

Exit App

Java Task returned value: 3.1415926535904264. Time Spent: 0 hr 0 min 12 sec 565 ms

C Code Task Not Started

Java Task returned value: 3.1415926535904264 Time Spent: 0 hr 0 min 12 sec 565 ms

C Code Task returned value: 3.1415926535904264 Time Spent: 0 hr 0 min 6 sec 378 ms

Exit app

(a) Application when it just started
(b) After running the Java task
(c) After running the C task

Figure 12-16. *Original version of NdkExp*

Figure 12-16(a) shows the application's main interface, including three buttons: Start Java Task, Start C Task, and Exit Application. Clicking the Start Java Task button starts a traditional Java task that calculates π. When the task is completed, the calculated results are displayed below the button along with the time spent, as shown in Figure 12-16(b). Clicking the Start C Task button starts a computing task written in C, using the same math formula to calculate π. When the task is completed, the calculated results are displayed below the button along with the time spent, as shown in Figure 12-16(c).

For the same task, the application written in traditional Java takes 12.565 seconds to complete; the application written in C and compiled by the NDK development tool takes only 6.378 seconds to complete. This example shows you the power of using NDK to achieve performance optimization.

This example is implemented as follows:

1. Generate the project in Eclipse, name it `NdkExp`, and choose the Build SDK option to support the x86 version of the API. Use the default values for the other options. Then generate the project.

2. Modify the main layout file. Put three `TextView` widgets and three `Button` widgets in the layout, set the `Text` and `ID` attributes, and adjust their size and position, as shown in Figure 12-17.

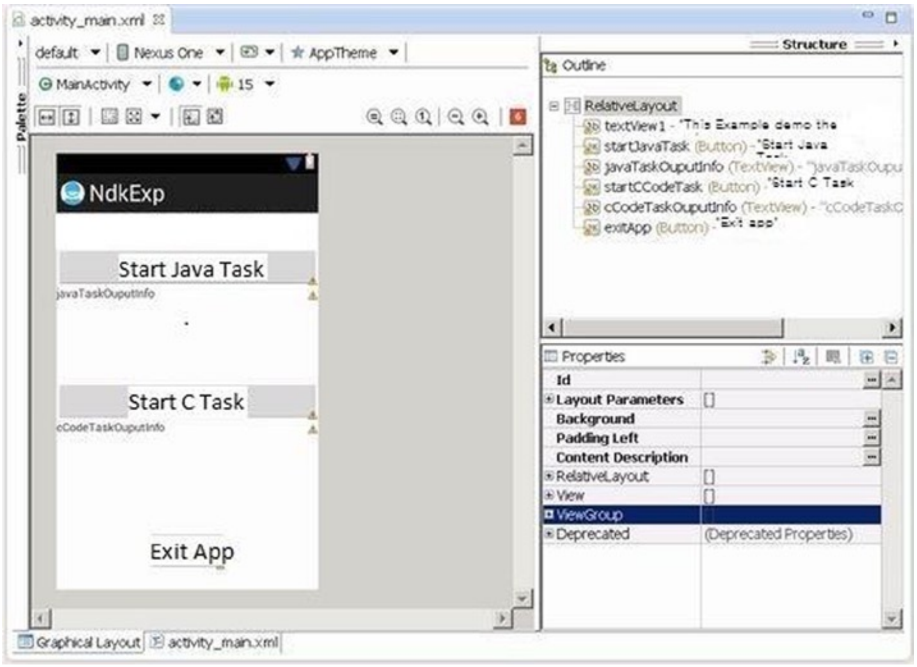


Figure 12-17. *Layout of the original NdkExp*

3. Modify the main layout of the class source code file `MainActivity.java` as follows:

```
package com.example.ndkexp;
import android.os.Bundle;
import android.app.Activity;
import android.view.Menu;
import android.widget.Button;
import android.view.View;
import android.view.View.OnClickListener;
import android.os.Process;
import android.widget.TextView;
import android.os.Handler;
import android.os.Message;

public class MainActivity extends Activity {
    private JavaTaskThread javaTaskThread = null;
    private CCodeTaskThread cCodeTaskThread = null;
    private TextView tv_JavaTaskOuputInfo;
    private TextView tv_CCodeTaskOuputInfo;
    private Handler mHandler;;
    private long end_time;
    private long time;
    private long start_time;
    @Override
    public void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(R.layout.activity_main);
        tv_JavaTaskOuputInfo = (TextView)findViewById(R.
        id.javaTaskOuputInfo);
        tv_JavaTaskOuputInfo.setText("Java the task is not started ");
        tv_CCodeTaskOuputInfo = (TextView)findViewById
        (R.id.cCodeTaskOuputInfo);
        tv_CCodeTaskOuputInfo.setText("C  code task is not start ");
        final Button btn_ExitApp = (Button) findViewById(R.id.exitApp);
        btn_ExitApp.setOnClickListener(new /*View.*/OnClickListener(){
            public void onClick(View v) {
                exitApp();
            }
        });
        final Button btn_StartJavaTask = (Button)
        findViewById(R.id.startJavaTask);
        final Button btn_StartCCodeTask = (Button)
        findViewById(R.id.startCCodeTask);
        btn_StartJavaTask.setOnClickListener(new /*View.*/OnClickListener(){
            public void onClick(View v) {
                btn_StartJavaTask.setEnabled(false);
                btn_StartCCodeTask.setEnabled(false);
                btn_ExitApp.setEnabled(false);
                startJavaTask();
            }
        });
        btn_StartCCodeTask.setOnClickListener(new /*View.*/OnClickListener(){
            public void onClick(View v) {
                btn_StartJavaTask.setEnabled(false);
                btn_StartCCodeTask.setEnabled(false);
                btn_ExitApp.setEnabled(false);
                startCCodeTask();
            }
        });
        mHandler = new Handler() {
            public void handleMessage(Message msg) {
            String s;
               switch (msg.what)
               {
               case JavaTaskThread.MSG_FINISHED:
                    end_time = System.currentTimeMillis();
                    time = end_time - start_time;
                s = " The return value of the Java task "+ (Double)
                      (msg.obj) +"  Time consumed:"
                     + JavaTaskThread.msTimeToDatetime(time);
                tv_JavaTaskOuputInfo.setText(s);
                btn_StartCCodeTask.setEnabled(true);
                btn_ExitApp.setEnabled(true);
              break;
            case CCodeTaskThread.MSG_FINISHED:
                end_time = System.currentTimeMillis();
                time = end_time - start_time;
                s = " The return value of the C code task"+ (Double)
                (msg.obj) +"  time consumed:"
                     + JavaTaskThread.msTimeToDatetime(time);
                tv_CCodeTaskOuputInfo.setText(s);
                btn_StartJavaTask.setEnabled(true);
                btn_ExitApp.setEnabled(true);
              break;
            default:
              break;
            }
        }
    };
}

@Override
public boolean onCreateOptionsMenu(Menu menu) {
   getMenuInflater().inflate(R.menu.activity_main, menu);
   return true;
}

private void startJavaTask() {
    if (javaTaskThread == null)
        javaTaskThread = new JavaTaskThread(mHandler);
    if (! javaTaskThread.isAlive())
    {
           start_time = System.currentTimeMillis();
           javaTaskThread.start();
           tv_JavaTaskOuputInfo.setText
           ("The Java task is running...");
    }
}

private void startCCodeTask() {
    if (cCodeTaskThread == null)
        cCodeTaskThread = new CCodeTaskThread(mHandler);
```

```
104.         if (! cCodeTaskThread.isAlive())
105.         {
106.                start_time = System.currentTimeMillis();
107.                cCodeTaskThread.start();
108.                tv_CCodeTaskOuputInfo.setText
                    ("C code task is running...");
109.         }
110.     }
111.     private void exitApp() {
112.         try {
113.             if (javaTaskThread !=null)
114.             {
115.                 javaTaskThread.join();
116.                 javaTaskThread = null;
117.             }
118.         } catch (InterruptedException e) {
119.         }
120.         try {
121.             if (cCodeTaskThread  !=null)
122.             {
123.                 cCodeTaskThread.join();
124.                 cCodeTaskThread = null;
125.             }
126.         } catch (InterruptedException e) {
127.         }
128.         finish();
129.         Process.killProcess(Process.myPid());
130.     }
131.
132.     static {
133.         System.loadLibrary("ndkexp_extern_lib");
134.     }
135. }
```

This code is basically the same as the example code for SerialPi. Only the code in lines 123–134 is ew. This code requires that the libndkexp_extern_lib.so shared library file be loaded before the application runs. The application needs to use local functions in this library.

4. The new thread task class JavaTaskThread in the project is used to calculate π. The code is similar to the MyTaskThread class code in the SerialPi example and is omitted here.

5. The thread task class CCodeTaskThread in the new project calls the local function to calculate π; its source code file CCodeTaskThread.java reads as follows:

```java
package com.example.ndkexp;
import android.os.Handler;
import android.os.Message;

public class CCodeTaskThread extends Thread {
   private Handler mainHandler;
   public static final int MSG_FINISHED = 2;  // The message after the end of the task
   private native double cCodeTask();   // Calling external C functions to accomplish computing tasks

   static String msTimeToDatetime(long msnum){
       long hh,mm,ss,ms, tt= msnum;
       ms = tt % 1000; tt = tt / 1000;
       ss = tt % 60; tt = tt / 60;
       mm = tt % 60; tt = tt / 60;
       hh = tt % 60;
       String s = "" + hh +" Hour "+mm+" Minute "+ss + " Second " + ms +" Millisecond ";
       return s;
   }

   @Override
   public void run()
   {
       double pi = cCodeTask();   // Calling external C function to complete the calculation
       Message msg = new Message();
       msg.what = MSG_FINISHED;
       Double dPi = Double.valueOf(pi);
       msg.obj = dPi;
       mainHandler.sendMessage(msg);
   }

   public CCodeTaskThread(Handler mh)
   {
       super();
       mainHandler = mh;
   }
}
```

This code is similar to the code framework of the MyTaskThread class of the SerialPi example. The main difference is at line 20. The original Java code for calculating π is replaced by calling a local function cCodeTask to achieve the task. To indicate that cCodeTask is a local function, you add the local declaration in line 7.

6. Build the project in Eclipse. Again, just build, rather than run.
7. Create the jni subdirectory in the project root directory.
8. Write the C implementation code for the cCodeTask function.
9. Compile the file into a .so library file. The main steps are as follows.
    a. Create a C interface file. Because it is a cCodeTaskThread class using a local function, you need to generate the class header file based on the class file of this class. At the command line, go to the project directory and run the following command:

```
E:\temp\Android Dev\workspace\NdkExp> javah
-classpath "D:\Android\android-sdk\platforms\
android-15\android.jar";bin/classes com.example.
ndkexp.CCodeTaskThread
```

This command generates a file in the project directory named com_example_ndkexp_CCodeTaskThread.h. The main content of the document is as follows:

```
    ......
23. JNIEXPORT jdouble
    JNICALL Java_com_example_ndkexp_CCodeTaskThread_cCodeTask
24. (JNIEnv *, jobject);
    ......
```

In lines 23–24, the prototype of the local function cCodeTask is defined.

    b. Based on these header files, create a corresponding C code file in the jni directory of the project. In this case, name it mycomputetask.c it reads as follows:

```
#include <jni.h>
jdouble Java_com_example_ndkexp_CCodeTaskThread_cCodeTask
(JNIEnv* env, jobject thiz )
{
    const long num_steps = 100000000;    // The total step length
    const double step = 1.0 / num_steps;
    double x, sum = 0.0;
    long i;
    double pi = 0;

10.     for (i=0; i< num_steps; i++){
11.         x = (i+0.5)*step;
11.         sum = sum + 4.0/(1.0 + x*x);
12.     }
13.     pi = step * sum;
14.
15.     return (pi);
16. }
```

Lines 4–16 are the body of the function—the code calculating π, which is the code that corresponds to the `MyTaskThread` class in `SerialPi`. It is not difficult to understand. Note that in line 4, the value of the variable `num_steps` (the total step length) must be the same as the value of the step size the `JavaTaskThread` class represents. Otherwise, it make no sense to compare the performance here.

The first line of each Jni file must contain the headers. Line 2 is the `cCodeTask` function prototype and is based on slightly modified header files obtained in the previous step.

Line 16 returns the results. With the Java `double` type, which corresponds to the C `jdouble` type, C can have a `pi` variable of type `double` returned directly to it. This is discussed in the introduction to this chapter.

c. In the project `jni` directory, by following the method Section: Using the Command Line Method to Generate a Library File on page 12 of this chapter3, create `Android.mk` and `Application.mk` files. The content of `Android.mk` reads as follows:

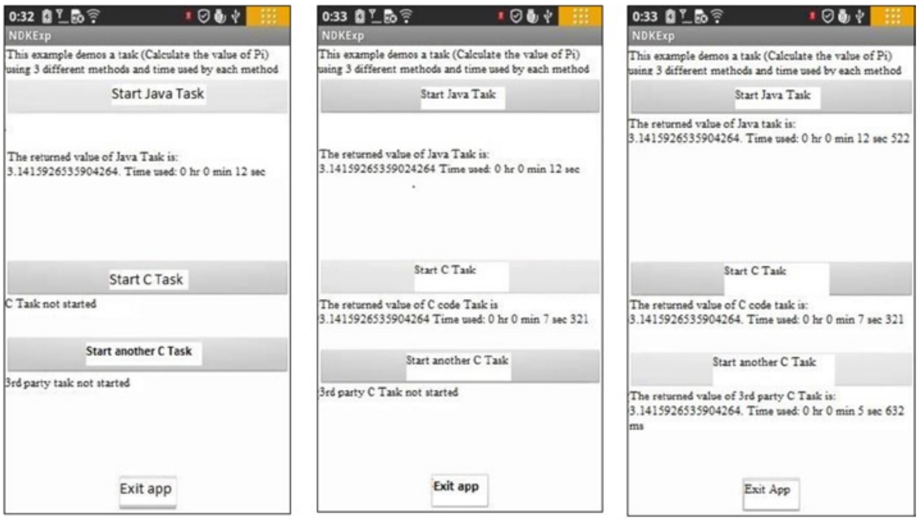
```
1.  LOCAL_PATH := $(call my-dir)
2.  include $(CLEAR_VARS)
3.  LOCAL_MODULE        := ndkexp_extern_lib
4.  LOCAL_SRC_FILES     := mycomputetask.c
5.  include $(BUILD_SHARED_LIBRARY)
```

Line 4 specifies the C code in the case file. Line 3 indicates the file name of the generated library; its name must be consistent with the parameters of the `System.loadLibrary` function in line 133 of the project file `MainActivity.java`.

d. Based on the method described in Section: Using the Command Line Method to Generate a Library File on page 12 of this chapter compile the C code into the `.so` library file under the `lib` directory of the project.

10. Run the project.

The application's running interface is shown in the next section, in Figure 12-18.


0:32
NDKExp
This example demos a task (Calculate the value of Pi) using 3 different methods and time used by each method
The returned value of Java Task is: 3.1415926535904264. Time used: 0 hr 0 min 12 sec
C Task not started
3rd party task not started

0:33
NDKExp
This example demos a task (Calculate the value of Pi) using 3 different methods and time used by each method
The returned value of Java Task is: 3.1415926535904264 Time used: 0 hr 0 min 12 sec
The returned value of C code Task is 3.1415926535904264 Time used: 0 hr 0 min 7 sec 321
3rd party C Task not started

0:33
NDKExp
This example demos a task (Calculate the value of Pi) using 3 different methods and time used bv each method
The returned value of Java task is: 3.1415926535904264. Time used: 0 hr 0 min 12 sec 522
The returned value of C code task is: 3.1415926535904264. Time used: 0 hr 0 min 7 sec 321
The returned value of 3rd party C Task is: 3.1415926535904264. Time used: 0 hr 0 min 5 sec 632 ms

(a) Java task running (b) Unoptimized C task running (c) Optimized C task is running

Figure 12-18. *Extended version of NdkExp*

Extending Compiler Optimization

The example demonstrates the capabilities of NDK for application acceleration. However, the application implements only one local function and is unable to provide information to compare the effects of compiler optimizations. For this purpose, in this section you rebuild the application and use it to experiment with the effects of compiler optimizations; see Figure 12-18.

The application has four buttons. When you click the Start Java Task button, the response code does not change. When you click the Start C Task or Start another C Task button, the application starts a local function running.

The code (the function body) of the two functions is the same. It calculates the values of π, but using different names. The first button calls the `cCodeTask` function, and the second button calls the `anotherCCodeTask` function. These functions are located in the `mycomputetask.c` and `anothertask.c` files, respectively, and they correspond to the library files `libndkexp_extern_lib.so` and `libndkexp_another_lib.so` after being compiled. In this case, you compile `libndkexp_extern_lib.so` using the `-O0` option and `libndkexp_another_lib.so` using the `-O3` option, so one is compiled unoptimized and the other is compiled optimized.

Clicking Start C Task runs the unoptimized version of the C function, as shown in Figure 12-20(b); and clicking Start Another C Task runs the optimized version, as shown in Figure 12-20(c). After task execution, the system displays the calculated results to the consumption of time.

As you can see in Figure 12-18, regardless of whether the compiler optimizations are used, the running time of the local function is always shorter than the running time (12.522 seconds) of the Java function. The execution time (5.632 seconds) of the `-O3` optimization function is less than the execution time (7.321 seconds) of the unoptimized (`-O0` compiler option) function. From this result comparison, you can see that using compiler optimizations actually reduces application execution time. Not only that, it is even less than the original application running time (6.378 seconds) in section C/C++: The Original Application Acceleration. This is because the original application without compiler options defaults to the `-O1` level of optimization, whereas the `-O3` optimization level is even higher than the original application, so it's not surprising that it has the shortest running time.

This application is a modified and extended version of the original application `NdkExp`. The steps are as follows:

1. Modify the main layout file. Add a `TextView` widget and a `Button` widget in a layout. Set the `Text` and `ID` properties, and adjust their size and position, as shown in Figure 12-19.

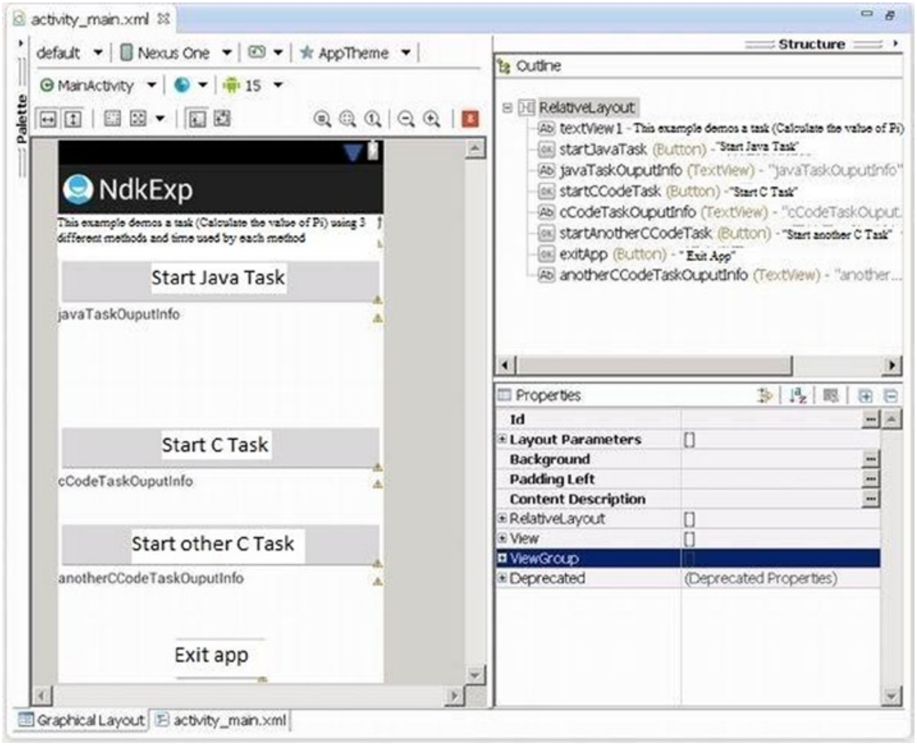

activity_main.xml
default
Nexus One
AppTheme
MainActivity
15
Palette
NdkExp
This example demos a task (Calculate the value of Pi) using 3 different methods and time used by each method
Start Java Task
javaTaskOuputInfo
Start C Task
cCodeTaskOuputInfo
Start other C Task
anotherCCodeTaskOuputInfo
Exit app
Structure
Outline
RelativeLayout
textView1 - This example demos a task (Calculate the value of Pi)
startJavaTask (Button) - "Start Java Task"
javaTaskOuputInfo (TextView) - "javaTaskOuputInfo"
startCCodeTask (Button) - "Start C Task"
cCodeTaskOuputInfo (TextView) - "cCodeTaskOuput...
startAnotherCCodeTask (Button) - "Start another C Task"
exitApp (Button) - " Exit App"
anotherCCodeTaskOuputInfo (TextView) - "another...
Properties
Id
Layout Parameters
Background
Padding Left
Content Description
RelativeLayout
View
ViewGroup
Deprecated
(Deprecated Properties)
Graphical Layout
activity_main.xml

Figure 12-19. *Extended* `NdkExp` *layout*

2. Modify the class source code file `MainActivity.java` of the main layout. The main changes are as follows:

```
    ...
13. public class MainActivity extends Activity {
14.     private JavaTaskThread javaTaskThread = null;
15.     private CCodeTaskThread cCodeTaskThread = null;
16.     private AnotherCCodeTaskThread anotherCCodeTaskThread = null;
17.     private TextView tv_JavaTaskOuputInfo;
18.     private TextView tv_CCodeTaskOuputInfo;
19.     private TextView tv_AnotherCCodeTaskOuputInfo;
    ......
182.    static {
183.        System.loadLibrary("ndkexp_extern_lib");
184.        System.loadLibrary("ndkexp_another_lib");
185.    }
186. }
```

On line 16 and line 19 respectively, add the required variables for the new Start Other C Task button.

The key change is in line 184; here, in addition to loading the original shared library files, you also add another library file.

3. In the project, add a thread task class `AnotherCCodeTaskThread` that calls a local function to calculate π. Its source code file `AnotherCCodeTaskThread.java` reads as follows:

```
package com.example.ndkexp;
import android.os.Handler;
import android.os.Message;

public class AnotherCCodeTaskThread extends Thread {
    private Handler mainHandler;
    public static final int MSG_FINISHED = 3;
// The message after the end of the task
    private native double anotherCCodeTask();
// Calling external C functions to complete computing tasks

    static String msTimeToDatetime(long msnum){
        long hh,mm,ss,ms, tt= msnum;
        ms = tt % 1000; tt = tt / 1000;
        ss = tt % 60; tt = tt / 60;
        mm = tt % 60; tt = tt / 60;
        hh = tt % 60;
14.          String s = "" + hh +"Hour "+mm+"Minute "+ss + "Second " + ms
             +"Millisecond";
15.          return s;
16.      }

17.      @Override
18.      public void run()
19.      {
20.          double pi = anotherCCodeTask();  // Calling external C function
                                                 to complete the calculation
21.          Message msg = new Message();
22.          msg.what = MSG_FINISHED;
23.          Double dPi = Double.valueOf(pi);
24.          msg.obj = dPi;
25.          mainHandler.sendMessage(msg);
26.      }

27.      public CCodeTaskThread(Handler mh)
28.      {
29.          super();
30.          mainHandler = mh;
31.      }
32. }
```

This code is almost identical to the code of the `CCodeTaskThread` class. It does a little processing by calling another external C function `anotherCCodeTask` to complete computing tasks in line 20. For this, in line 7 it provides appropriate instructions for local functions and changes the value of the message type in line 6. This way, it distinguishes itself from the previous C with a message. Line 4 shows the task class, inherited from the `Thread` class.

4. Build the project in Eclipse: just a build, not a run.

5. Modify the makefile file of `mycomputetask.c`, and rebuild library files. To do so, first modify the `Android.mk` file under the `jni` directory of the project, which reads as follows:

```
1.  LOCAL_PATH      := $(call my-dir)
2.  include $(CLEAR_VARS)
3.  LOCAL_MODULE    := ndkexp_extern_lib
4.  LOCAL_SRC_FILES := mycomputetask.c
5.  LOCAL_CFLAGS    := -O0
6.  include $(BUILD_SHARED_LIBRARY)
```

Unlike the original application, in line 5 you add parameters for the command `LOCAL_CFLAGS` passed to gcc. The value `-O0` means no optimization.

6. compile the C code file into the `.so` library file in the `lib` directory of the project.

7. Save the `.so` library files in the `lib` directory of the project (in this example, the file is `libndkexp_extern_lib.so`) to some other directory, because the following operations will delete this `.so` library file.

8. Write the C implementation code for the `anotherCCodeTask` function. Copy the processing steps for the `cCodeTask` function in the previous section. Using the method in the section "NDK Examples," compile the file into the `.so` library file. The main steps are as follows:

   a. Create a C interface file. At the command line, go to the project directory, and then run the following command:

```
E:\temp\Android Dev\workspace\NdkExp> javah
-classpath "D:\Android\android-sdk\platforms\
android-15\android.jar";bin/classes com.example.
ndkexp.AnotherCCodeTaskThread
```

This command generates a `com_example_ndkexp_AnotherCCodeTaskThread.h` file. The main contents of the file are as follows:

```
     ......
23. JNIEXPORT jdouble JNICALL Java_com_example_ndkexp_
    AnotherCCodeTaskThread_anotherCCodeTask
24.   (JNIEnv *, jobject);
    ......
```

Lines 23–24 define the local function, which is `anotherCCodeTask` prototype.

   b. Based on the previously mentioned header files in the project `Jni` directory, establish corresponding C code files, in this case `anothertask.c`. The content is a modification of `mycomputetask.c`:

```
1.  #include <jni.h>
2.  jdouble Java_com_example_ndkexp_
    AnotherCCodeTaskThread_anotherCCodeTask
    (JNIEnv* env,  jobject thiz )
3.  {
      ......
17. }
```

The second line of `mycomputetask.c` is replaced by the prototype of the `anotherCCodeTask` function. This is the same function prototype copied from that in the `.h` file created in the previous step, with minor revisions. The final form is in line 2.

c. Modify the `Android.mk` file in the `jni` directory as follows:

```
1.  LOCAL_PATH      := $(call my-dir)
2.  include $(CLEAR_VARS)
3.  LOCAL_MODULE    := ndkexp_another_lib
4.  LOCAL_SRC_FILES := anothertask.c
5.  LOCAL_CFLAGS    := -O3
6.  include $(BUILD_SHARED_LIBRARY)
```

In line 4, the value is replaced with the new C code file `anothertask.c`. In line 3, the value is replaced with a new library file name consistent with the parameters of the `System.loadLibrary` function, which is in line 184 of the `MainActivity.java` file. In line 5, the value of the `LOCAL_CFLAGS` parameter for the passed `gcc` command is replaced with `-O3`, which represents the highest level of optimization.

d. Follow the method described in section 3.1 to compile the C code file into the `.so` library file under the `lib` directory of the project. The `libndkexp_extern_lib.so` documents in the `lib` directory disappear and are replaced by a newly generated `libndkexp_another_lib.so` file. So, it is very important to save the library files.

9. Put the previously saved `libndkexp_extern_lib.so` library file back into the `libs` directory. There are now two files in the directory. You can use the `dir` command to verify:

```
E:\temp\Android Dev\workspace\NdkExp>dir libs\x86
2013-02-28  00:31     5,208 libndkexp_another_lib.so
2013-02-28  00:23     5,208 libndkexp_extern_lib.so
```

10. Run the project.

Comparing Compiler Optimizations

Through this case study, you have learned the effects of compiler optimization. The task execution time was shortened from 7.321 seconds before optimization to 5.632 seconds after optimization. But you only compared the difference between the `gcc` `-O3` and `-O0` command options in the example. You can extend this configuration by modifying the `Android.mk` file content when compiling the two files `mycomputetask.c` and `anothertask.c`, and compare the difference in the optimizing effects when using different compiler command options. To modify the `Android.mk` file, you only need to modify the value of the `LOCAL_CFLAGS` item; you can select many `gcc` command options to compare. Let’s look at an example.

Example 1. Comparing Optimization Results Using SSE Instructions

Compile the Start C Task button corresponding to the `Android.mk` file of `mycomputetask.c`:

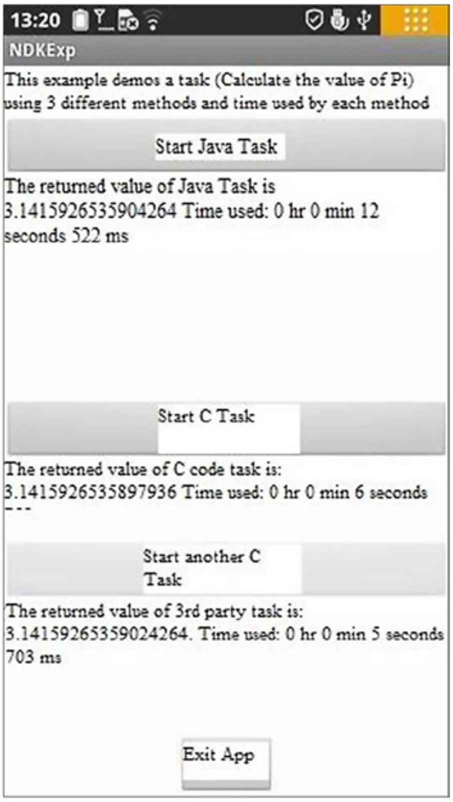
```
LOCAL_CFLAGS := -mno-sse
```

And compile the Start other C Task button corresponding to the `Android.mk` file of `anothertask.c`:

```
LOCAL_CFLAGS := -msse3
```

The former tells the compiler not to compile SSE instructions; the latter allows the compiler to program into SSE3 instructions. The reason to choose SSE3 instructions is that SSE3 is the highest level of instructions the Intel Atom processor supports.

The results of running the application are shown in Figure 12-20.



This example demos a task (Calculate the value of Pi) using 3 different methods and time used by each method

The returned value of Java Task is 3.1415926535904264 Time used: 0 hr 0 min 12 seconds 522 ms

The returned value of C code task is: 3.1415926535897936 Time used: 0 hr 0 min 6 seconds ---

The returned value of 3rd party task is: 3.14159265359024264. Time used: 0 hr 0 min 5 seconds 703 ms

Figure 12-20. *Optimization comparison of compiler SSE instructions for NdkExp*

The same task using an SSE instruction has a shorter execution time than not using an SSE instruction. The execution time is shortened from the original 6.759 seconds to 5.703 seconds.

Noted that, in this example, we finished modifying `Android.mk` and reran `ndk-build` to generate the `.so` library file. We immediately deployed and ran the `NdkExp` project but found out that we could not achieve the desired effect because only the `.so` library files are updated. The Eclipse project manager does not detect that that the project needs to rebuild. As a result, the `.apk` was not updated, and `NdkExp` on the target machine would not run updates or the original code. Considering this situation, you can use the following methods to avoid this problem:

1. Uninstall the application from the phone.
2. Delete the three documents `classes.dex`, `jarlist.cache`, and `NdkExp.apk` in the `bin` subdirectory of the host project directory.
3. Delete the project in Eclipse.
4. In Eclipse, re-import the project.
5. Re-deploy and run the projects.

Here you only compared the effect of SSE instructions. You can try other `gcc` compiler options and compare their operating results.

In addition, the previous examples are only concerned with the NDK effect, so the C functions still use single-threaded code. You can combine the NDK optimization knowledge from this chapter with the multithreading optimization from the previous chapter and change the C function to multithreading, and implement it along with the compiler optimization. Such a set of written optimization techniques in a variety of applications will allow the applications to run faster.

Summary

This chapter introduced the Android NDK for C/C++ application development, along with related optimization methods, and optimization tools. The Intel mobile hardware and software provide a basis for low-power design. The Intel Atom processor provides hardware support for low power, which is a major feature of the Android operating system.

The next chapter presents an overview of low-power design. It also discusses the Android power-control mechanisms and how to achieve the goal of low-power application design.