Persistence

CE881: Mobile and Social Application Programming

Simon Lucas & Spyros Samothrakis

Febrary 23, 2015

Theme: "Persistence and Memory"

- Johny Mnemonic (Movie - 1995)
- 320GB of storage was a big thing
- Total Recall

Main Approaches

- Saving Key-Value pairs in preferences
  - Easy but limited
- Using the File System
  - Android sits on top of a Linux file system
  - There are restrictions on where files can be opened (more of this later)
  - But once you have a FileInputStream or a FileOutputStream, it is simply standard Java
- Using an SQLite database
  - Lightweight standalone SQL database
  - Standard on Android Platform

Binary versus Character Data

- jpeg, mp3, Java serialized objects are all binary format
  - This means that each byte in the body of the file can contain any bytes
- Any one with the word Reader or Writer is limited to character data
  - Writing certain bytes will not work: they will be escaped and cause an error in the binary file format
  - Example: try writing a jpeg image using a FileWriter object;
    - It won't work!

Character Data

- Plain text files
- HTML, XML files
- But: sometimes we need to encode binary data over Character channels
- **Question:** when does this need arise?
  - Solution: use base-64
  - This encodes arbitrary byte sequences using bytes allowed character sequences
  - The cost is that it requires 1/3 more space
  - Each 3 bytes of binary require 4 bytes of base 64

Key-Value Sets

- Like Map structures in Java
- But limited in the range of values they can store
- Cannot store general Objects
- Writing:

```
SharedPreferences sharedPref =
  getActivity().getPreferences(Context.MODE_PRIVATE);
SharedPreferences.Editor editor = sharedPref.edit();
editor.putInt(getString(R.string.saved_high_score), newHighScore);
editor.commit()
```


Reading from a Key-Value Set

```
haredPreferences sharedPref =
  getActivity().getPreferences(Context.MODE_PRIVATE);
int defaultValue =
  getResources().getInteger(R.string.saved_high_score_default);
long highScore =
  sharedPref.getInt(getString(R.string.saved_high_score),
      defaultValue);
```

Note: can only save simple types and Strings

Plain text files

- HTML, XML files
- But: sometimes we need to encode binary data over Character channels
- **Question:** when does this need arise?
  - Solution: use base-64
  - This encodes arbitrary byte sequences using bytes allowed character sequences
  - The cost is that it requires 1/3 more space
  - Each 3 bytes of binary require 4 bytes of base 64

File Storage

- First we'll look at some Android specific features of file storage
- This relates to where files can be opened
- And what permissions are required
- Then we'll move on to more general points about file storage
  - In particular, storing data in files with minimal programming effort

Android File System

- http://developer.android.com/training/basics/data-storage/files.html
- Internal versus External Storage
- Internal:
  - By default readable and writable only by this App
  - Other more liberal modes have been deprecated
  - Every app can access its own internal storage
  - No need to request permission in the manifest file
  - All files deleted when an app is removed from a device

Internal Files No.1 – Direct File Access

File Creation and Appending:

```
FileOutputStream fos =
  openFileOutput("test.txt", Context.MODE_PRIVATE); // create new
FileOutputStream fos =
  openFileOutput("test.txt", Context.MODE_APPEND); // append
```

- **openFileOutput()** is a method of the Context class
- Activity is a subclass of Context
- Opening for reading:
  - **FileInputStream fis = openFileInput("test.txt");**

Internal Files No.2

- Alternatively, can make calls to get a File object and then open it for reading, writing or appending in standard Java ways:
  - File file = new File(context.getFilesDir(), filename);
- Replace the call to context.getFilesDir() with context.getCacheDir() for temporary files

External Storage

- Memory outside of an App's own area
  - May even be on an SD-card
  - Therefore an App cannot guarantee access to it
- Should handle this gracefully!
- Potentially readable/writable by the user and by other apps
- An obvious choice for sharing data

Using External Storage

- Add the permission to the manifest file:

```
<manifest ...>
  <uses-permission
  android:name=
  "android.permission.WRITE_EXTERNAL_STORAGE" />
 ... </manifest>
```

- Replace with .READ_EXTERNAL_STORAGE for read-only
- Then use file system in standard Java ways

More on External Storage

- Check availability before using:

```
/* Checks if external storage
is available for read and write */
public boolean isExternalStorageWritable() {
   String state =
      Environment.getExternalStorageState();
   if
    (Environment.MEDIA_MOUNTED.equals(state)) {
        return true;
    }
    return false;
}
```

- Similar method for Read Only test – see docs

Ad Hoc File Formats

- Data is written out in an entirely application specific way
- Conventions are adopted or invented on the fly by the programming team
  - Very flexible
  - Can choose exactly what data to write and how to format it
- Hard work:
  - May need lots of lines of code
  - And careful effort is needed to keep reader and writer in perfect harmony!
- Okay for simple cases, not for complex Apps

Object Serializers

- Unlike application specific formats, these read and write a wide variety of Object structures
  - In a domain-independent way
  - Some of them may have readers and writers in a variety of languages: hence can exchange object data between different languages
  - If they do what you want, they:
  - Are easy to use
- Involve minimal programming effort
- We'll look at three examples...

Java's Native Object Serialisation

- If a class that "implements" Serializable
  - Then Objects of that class can automatically be written to and read from Object streams
  - Very easy
  - Fast binary format, low storage space
  - Handles circular references
- But:
  - Can be hard to recover objects if the classes change
  - Restricted to Java
  - Not human readable
  - Binary format cannot directly be sent over text channels

XML Serializers e.g. WOX

- WOX = Web Objects in XML
- Java version by Lucas (2004) and extended by Jaimez: addition of base-64 for byte arrays and C# readers and writers
- Handles objects of most classes
- XML-based, so not as compact as plain text or as binary
- But given that it's XML, is efficient
- Important: handles circular references

JSON = JavaScript Object Notation

- Simple lightweight text-based standard for reading-and writing objects
- Efficient and compact
- Supported by MANY languages and platforms
- In many cases the best option except for:
- Binary formats (image, audio, video)
- Object graphs with circular references
- Infuriatingly, JSON cannot handle these
- However, might be worth trying to work around this. . .

JSON Continued

- I recommend the GSON library from Google for using JSON
- Very easy to use
- However, due to limitations of GSON format there are some cases it does not handle easily
  - E.g. When the declared type of a field is an interface type
  - (Can customise it to cope with this, but this is extra work
- (WOX handles those cases easily)

GSON Sample (part 1; from doc)

```
public class GsonTest {
    public static void main(String[] args) {

        // (Serialization)
        BagOfPrimitives obj = new BagOfPrimitives();
        Gson gson = new Gson();
        String json = gson.toJson(obj);
        // ==> json is {"value1":1,"value2":"abc"}

        // Note that you can not serialize objects with
        // circular references since that will result in infinite recursion.

        System.out.println(json);
        // (Deserialization)
        BagOfPrimitives obj2 =
                gson.fromJson(json, BagOfPrimitives.class);
    }
```


GSON Test Class: Bag of Primitives (but works for reference types also)

```
    static class BagOfPrimitives {
        private int value1 = 1;
        private String value2 = "abc";
        private transient int value3 = 3;

        public static String test = "BOO";

        BagOfPrimitives() {
            // no-args constructor
        }
    }
}
```

SQL DBs and Android

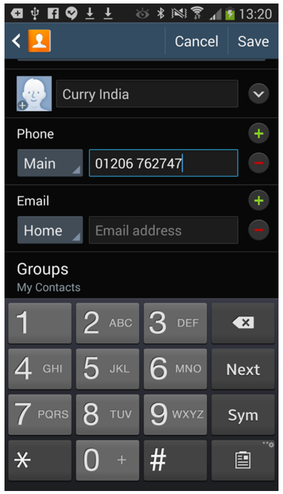
- If your app needs to store and retrieve data in a flexible way
  - Consider using a relational DB
  - Helps ensure data integrity
  - Well designed relations cannot store self-inconsistent data
- Standard SQL language
  - Very powerful for sorting and selecting the data needed
  - For simple apps using SQL is harder work than simply writing data in JSON format to file system
  - But worth the effort when appropriate

Relational Modelling

- Relation == table
- Each column specifies the column name and type
- Database Schema (loosely speaking)
- The column names and types for each table
- Each row is a single record of data with a value for each column
- Depending on settings, cell entries may be NULL
- Dilemmas sometimes arise regarding how far to normalise a table

Normalisation

- How would you model the following Contact DB?
- Each person is identified by name and primary email address
  - Each person may have a number of telephones (home, office, mobile etc.)
  - When designing an App be prepared to compromise:
  - Perfect normalisation versus realistic usage
  - Higher normal forms can sometimes be less efficient



SQLite

- Separate open-source project
  - On Android platform as standard
  - Hence default choice of relational DB for Android
  - Other choices of pure Java DB also possible
- But would add to size of App
  - Standalone DB
  - Does not run as a separate server process
  - Supports most but not all SQL statements
- Transactions

Transactions

- Help ensure that DB is always kept in a consistent state
- Each transaction maps the state of the data from one consistent state to the next
- ACID properties

Atomicity

- A transaction may involve a set or sequence of updates
- Atomicity ensures that either that ALL happen, or NONE of them happen
- Enclose sequence between begin transaction and end transaction statements
- Example: imagine the phone battery died during a transaction
- All the statements executed so far are held in temporary storage
- And only committed at the end (e.g. by moving a file pointer)

Consistency

- The database is always kept consistent
- Helped by:
  - Suitably high normal form
- Other transactional properties: Atomicity and Isolation

Isolated

- When concurrent threads are hitting the DB
- Or data is being processed in App using concurrent threads
- Must ensure that threads do not interfere
  - (see example in Threads and Surface Views lecture notes)
- Isolated / Isolation property guarantees this
- May be achieved using locking mechanisms such as Semaphores, or Java statements such as synchronized

Durable

- An obvious property!
- Once made a transaction should be saved permanently
- And not be affected by systems crashes or power loss

Package: android.database.sqlite

- Contains the SQLite database management classes that an application can use to manage its own private database
- Also has the sqlite3 database tool in the tools/ folder
- Use this tool to browse or run SQL commands on the device. Run by typing sqlite3 in a shell window.

SQLite versus JDBC

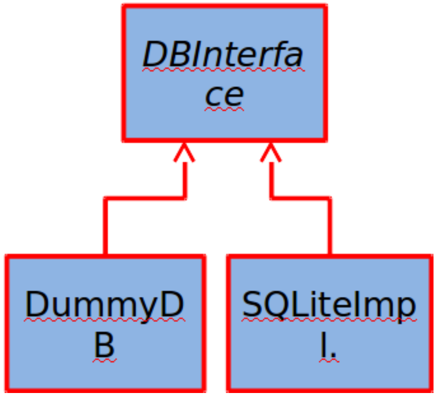
- Android has a set of non-JDBC classes to work directly with SQLite
  - However, JDBC drivers are also available for SQLite
  - See: https://github.com/SQLDroid/SQLDroid
  - http://en.wikibooks.org/wiki/Java_JDBC_using_SQLite/Introduction
- Hence another possible option would be to use a JDBC driver
- This offers better standardisation, and could be worth exploring
- For these notes we're going to stick with the Android API

Accessing DBs from Code

- A number of approaches possible
  - Can embed SQL strings in App
  - And make DB calls from wherever needed
- Or:
  - Define a special data handling class
  - All DB access is via handler
  - Main App code only sees objects, never SQL strings
- Or:
  - Can use an automated / semi-automated tool such as Spring / Hibernate
- Discussion question: which way is best?

DB Interface / Helper Approach

- Define all DB access methods in an interface
- Then provide one or more implementations of this as required e.g.:
- SQLite Implementation: the real thing
  - DummyDB: implement all the methods but don't actually save the data persistently
  - DummyDB can be very useful for testing the App



Exercise

- Write a DB interface class called ScoreDBInterface to support the storage and retrieval of all scores for a game
- Interface should allow storage of each score as it occurs
- And retrieval of high score, and list of top N scores
- Each score record consists of:
  - Time Stamp of type long
  - Player Name of type String
  - Score achieved of type int
- Write the method signatures and also any convenience classes that you need

Android Approach

- Similar to DBInterface approach
- Defines data contract class
  - This includes an inner class for each table defining its column names
  - Methods to create tables and drop them
  - Methods to execute queries
- See Android Developer example
  - http://developer.android.com/training/basics/data-storage/databases.html
  - Also CE881 Lab code, outlined below

SQLite in Android

- Construct SQL strings
- Execute SQL strings to perform actions
  - Also use specific helper methods such as query()
- These take arguments to build a SELECT clause with
- Or use rawQuery() – pass the SQL string
- Both query() and rawQuery() return a Cursor object
- This is used to iterate over the resulting table of rows

Score DB Example

- Adapted from FeedReader example:
- http://developer.android.com/training/basics/data-storage/databases.html
- ScoreDBContract
  - Class used to define table names
  - Has inner classes for each table
  - In this case, just one table called entry (for entries in the score table)
  - All columns defined in abstract class **ScoreEntry**
- ScoreHelper class
  - Manages access to the DB
  - Declares types for each table column
  - Methods for creating and dropping tables
  - May also implement **ScoreDBInterface**

Snippets from ScoreHelper

```
private static final String SQL_CREATE_ENTRIES =
        "CREATE TABLE " + TABLE_NAME + " (" +
            ScoreDBContract.ScoreEntry._ID +
            " INTEGER PRIMARY KEY," +
            ScoreDBContract.ScoreEntry.COLUMN_NAME_ENTRY_ID +
            TEXT_TYPE + COMMA_SEP +
            ScoreDBContract.ScoreEntry.COLUMN_NAME_PERSON +
            TEXT_TYPE + COMMA_SEP +
            ScoreDBContract.ScoreEntry.COLUMN_NAME_SCORE +
            "INTEGER" + " ) ";

    private static final String SQL_DELETE_ENTRIES =
            "DROP TABLE IF EXISTS " + TABLE_NAME;

   public void onCreate(SQLiteDatabase db) {
        db.execSQL(SQL_CREATE_ENTRIES);
    }
```


Adding an Entry...

```
SQLiteDatabase db =
    scoreHelper.getWritableDatabase();
scoreHelper.addEntry(db, "Simon", "" +
             10 * (1 + random.nextInt(100)));
Log.i(TAG, "Populated Table");
db.close();
```


addEntry Method

```
public void addEntry(SQLiteDatabase db, String person, String score) {
    // Create a new map of values, where column names are the keys
    ContentValues values = new ContentValues();
    values.put(ScoreDBContract.ScoreEntry.COLUMN_NAME_ENTRY_ID, id++);
    values.put(ScoreDBContract.ScoreEntry.COLUMN_NAME_PERSON, person);
    values.put(ScoreDBContract.ScoreEntry.COLUMN_NAME_SCORE, score);


    // Insert the new row, returning the primary key value of the new row
    long newRowId;
    newRowId = db.insert(
            ScoreDBContract.ScoreEntry.TABLE_NAME,
            ScoreDBContract.ScoreEntry.COLUMN_NAME_NULLABLE,
            values);
    Log.i(SQLiteActivity.TAG, "Inserted row: " + newRowId);
}
```

Using a Cursor with a Query Selecting all scores

```
Cursor cursor = db.rawQuery("Select * from " +
        ScoreDBContract.ScoreEntry.TABLE_NAME,
        new String[]{});
cursor.moveToFirst();
// need to find index of each column before retrieving it
int scoreIndex =
    cursor.getColumnIndex(ScoreDBContract.ScoreEntry.COLUMN_NAME_SCORE);
while (!cursor.isAfterLast()) {
    int score = cursor.getInt(scoreIndex);
    boolean flag = cursor.moveToNext();
    Log.i(TAG, flag + " : " + score);
}
```


More details. . .

- See SQLite lab exercise
  - Including .zip with all the details
  - The example opens and closes a DB Connection each time it is needed
  - This is perhaps not the most efficient way
  - But it saves thinking through lifecycle methods
- More efficient way:
  - open connection when activity is created
  - Close connection when activity is destroyed

Summary (1)

- Data serialization is an important topic
- These notes discussed storage and retrieval on file systems
- But much of this same applies for sending over a network
- Choose carefully: when given a free choice JSON is a good default

Summary (2)

- Android ships with SQLite database
- Natural choice for storing data that must be flexibly queried
- And have guaranteed integrity
- However, API is rather low level
- Best approach is to embed all DB access code in a separate helper class (or classes)
- My favourite: all access goes through a DB interface class
- Can then test rest of app using a dummy implementation
- Work through (next week's) lab exercise