ALMA MATER STUDIORUM - UNIVERSITY OF BOLOGNA

# Android Sensors Support

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# Contents

**Abstract**

Most Android-powered device have several built-in sensors that measure motion, orientation and other various enviromental condition, provide raw data with high precision and accuracy, and are useful to monitor three-dimensional device movement and positioning or monitor changes in the ambiental environment near a device.

Android platform supports three category of sensors:

**Motion sensors**: measure acceleration and rotational forces along three axis. This category includes *accelerometer*, g*ravity sensor*, *gyroscope* and *rotational vector sensor*.

**Enviromental sensors**: sensors included in this category (*barometer*, *photometer* and *thermometer*) measure various enviromental parameters such as temperature, pressure, illumination, humidity.

P**osition sensor**s: measure physical position of a device using *orientation sensor* and *magnetometer*.

The access to a sensor and the raw sensor data acquisition are simplified by using Android Sensor Framework that provides several classes and interfaces that helps developer to perform a large number of sensor-related task.

The first part of this paper is based on the Adroid Developers sensors documentation[1]: introduces the Android sensor framework and explains how to use sensors.

In the second part is introduced a new layer between Android Sensor Framework and the final application, developed as project activity related to the Engineering of Software System course. This layer simplifies the sensor usage and allow a developer to ask to the sensor his data value (Android Sensor Framework only notify a change, but developers cannot request information to the sensor without save the last update in a variable).

All source code are available at https://github.com/CarloAntenucci/AndroidSensorSupport.git

# 1. Android Sensor Framework

## 1.1. Introduction to sensors

The Android Sensor Framework lets access to access many type of sensors, some of these are hardware-based (real sensors) and some are are software-based (virtual sensors).

Hardware-based sensors are built into the device and they derive data by directly measuring specific environmental properties, while software-based sensors are not physical devices despite they mimic an hardware-based sensor. This second group derive their data from one ore more of the hardware-based sensors.

Table 1: Sensor types supported by the Android platform

| Sensor | Type | Description | Sensor fusion |
|---|---|---|---|
| `TYPE_ACCELEROMETER` | Hardware | Measures the acceleration force in $m/s^2$ that is applied to a device on all three physical axes (x, y, and z), including the force of gravity. | |
| `TYPE_GRAVITY` | Software or Hardware | Measures the force of gravity in $m/s^2$ that is applied to a device on all three physical axes (x, y, and z). | If it is software uses Accelerometer to derive data |
| `TYPE_GYROSCOPE` | Hardware | Measures a device's rate of rotation in $rad/s$ that is applied to a device on all three physical axes (x, y, and z). | |
| `TYPE_LINEAR_ACCELERATION` | Software | Measures the acceleration force in $m/s^2$ that is applied to a device on all three physical axes (x, y, and z), excluding the force of gravity. | — Acceleromter<br>— Gravity sensor |
| `TYPE_ORIENTATION` | Software | Measures degrees of rotation that a device makes around all three physical axes (x, y, z). As of API level 3 you can obtain the inclination matrix and rotation matrix for a device by using the gravity sensor and the geomagnetic field sensor in conjunction with the getRotationMatrix() method. | — Accelerometer<br>— Geomagnetic field |
| `TYPE_ROTATION_VECTOR` | Software or Hardware | Measures the orientation of a device by providing the three elements of the device's rotation vector. | If it is software uses Gyroscope to derive data |
| `TYPE_AMBIENT_TEMPERATURE` | Hardware | Measures the ambient room temperature in degrees Celsius (°C). | |
| `TYPE_LIGHT` | Hardware | Measures the ambient illumination in lx. | |
| `TYPE_PRESSURE` | Hardware | Measures the ambient air pressure in $hPa$ or $mbar$. | |
| `TYPE_RELATIVE_HUMIDITY` | Hardware | Measures the ambient humidity in percent (%). | |
| `TYPE_TEMPERATURE` | Hardware | Measures the temperature of the device in degree Celsius (°C). | |
| `TYPE_MAGNETIC_FIELD` | Hardware | Measures the ambient geomagnetic field for all three physical axes (x, y, z) in $\mu T$. | |
| `TYPE_PROXIMITY` | Hardware | Measures the proximity of an object in cm relative to the view screen of a device. | |

## 1.2. Android sensor framework

Android sensor framework is part of the `android.hardware` package. This subsystem includes the interface, named sensor Hardware Abstraction Layer (sensor HAL), between the hardware driver and the other framework classes and interfaces which allows developers to

— Indentify sensors and sensor capabilities
useful for application with features that needs a specific sensor type or capabilities (identify all sensors that are present on a device and disable features that rely on sensors not present)

— Monitor sensor events
raw sensors data acquisition. Every time a sensor detects a change (normally every x nanoseconds, with x defined by one of `SENSOR_DELAY_*` value) in the parameter that is measuring, notify this change using a sensor event that provides four different informations:
  — Name of the sensor that triggered the event
  — Timestamp of the event in nanoseconds[1]
  — Accuracy of the event
  — Raw data that triggered the event

This tasks can be performed using the sensor-related APIs introduced by classes and interfaces included in Android sensor framework:

`SensorManager` This class creates an instance of the sensor service and provides methods to access and listens sensors, register and un register sensor listeners, acquire device orientation informations and also defines several sensors constants useful to report sensor accuracy, set data acquisition rates, and calibrate sensors.

`Sensor` This class is useful to create an instance of a specific sensor and provides various methods that determine sensor's capabilities.

`SensorEvent` Android uses this class to create a sensor event object which provides sensor event's informations such as raw sensor data, sensor type that generated the event, event accuracy and time stamp.

`SensorEventListener` This interface is useful to create two callback methods that receive notification (a sensor event) when sensor values or sensor accuracy change.

## 1.3. Sensor availability

Sensors availability is different within devices and is different too among Android versions because the Android sensors have been introduced in different platmorm releases.

Many sensors have been introduced by Android 1.5 Cupcake (API Level 3), but some were not implemented and not available until Android 2.3 Gingerbread (API Level 9) that introduces too new sensors. Other sensors were introduced by Android 4.0 Ice Cream Sandwich (API Level 14) that also deprecates two sensors, replaced by newer and better sensors.

The following table summarize the availability of each sensor in each Android release.

[1] An Android Project Member says: "[...]The timestamps are not defined as being the Unix time; they're just "a time" that's only valid for a given sensor. [...]"[2]

Table 2: Sensor types supported by the Android platform

| **Sensor** | **Android 4 Ice Cream Sandwich** (API Level 14) | **Android 2.3 Gingerbread** (API Level 9) | **Android 2.2 Froyo** (API Level 8) | **Android 1.5 Cupcake** (API Level 3) |
|---|---|---|---|---|
| `TYPE_ACCELEROMETER` | YES | YES | YES | YES |
| `TYPE_GRAVITY` | YES | YES | n/a | n/a |
| `TYPE_GYROSCOPE` | YES | YES | n/a[a] | n/a[a] |
| `TYPE_LINEAR_ACCELERATION` | YES | YES | n/a | n/a |
| `TYPE_ORIENTATION` | YES[b] | YES[b] | YES[b] | YES |
| `TYPE_ROTATION_VECTOR` | YES | YES | n/a | n/a |
| `TYPE_AMBIENT_TEMPERATURE` | YES | n/a | n/a | n/a |
| `TYPE_LIGHT` | YES | YES | YES | YES |
| `TYPE_PRESSURE` | YES | YES | n/a[a] | n/a[a] |
| `TYPE_RELATIVE_HUMIDITY` | YES | n/a | n/a | n/a |
| `TYPE_TEMPERATURE` | YES[b] | YES | YES | YES |
| `TYPE_MAGNETIC_FIELD` | YES | YES | YES | YES |
| `TYPE_PROXIMITY` | YES | YES | YES | YES |

[a] Added in Android 1.5 (API Level 3), but not available untin Android 2.3 (API Level 9).
[b] Sensor available but deprecated

### 1.4. Sensor coordinate system

Generally the sensor framework uses a standard 3-axis coordinate system to express data values.

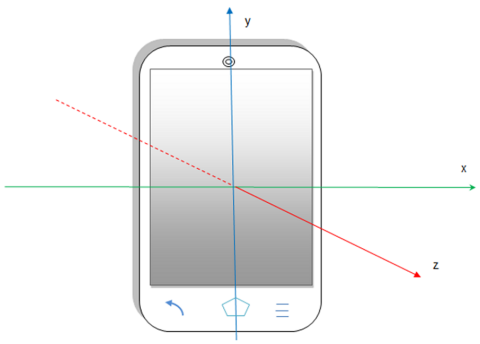
X, Y and Z values are represented respectively by `values[0]`, `values[1]` and `values[2]` of `SensorEvent` object. Some sensors, such as proximity sensor, light sensor, pressure sensor and temperature sensor, provides single values represented by the only `values[0]`.

For `TYPE_ACCELEROMETER`, `TYPE_GRAVITY`, `TYPE_GYROSCOPE`, `TYPE_LINEAR_ACCELERATION` and `TYPE_MAGNETIC_FIELD` the sensors the coordinate system is defined relatively to the device's screen when the device in held in its default orientation (portrait for smartphones, landscape for many tablet). When the device is in its default orientation the X axis is horizontal and points to the right, the Y axis is vertical and points up and the Z axis points toward the outside of the screen face.

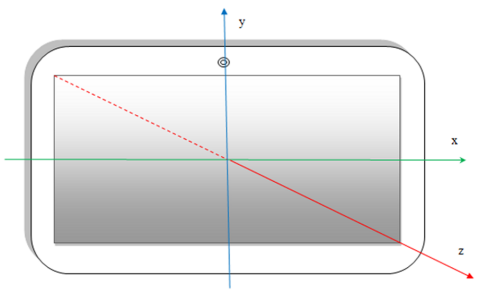
The most important thing to understand is that the axes are not swapped when the device screen orientation changes.

Figure 1.1: Sensor coordinate system[?]

(a) Sensor coordinate system for smartphone




(b) Sensor coordinate system for tablet




### 1.5. Identifying sensors and sensor capabilities

The Android sensor framework provides several methods that make it easy determine at runtime which sensors are on a device and the capabilities of each sensor, such as maximum range, resolution, power requirements, minimum delay and vendor.

First of all, to identify the sensors on a device, is necessary to obtain a reference to the sensor service by creating an instance of the `SensorManager` class by calling the `getSystemService()` method using the `SENSOR_SERVICE` as parameter:

```
private SensorManager mSensorManager;
mSensorManager = (SensorManager) getSystemService(Context.SENSOR_SERVICE);
```

Now, calling the `getSensorList()` method and using `TYPE_ALL` constant as parameter, `SensorManager` returns the list of every sensor on the device:

```
List<Sensor> deviceSensors = mSensorManager.getSensorList(Sensor.TYPE_ALL);
```

Using, instead of `TYPE_ALL` constant, another constant provided by `Sensor` class such as `TYPE_GYROSCOPE`, `TYPE_LINEAR_ACCELERATION`, `TYPE_GRAVITY` etc. `SensorManager` class returns a lists all sensors of the given type.

Is also possible determine if a specific type of sensor exists on a device by using the `getDefaultSensor()` method with the sensor type constant as parameter. If a device has more then one sensor for the given type, one of its must be designed as the default sensor and if the default sensor does not exist, the method returns null (which means that the device does not have thay type of sensor). The following code checks if there is an accelerometer on the device:

```
private SensorManager mSensorManager;
...
mSensorManager = (SensorManager) getSystemService(Context.SENSOR_SERVICE);
if ( mSensorManager.getDefaultSensor(Sensor.TYPE_ACCELEROMETER) != null ) {
    // Success! There's an accelerometer.
}
else{
    // Failure! No accelerometer.
}
```

In addition to listing the sensors on a device, in possible, using public methods of Sensor class, determine capabilities and attributes of each sensor. This is useful if an application can have different behavior depending on sensors, or sensor capabilities, available on a device. With this methods is possible to obtain sensor's resolution and maximum range of measurement (using `getResolution()` and `getMaximumRange()`) or sensor's power requirement with `getPower()` method; other two methods particularly useful to optimize an application for different manufacturers' sensors or different sensors' version are `getVendor()` -for the manufacturer- and `getVersion()` -to obtain sensor's version-.

The following sample code shows how to use `getVendor()` and `getVersion()` methods to optimize an application using gravity sensor if its vendor is *Google Inc.* and its version is *3*, if that particular sensor is not present on device the application try to use the accelerometer:

Another useful methods is the `getMinDelay()` which returns the minimum time interval (in microseconds) between two data sensed by a sensor. Any sensor that returns a *non-zero* value is a streaming sensor -this type of sensors sense data at regular intervals and were introduced by Android 2.3 Gingerbread (API Level 9)- while if a sensor returns zero, it means that the sensor is not streaming sensor, and it reports data only when there is a chenge in the paremeter it is sensing. This method is useful because using it in possible to determine the maximum rate at which a sensor can acquire data.

**Sensors identification code**[2] The following code realize an Android application that lists all sensors in a device and its own properties. Some methods were not introduced until API Level 9, so it works on Android 2.3 (Gingerbread) or latest.

The layout file (`res/layout/activity_about_sensors.xml`) defines the Android widgets used, their ID and their properties (position, dimensions, alignment, etc.). In this application is needed a `Spinner` to select which is the sensor to be inspected and a `TableLayout` that contains a row for each property and every row contains two `TextView` (a label and a value field).

*activity_about_sensors.xml*

```
<?xml version="1.0" encoding="utf-8"?>
<RelativeLayout xmlns:android="http://schemas.android.com/apk/res/android"
    android:layout_width="match_parent"
    android:layout_height="match_parent" >
    <Spinner
        android:id="@+id/spinner_sensors"
        android:layout_width="wrap_content"
        android:layout_height="wrap_content"
        android:layout_alignParentLeft="true"
        android:layout_alignParentTop="true" />
    <TableLayout
        android:layout_width="wrap_content"
        android:layout_height="wrap_content"
        android:layout_alignParentLeft="true"
        android:layout_alignParentRight="true"
        android:layout_below="@+id/spinner_sensors" >
        <TableRow
            android:id="@+id/tableRowVersion"
            android:layout_width="wrap_content"
            android:layout_height="wrap_content" >
            <TextView
               android:id="@+id/labelVersion"
                android:layout_width="wrap_content"
                android:layout_height="wrap_content"
                android:text="Version:␣"
                android:textAppearance="?android:attr/textAppearanceMedium" />
            <TextView
                android:id="@+id/valueVersion"
                android:layout_width="wrap_content"
                android:layout_height="wrap_content"
                android:text=""
                android:textAppearance="?android:attr/textAppearanceMedium" />
        </TableRow>
        <TableRow
            android:id="@+id/tableRowVendor"
            android:layout_width="wrap_content"
            android:layout_height="wrap_content" >
            <TextView
                android:id="@+id/labelVendor"
                android:layout_width="wrap_content"
                android:layout_height="wrap_content"
                android:text="Vendor:␣"
                android:textAppearance="?android:attr/textAppearanceMedium" />
            <TextView
                android:id="@+id/valueVendor"
                android:layout_width="wrap_content"
                android:layout_height="wrap_content"
                android:text=""
                android:textAppearance="?android:attr/textAppearanceMedium" />
        </TableRow>
```

[2] This app is available on github in AboutSensors project

```
        <TableRow
            android:id="@+id/tableRowPower"
            android:layout_width="wrap_content"
            android:layout_height="wrap_content" >
            <TextView
                android:id="@+id/labelPower"
                android:layout_width="wrap_content"
                android:layout_height="wrap_content"
                android:text="Power:␣"
                android:textAppearance="?android:attr/textAppearanceMedium" />
            <TextView
                android:id="@+id/valuePower"
                android:layout_width="wrap_content"
                android:layout_height="wrap_content"
                android:text=""
                android:textAppearance="?android:attr/textAppearanceMedium" />
        </TableRow>
        <TableRow
            android:id="@+id/tableRowMaxRange"
            android:layout_width="wrap_content"
            android:layout_height="wrap_content" >
            <TextView
                android:id="@+id/labelMaxRange"
                android:layout_width="wrap_content"
                android:layout_height="wrap_content"
                android:text="Maximum␣Range:␣"
                android:textAppearance="?android:attr/textAppearanceMedium" />
            <TextView
                android:id="@+id/valueMaxRange"
                android:layout_width="wrap_content"
                android:layout_height="wrap_content"
                android:text=""
                android:textAppearance="?android:attr/textAppearanceMedium" />
        </TableRow>
        <TableRow
            android:id="@+id/tableRowResolution"
            android:layout_width="wrap_content"
            android:layout_height="wrap_content" >
            <TextView
                android:id="@+id/labelResolution"
                android:layout_width="wrap_content"
                android:layout_height="wrap_content"
                android:text="Resolution:␣"
                android:textAppearance="?android:attr/textAppearanceMedium" />
            <TextView
                android:id="@+id/valueResolution"
                android:layout_width="wrap_content"
                android:layout_height="wrap_content"
                android:text=""
                android:textAppearance="?android:attr/textAppearanceMedium" />
        </TableRow>
        <TableRow
            android:id="@+id/tableRowMinDelay"
            android:layout_width="wrap_content"
            android:layout_height="wrap_content" >
            <TextView
                android:id="@+id/labelMinDelay"
                android:layout_width="wrap_content"
                android:layout_height="wrap_content"
                android:text="Minimum␣Delay:␣"
                android:textAppearance="?android:attr/textAppearanceMedium" />
            <TextView
                android:id="@+id/valueMinDelay"
                android:layout_width="wrap_content"
                android:layout_height="wrap_content"
                android:text=""
                android:textAppearance="?android:attr/textAppearanceMedium" />
        </TableRow>
    </TableLayout>
</RelativeLayout>
```

The activity code is really simple: when Android system creates the activity (`onCreate()` method), the first thing to do is the initialization of resources. The `initializeResources()` method assigns to each field its resource referenced in layout file, creates the `Spinner`'s `ArrayAdapter` with sensors' names and call the `addSpinnerListener()` method that assigns to the `Spinner` a new `onItemSelectedListener` that changes the shown values with the sensor selected values.

*AboutSensors.java*

```
package it.unibo.android.aboutSensors;

import java.util.ArrayList;
import java.util.List;

import android.app.Activity;
import android.hardware.Sensor;
import android.hardware.SensorManager;
import android.os.Bundle;
import android.view.View;
import android.widget.AdapterView;
import android.widget.AdapterView.OnItemSelectedListener;
import android.widget.ArrayAdapter;
import android.widget.Spinner;
import android.widget.TextView;

public class AboutSensors extends Activity {

    //fields definition
    private Spinner spinnerList;
    private SensorManager manager;
    private List<Sensor> sensors;
    private Sensor sensorSelected;
    private ArrayAdapter<String> adapter;
    private TextView textVersion;
    private TextView textVendor;
    private TextView textPower;
    private TextView textMaxRange;
    private TextView textResolution;
    private TextView textMinDelay;

    @Override
    protected void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        //set the default layout
        setContentView(R.layout.activity_about_sensors);
        //initialize the resources
        initializeResources();
    }

    private void initializeResources() {
        //obtain the SensorManager instance and get the sensors list
        manager = (SensorManager) getSystemService(SENSOR_SERVICE);
        sensors = manager.getSensorList(Sensor.TYPE_ALL);
        //get the TextView where put the sensor information
        textVersion = (TextView)findViewById(R.id.valueVersion);
        textVendor = (TextView)findViewById(R.id.valueVendor);
        textPower = (TextView)findViewById(R.id.valuePower);
        textMaxRange = (TextView)findViewById(R.id.valueMaxRange);
        textResolution = (TextView)findViewById(R.id.valueResolution);
        textMinDelay = (TextView)findViewById(R.id.valueMinDelay);
        //get the spinner
        spinnerList = (Spinner)findViewById(R.id.spinner_sensors);
        //set up the spinner adapter with sensors names
        adapter = new ArrayAdapter<String>(this, android.R.layout.simple_spinner_item,
                                           getSensorsNames());
        adapter.setDropDownViewResource(android.R.layout.simple_dropdown_item_1line);
        spinnerList.setAdapter(adapter);
        //add the spinner listener
        addSpinnerListener();
    }
```

```
    private void addSpinnerListener() {
        spinnerList.setOnItemSelectedListener(new OnItemSelectedListener(){

            @Override
                public void onItemSelected(AdapterView<?> parent, View view,
                                           int position, long id) {
                    //when an item is selected update the text view
                    //with the selected sensor's informations
                    Sensor s = sensors.get(position);
                    if(s != sensorSelected){
                        System.out.println(s.toString());
                        textVersion.setText(""+s.getVersion());
                        textVendor.setText(""+s.getVendor());
                        textPower.setText(s.getPower()+" mA");
                        textMaxRange.setText(""+s.getMaximumRange());
                        textResolution.setText(""+s.getResolution());
                        textMinDelay.setText(s.getMinDelay()/1000+" ms");
                        sensorSelected = s;
                    }
                }

                @Override
                public void onNothingSelected(AdapterView<?> parent) {
                    textVersion.setText("");
                    textVendor.setText("");
                }
            });
    }

    private List<String> getSensorsNames() {
        //returns the list that contains the names of all available sensors
        List<String> sensorNames = new ArrayList<String>();
        for (Sensor s: sensors)
            sensorNames.add(s.getName());
        return sensorNames;
    }
}
```

## 1.6. Monitoring sensor events

SensorEventListener interface introduces two callback methods which must be implemented to monitor raw sensor data. This methods are `onAccuracyChanged()` and `onSensorChanged()`.

This two methods are invoked by Android system, the first whenever the sensor's accuracy changes (this method provides the reference to the `Sensor` object that changed and its new accuracy, whose state is represented by one of four constants defined in `SensorManager` class:

— `SENSOR_STATUS_ACCURACY_LOW`
— `SENSOR_STATUS_ACCURACY_MEDIUM`
— `SENSOR_STATUS_ACCURACY_HIGH`
— `SENSOR_STATUS_ACCURACY_UNRELIABLE`

The `onSensorChanged()` method, insted, is invoked by system when a sensor reports a new value. This method provides a new `SensorEvent` object that contains informations about the new sensor data (the new data recorded by the sensor, its accuracy, the sensor which generates the new data and the relative timestamp).

**Sensor events code**[3] The following code is based on AboutSensors project. In this application is shown, with the previous informations, the raw sensor data, received by the selected sensor.

In layout file (`res/layout/activity_about_sensor_events.xml`) above the sensor informations table is defined a new table that contains 3 rows with 3 labels and 3 `TextView`, one for each axes value (X, Y and Z). The following code shown only the difference between the previous and the new layout.

This part of code begins after the `</TableLayout>` tag.

[3] This app is available on github in the project AboutSensorEvents

*activity_about_sensor_events.xml*

```
    <TextView
        android:id="@+id/LabelSensorData"
        android:layout_width="wrap_content"
        android:layout_height="wrap_content"
        android:layout_alignParentLeft="false"
        android:layout_alignParentRight="false"
        android:layout_below="@+id/tableLayout1"
        android:layout_centerHorizontal="true"
        android:text="Sensor␣Data:"
        android:textAppearance="?android:attr/textAppearanceLarge" />
    <TableLayout
        android:id="@+id/SensorData"
        android:layout_width="wrap_content"
        android:layout_height="wrap_content"
        android:layout_alignParentLeft="true"
        android:layout_alignParentRight="true"
        android:layout_below="@+id/LabelSensorData" >
        <TableRow
            android:id="@+id/SensorDataX"
            android:layout_width="wrap_content"
            android:layout_height="wrap_content" >
            <TextView
                android:id="@+id/LabelDataX"
                android:layout_width="wrap_content"
                android:layout_height="wrap_content"
                android:text="SensorDataX:␣"
                android:textAppearance="?android:attr/textAppearanceMedium" />
            <TextView
                android:id="@+id/ValueDataX"
                android:layout_width="wrap_content"
                android:layout_height="wrap_content"
                android:textAppearance="?android:attr/textAppearanceMedium" />
        </TableRow>
        <TableRow
            android:id="@+id/SensorDataY"
            android:layout_width="wrap_content"
            android:layout_height="wrap_content" >
            <TextView
                android:id="@+id/LabelDataY"
                android:layout_width="wrap_content"
                android:layout_height="wrap_content"
                android:text="SensorDataY:␣"
                android:textAppearance="?android:attr/textAppearanceMedium" />
            <TextView
                android:id="@+id/ValueDataY"
                android:layout_width="wrap_content"
                android:layout_height="wrap_content"
                android:textAppearance="?android:attr/textAppearanceMedium" />
        </TableRow>
        <TableRow
            android:id="@+id/SensorDataZ"
            android:layout_width="wrap_content"
            android:layout_height="wrap_content" >
            <TextView
                android:id="@+id/LabelDataZ"
                android:layout_width="wrap_content"
                android:layout_height="wrap_content"
                android:text="SensorDataZ:␣"
                android:textAppearance="?android:attr/textAppearanceMedium" />
            <TextView
                android:id="@+id/ValueDataZ"
                android:layout_width="wrap_content"
                android:layout_height="wrap_content"
                android:textAppearance="?android:attr/textAppearanceMedium" />
        </TableRow>
    </TableLayout>
</RelativeLayout>
```

The activity, like the `AboutSensor` application, changes sensors information when a new sensor is selected from `Spinner` and shows, in addition to sensor informations, the sensor row data updated by the sensor event listener, in fact, the `SpinnerListener`, by `onItemSelected` method, changes the `SensorEventsListener` calling the `updateSensorListener` method, which removes old listener from previous selected sensor and attaches to the new selected sensor a new listener. This method is called too when the application is resumed (`onResume()` method), and, when the application is paused (`onPause()` method) the sensor listener is detached from sensor.

The `SensorEventsListener` class extends `SensorEventListener` interface the defines

— `onSensorChanged` method that updates the sensor data's text views

— `onAccuracyChanged` that, in this case, does nothing

*AboutSensorEvents.java*

```
package it.unibo.android.aboutSensorEvents;

import java.util.ArrayList;
import java.util.List;

import android.app.Activity;
import android.hardware.Sensor;
import android.hardware.SensorEvent;
import android.hardware.SensorEventListener;
import android.hardware.SensorManager;
import android.os.Bundle;
import android.view.View;
import android.widget.AdapterView;
import android.widget.AdapterView.OnItemSelectedListener;
import android.widget.ArrayAdapter;
import android.widget.Spinner;
import android.widget.TextView;

public class AboutSensorEvents extends Activity {
    //fields definition
    private Spinner spinnerList;
    private SensorManager manager;
    private List<Sensor> sensors;
    private Sensor sensorSelected;
    private ArrayAdapter<String> adapter;
    private TextView textVersion;
    private TextView textVendor;
    private TextView textPower;
    private TextView textMaxRange;
    private TextView textResolution;
    private TextView textMinDelay;
    private SensorEventListener listener;
    private TextView textX;
    private TextView textY;
    private TextView textZ;

    @Override
    protected void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        //set the default layout
        setContentView(R.layout.activity_about_sensor_events);
        //initialize the resources
        initializeResources();
    }

    @Override
    protected void onResume() {
        super.onResume();
        manager.registerListener(listener, sensorSelected, SensorManager.SENSOR_DELAY_NORMAL);
    }

    @Override
    protected void onPause() {
        super.onPause();
        manager.unregisterListener(listener, sensorSelected);
    }
```

```
private void initializeResources() {
    //obtain the SensorManager instance and get the sensors list
    manager = (SensorManager) getSystemService(SENSOR_SERVICE);
    sensors = manager.getSensorList(Sensor.TYPE_ALL);
    //get the TextView where put the sensor information
    textVersion = (TextView)findViewById(R.id.valueVersion);
    textVendor = (TextView)findViewById(R.id.valueVendor);
    textPower = (TextView)findViewById(R.id.valuePower);
    textMaxRange = (TextView)findViewById(R.id.valueMaxRange);
    textResolution = (TextView)findViewById(R.id.valueResolution);
    textMinDelay = (TextView)findViewById(R.id.valueMinDelay);
    //get the TextView where put sensor raw data received
    textX = (TextView)findViewById(R.id.ValueDataX);
    textY = (TextView)findViewById(R.id.ValueDataY);
    textZ = (TextView)findViewById(R.id.ValueDataZ);
    //get the spinner
    spinnerList = (Spinner)findViewById(R.id.spinner_sensors);
    //set up the spinner adapter with sensors names
    adapter = new ArrayAdapter<String>(this, android.R.layout.simple_spinner_item,
                                       getSensorsNames());
    adapter.setDropDownViewResource(android.R.layout.simple_dropdown_item_1line);
    spinnerList.setAdapter(adapter);
    //add the spinner listener
    addSpinnerListener();
}

private void updateSensorListener() {
    //if exist a defined listener remove it from sensor
    if(listener!=null)
        manager.unregisterListener(listener, sensorSelected);
    //register new listener
    listener = new SensorEventsListener();
    manager.registerListener(listener,
                             sensors.get(spinnerList.getSelectedItemPosition()),
                             SensorManager.SENSOR_DELAY_NORMAL);
}

private void addSpinnerListener() {
    spinnerList.setOnItemSelectedListener(new OnItemSelectedListener(){

    @Override
        public void onItemSelected(AdapterView<?> parent, View view,
                                   int position, long id) {
            //when an item is selected update the text view
            //with the selected sensor's informations
            Sensor s = sensors.get(position);
            if(s != sensorSelected){
                System.out.println(s.toString());
                textVersion.setText(""+s.getVersion());
                textVendor.setText(""+s.getVendor());
                textPower.setText(s.getPower()+" mA");
                textMaxRange.setText(""+s.getMaximumRange());
                textResolution.setText(""+s.getResolution());
                textMinDelay.setText(s.getMinDelay()/1000+" ms");
                updateSensorListener();
                sensorSelected = s;
            }
        }

        @Override
        public void onNothingSelected(AdapterView<?> parent) {
            textVersion.setText("");
            textVendor.setText("");
        }
    });
}
```

```
    private List<String> getSensorsNames() {
        //returns the list that contains the names of all available sensors
        List<String> sensorNames = new ArrayList<String>();
        for (Sensor s: sensors)
            sensorNames.add(s.getName());
        return sensorNames;
    }

    private class SensorEventsListener implements SensorEventListener {

        @Override
        public void onSensorChanged(SensorEvent event) {
            //show values
            textX.setText(""+event.values[0]);
            textY.setText(""+event.values[1]);
            textZ.setText(""+event.values[2]);
        }

        @Override
        public void onAccuracyChanged(Sensor sensor, int accuracy) {
            //do something when accuracy changes
        }
    }
}
```

## 1.7. Best practices for accessing and using sensors

In this section are discussed the guidelines to design an optimized sensor implementation.

These guidelines are recommended best practices for anyone who is using the sensor framework to access sensors and acquire sensor data.

### Verify sensors' availability

Android platform does not require to the manufacturer that a device includes particular sensors, then, before using a specific sensor it is necessary to check if this sensor exists.

Assume the existence of a sensor simply because is frequently used is a bad practice.

### Unregister sensor listeners

If a sensor listener is registered and its activity is paused, the sensor will continue to acquire data and use battery resources unless the listener is unregisterd. The bettter way to optimize resources usage is to unregister the listener each time the application is paused, or the sensor is no longer needed, and then register it again when the app is resumed. This is possible using two methods provided by the `Activity` class:
`onPause()` called when the application is going down (or lost the screen)
`onResume()` invoked when the application comes back to the screen
The following code is an example that show how to use this two methods in an `Activity` that implements `SensorEventListener` interface:

```
  private SensorManager mSensorManager;
  private Sensor mSensor
    ...

  @Override protected void onPause() {
    super.onPause();
    mSensorManager.unregisterListener(this, mSensor);
  }

  @Override protected void onResume() {
    super.onResume();
    mSensorManager.registerListener(this, mSensor, SensorManager.SENSOR_DELAY_NORMAL);
  }
```

### Don't test your code on the emulator

The Android emulator cannot emulate sensors, thus, currently, is not possible to test the sensor code on Android Virtual Devices. The best way to run a test on sensor code is by using a physical device. There are, however, sensor simulators that can be used to simulate sensor output.

### Don't block the `onSensorChanged()` method

Android system may call the `onSensorChanged(SensorEvent)` method quite often because sensor data can changes at high rate, hence is recommended, as the best practice, do as little is possible into `onSensorChanged(SensorEvent)` so as not to block his execution.

If an application requires any data filtering or reduction of sensor data, it would be better perform that work outside of the `onSensorChanged(SensorEvent)` method.

*Remark.* If the `onSensorChange(SensorEvent)` contains a loop the application is stopped by the system.

### Avoid using deprecated methods or sensor types

Several methods and constants, such as `TYPE_ORIENTATION` or `TYPE_TEMPERATURE`, have been deprecated, the first has been replaced by `getOrientation()` method and the second, in devices that are running Android 4 Ice Cream Sandwich, by `TYPE_AMBIENT_TEMPERATURE` constant.

### Choose sensor delay carefully

The `registerListener()` method requires, in addiction to the listener and the sensor, the minimum delay between two notifications. The choise of the delivery rate must be suitable for the application or use-case: sensors can provide data at very high rates and allowing the system to send extra data which is not needed wastes system resources and uses battery power. Like the accuracy, Android provides, in `SensorManager` class, four differents constants that defines four different delivery rate:

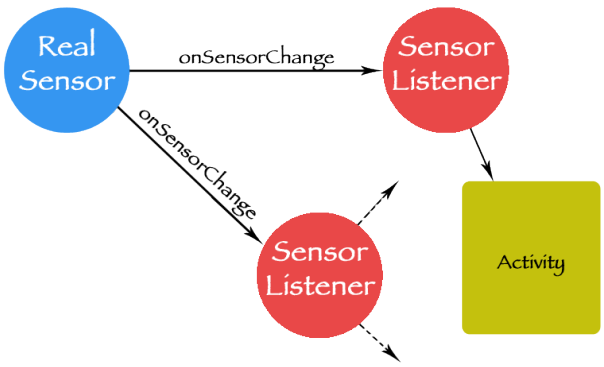
`SENSOR_DELAY_NORMAL` delivery rate of 200000µs
`SENSOR_DELAY_UI` delivery rate of 60000µs
`SENSOR_DELAY_GAME` delivery rate of 20000µs
`SENSOR_DELAY_FASTEST` delivery rate of 0µs (enable the real delay time of the sensor, obtained by `getMinDelay()` method)

## 1.8. How Android Sensor Framework works

As mentioned, to access sensor information, developer must register one (or more) listener to a sensor through the sensor manager, after that Android System, according with the delay selected, calls the call-back method (`onSensorChanged()`) passing a `SensorEvent` object, that contains all informations, as parameter. This interaciont can be seen like a sort of observer pattern in which the sensor represent the observable object; when it changes its state the Android System notifies this change to the observers (each class that implements `SensorEventListener`) registered to the sensor through the `SensorManager` register method.

The following image tries to represent this interaction.

Figure 1.2: How Android Sensor Framework works



## 2. AndroidSensorSupport

`AndroidSensorSupport` models Android sensors and extends the Android Sensor Framework and simplifies the interaction with Android sensors: each `AndroidSensor`, defined in this layer contains a specific `AndroidSensorData` that contains all informations relative to the last sensor update and it can be always requested with a get method and not only when the data changes. For example, using this layer, we can request the accelerometer data when the magnetic field changes or vice-versa.

All `AndroidSensors` defined are, at the same time observer (of the phisic sensor because implements `SensorEventListener`) and observable: the developer can attach to the `AndroidSensor` a listener that does something when the data changes. The only operation that the `AndroidSensor` does when the system calls `onSensorChanged` is to update his sensor data and notifies this change to all his observers.

Another advantage is the `SensorFactory` that the developer must use to obtain an `AndroidSensor`: passing to the factory the `SensorManager` instance, the sensor type and the delay (one of delays defined in `SensorManager` class) and it returns an instance of `AndroidSensor` of the specific type requsted.

Last, but not least, `AndroidSensorData` contains methods to convert it-self in strings: there are two possible representations: `JSON` representation and Prolog-like representation that have a functor for the data type and contains other functors for each data (values, accuracy, timestamp, ...). Is defined also an utility class that recostruct an `AndroidSensorData` from `JSON` string.

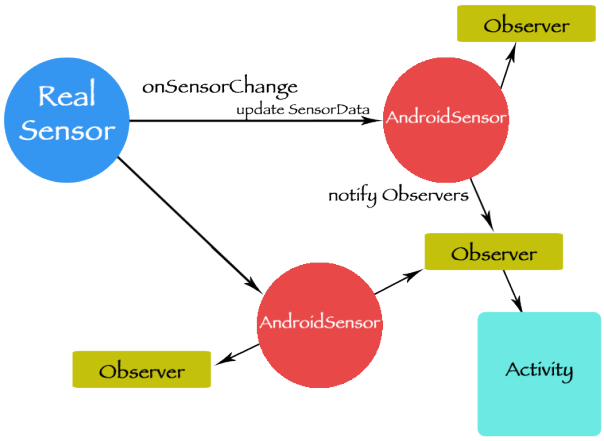
In the following sub-sections is analyzed the project and described how to use this layer with a final example.

### 2.1. How `AndroidSensorSupport` works

`AndroidSensorSupport` provides a new layer between the application and the Android Sensor Framework: now developers can insert the business logic tha needs sensors informations directly into an observer which is connected to the real sensor through the `AndroidSensor` class (which implements the `SensorEventListener` and extends the `Observable` class.

The following figure shows how the `AndroidSensorSupport` works:

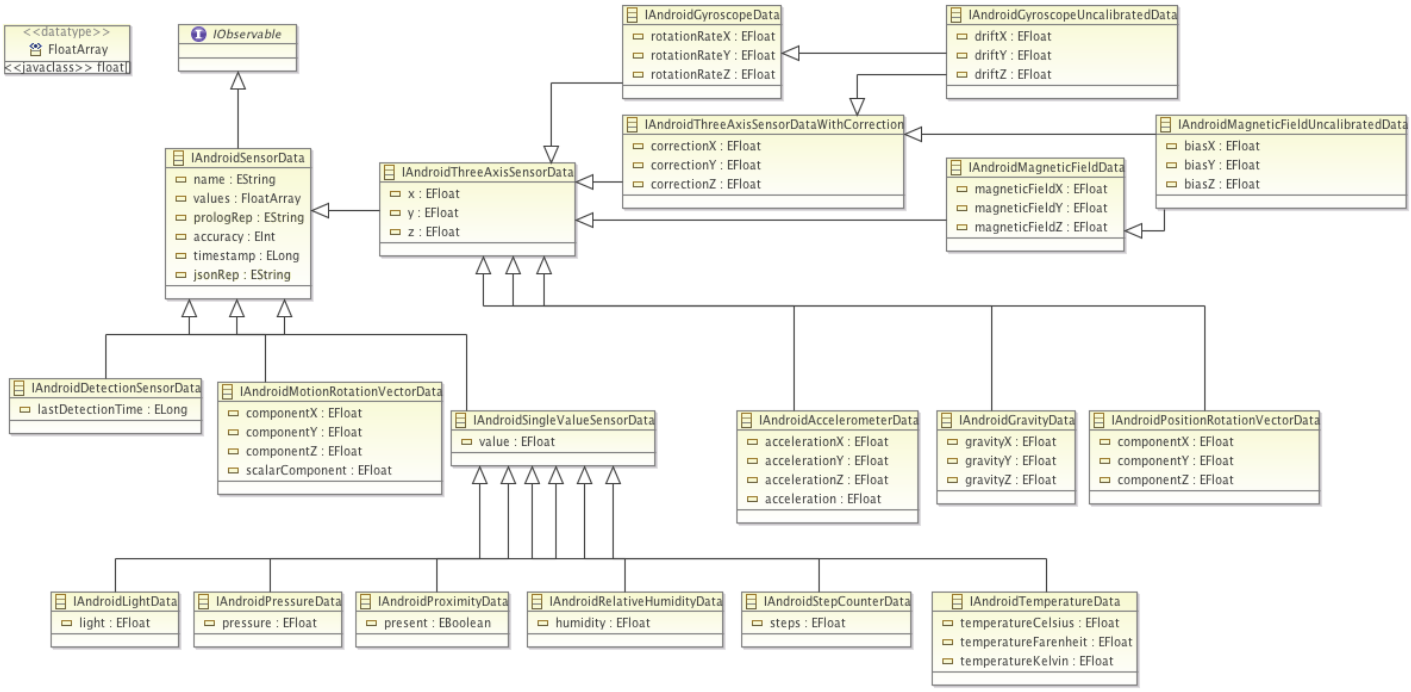
Figure 2.1: How Android Sensor Support works



## 2.2. AndroidSensorData package

The it.unibo.android.sensorData package contains all interfaces and implementations that realizes the SensorData model. Each sensor has a particular instance of AndroidSensorData that extends the superclass as shown in the image below:

Figure 2.2: SensorData class diagram




### 2.2.1. AndroidSensorData

This class provides the standard methods and variables of each subclass. It only implements the IObserver interface defined in the uniboInterfaces.jar library and extends the Observable java class.

The following codes shows the AndroidSensorData interface:

*IAndroidSensorData.java*

```
package it.unibo.android.sensorData.interfaces;

import it.unibo.is.interfaces.IObservable;

public interface IAndroidSensorData extends IObservable {

    public String getName();
    public float[] getValues();
    public String getPrologRep();
    public int getAccuracy();
    public long getTimestamp();
    public String getJsonRep();
}
```

This methods are useful to obtain all standard informations such as values as array of float, accuracy, timestamp, name and the two string representations. In the following code, is shown the implementation of a generic AndroidSensorData.

*AndroidSensorData.java*

```
package it.unibo.android.sensorData.implementation;

import java.util.Observable;
import it.unibo.android.sensorData.interfaces.IAndroidSensorData;
import it.unibo.is.interfaces.IObserver;
import com.google.gson.Gson;

public class AndroidSensorData extends Observable implements IAndroidSensorData{
    private String name;
    private float[] values;
    private long timestamp;
    private int accuracy;
    private boolean init;

    public AndroidSensorData(){
        this.init = false;
    }

    public AndroidSensorData(float[] values, int accuracy, long timestamp){
        this.name = this.getClass().getSimpleName();
        this.values = values;
        this.accuracy = accuracy;
        this.timestamp = timestamp;
        this.init = true;
    }

    @Override
    public String getName() {
        if(initialized())
            return name;
        else
            return "Not yet initialized";
    }
    @Override

    public float[] getValues() {
        return values;
    }

    @Override
    public int getAccuracy() {
        return accuracy;
    }

    @Override
    public long getTimestamp() {
        return timestamp;
    }

    @Override
    public String getPrologRep() {
        if(initialized()){
            String rep = getName()+"(values(";
            for(int i=0;i<values.length;i++){
                rep += "v"+i+"("+values[i]+")";
                if(i!=values.length)
                    rep += ",";
            }
            rep += "),timestamp("+getTimestamp()+"),accuracy("+getAccuracy()+"))";
            return rep;
        }
        else
            return "Not yet initialized";
    }
```

```
    @Override
    public String getJsonRep(){
        if(initialized())
            return (new Gson()).toJson(this);
        else
            return null;
    }

    @Override
    public void addObserver(IObserver observer) {
        if(initialized())
            super.addObserver(observer);
    }

    protected boolean initialized() {
        return init;
    }
}
```

Each `AndroidSensorData` extends this class and provides specific features for his particular case.

### 2.2.2. AndroidSingleValueSensorData

This class adds to the AndroidSensorData only one method that returns the single value measured by the sensor:

*IAndroidSingleValueSensorData.java*

```
package it.unibo.android.sensorData.interfaces;

public interface IAndroidSingleValueSensorData extends IAndroidSensorData{

    public float getValue();

}
```

In the implementation is extended the constructor that saves in a variable the measured value (value[0] passed as argument) and overrides the getPrologRep() method:

*AndroidSingleValueSensorData.java*

```
package it.unibo.android.sensorData.implementation;
import it.unibo.android.sensorData.interfaces.IAndroidSingleValueSensorData;

public class AndroidSingleValueSensorData extends AndroidSensorData implements
        IAndroidSingleValueSensorData {
    protected float value;

    public AndroidSingleValueSensorData(){
        super();
    }

    public AndroidSingleValueSensorData(float[] values, int accuracy, long timestamp) {
        super(values, accuracy, timestamp);
        value = values[0];
    }

    @Override
    public float getValue() {
        return value;
    }

    @Override
    public String getPrologRep(){
        if(initialized()){
            String rep = getName()+"(value("+getValue()+"),";
            rep += "timestamp("+getTimestamp()+"),accuracy("+getAccuracy()+"))";
            return rep;
        }
        else
            return "Not yet initialized";
    }
}
```

From this class are extended other subclasses that provides specific methods that calls the super getValue() and in some cases had a conversion:

IAndroidLightData
- getLight(); returns the light in lx.

IAndroidPressureData
- getPressure(); returns the pressure in hPa or mbar.

IAndroidProximityData
- isPresent(); this method returns a boolean: if the device detects something returns true.

IAndroidRelativeHumidity
- getHumidity(); returns the relative humidity in %.

IAndroidTemperatureData
- getTemperatureCelsius(); returns the temperature in Celsius degrees.
- getTemperatureFarenheit(); returns the temperature in Farenheit degrees.
- getTemperatureKelvin(); returns the temperature in Kelvin degrees.

### 2.2.3. AndroidThreeAxisSensorData

This class defines the standard `SensorData` for each three axis sensor (accelerometer, gyroscope, etc.). It adds to the `AndroidSensorData` three methods (one for each axis' values).

*IAndroidThreeAxisSensorData.java*

```
package it.unibo.android.sensorData.interfaces;

public interface IAndroidThreeAxisSensorData extends IAndroidSensorData {

        public float getX();
        public float getY();
        public float getZ();

}
```

Like the `AndroidSingleValueSensorData` it defines a variable for each axis' value, extends the constructor and overrides the `getPrologRep()` method:

*AndroidThreeAxisSensorData.java*

```
package it.unibo.android.sensorData.implementation;

import it.unibo.android.sensorData.interfaces.IAndroidThreeAxisSensorData;

public class AndroidThreeAxisSensorData extends AndroidSensorData implements
        IAndroidThreeAxisSensorData {

    float x, y, z;

    public AndroidThreeAxisSensorData(){
        super();
    }

    public AndroidThreeAxisSensorData(float[] values, int accuracy, long timestamp) {
        super(values, accuracy, timestamp);
        x = values[0];
        y = values[1];
        z = values[2];
    }

    @Override
    public float getX() {
        return x;
    }

    @Override
    public float getY() {
        return y;
    }

    @Override
    public float getZ() {
        return z;
    }

    @Override
    public String getPrologRep(){
        if(initialized()){
            String rep = getName()+"(x("+getX()+"),y("+getY()+"),z("+getZ()+"),";
            rep += "timestamp("+getTimestamp()+"),accuracy("+getAccuracy()+"))";
            return rep;
        }
        else
            return "Not yet initialized";
    }
}
```

and, still other `SensorData`, each class that extends this have specific methods:

`IAndroidAccelerometerData`
- `getAccelerationX()`; returns the acceleration value along the X axis;
- `getAccelerationY()`; returns the acceleration value along the Y axis;
- `getAccelerationZ()`; returns the acceleration value along the Z axis;
- `getAcceleration()`; returns the device's acceleration calculating as $\sqrt{a_x^2 + a_y^2 + a_z^2}$

`IAndroidGravityData`
- `getGravityX()`; returns the gravity value along the X axis;
- `getGravityY()`; returns the gravity value along the Y axis;
- `getGravityZ()`; returns the gravity value along the Z axis

`IAndroidGyroscopeData`
- `getRotationRateX()`; returns the rotation rate value around the X axis;
- `getRotationRateY()`; returns the rotation rate value around the Y axis;
- `getRotationRateZ()`; returns the rotation rate value around the Z axis

`IAndroidMagneticFieldData`
- `getMagneticFieldX()`; returns the magnetic field value along the X axis;
- `getMagneticFieldY()`; returns the magnetic field value along the Y axis;
- `getMagneticFieldZ()`; returns the magnetic field value along the Z axis

`IAndroidPositionRotationVectorData`
- `getComponentX()`; returns the rotation component value around the X axis;
- `getComponentY()`; returns the rotation component value around the Y axis;
- `getComponentZ()`; returns the rotation component value around the Z axis

### 2.2.4. AndroidThreeAxisSensorDataWithCorrection

This class extends the `ThreeAxisSensorData` and adds to it other three values that represents the correction applied by the system accordin to the sensor informations:

*IAndroidThreeAxisSensorDataWithCorrection.java*

```
package it.unibo.android.sensorData.interfaces;

public interface IAndroidThreeAxisSensorDataWithCorrection extends IAndroidThreeAxisSensorData{

        public float getCorrectionX();
        public float getCorrectionY();
        public float getCorrectionZ();

}
```

Like the other subclasses it defines a variable for each axis' correction values, extends the constructor and overrides the `getPrologRep()` method:

*AndroidThreeAxisSensorData.java*

```
package it.unibo.android.sensorData.implementation;

import it.unibo.android.sensorData.interfaces.IAndroidThreeAxisSensorDataWithCorrection;

public class AndroidThreeAxisSensorDataWithCorrection extends AndroidThreeAxisSensorData
                implements  IAndroidThreeAxisSensorDataWithCorrection {

    float correctionX, correctionY, correctionZ;

    public AndroidThreeAxisSensorDataWithCorrection(){
        super();
    }

    public AndroidThreeAxisSensorDataWithCorrection(float[] values, int accuracy,
                                                    long timestamp) {
        super(values, accuracy, timestamp);
        correctionX = values[3];
        correctionY = values[4];
        correctionZ = values[5];
    }

    @Override
    public float getCorrectionX() {
        return correctionX;
    }

    @Override
    public float getCorrectionY() {
        return correctionY;
    }

    @Override
    public float getCorrectionZ() {
        return z;
    }

    @Override
    public String getPrologRep(){
        if(initialized()){
            String rep = getName()+"(x("+getX()+"),y("+getY()+"),z("+getZ()+"),";
            rep += "correctionX("+getCorrectionX()+"),correctionY("+getCorrectionY()+"),";
            rep += "correctionZ("+getCorrectionZ()+"),";
            rep += "timestamp("+getTimestamp()+"),accuracy("+getAccuracy()+"))";
            return rep;
        }
        else
            return "Not yet initialized";
    }
}
```

The only two sensors that have this type of data representation are the `GyroscopeUncalibrated` and the `MagneticFieldUncalibrated` and their data representation extends this class but implements also the `GyroscopeData` or `MagneticFieldData` representation. In the following code is show the `AndroidGyroscopeUncalibratedData`, for the `AndroidMagneticFieldUncalibratedData` the implementation is similar, the only difference is the name of get methods for correction (the gyroscope have `getDrift` and the magnetic field have `getBias`):

*IAndroidGyroscopeUncalibratedData.java*

```
package it.unibo.android.sensorData.interfaces.motionSensors;

import it.unibo.android.sensorData.interfaces.IAndroidThreeAxisSensorDataWithCorrection;

public interface IAndroidGyroscopeUncalibratedData extends
                    IAndroidThreeAxisSensorDataWithCorrection, IAndroidGyroscopeData {

    public float getDriftX();
    public float getDriftY();
    public float getDriftZ();

}
```

*AndroidGyroscopeUncalibratedData.java*

```
package it.unibo.android.sensorData.implementation.motionSensors;

import it.unibo.android.sensorData.implementation.AndroidThreeAxisSensorDataWithCorrection;
import it.unibo.android.sensorData.interfaces.motionSensors.IAndroidGyroscopeUncalibratedData;

public class AndroidGyroscopeUncalibratedData extends
                AndroidThreeAxisSensorDataWithCorrection implements
                IAndroidGyroscopeUncalibratedData{

    public AndroidGyroscopeUncalibratedData(){
        super();
    }

    public AndroidGyroscopeUncalibratedData(float[] values, int accuracy, long timestamp) {
        super(values, accuracy, timestamp);
    }

    @Override
    public float getRotationRateX() {
        return getX();
    }

    @Override
    public float getRotationRateY() {
        return getY();
    }

    @Override
    public float getRotationRateZ() {
        return getZ();
    }

    @Override
    public float getDriftX() {
        return getCorrectionX();
    }

    @Override
    public float getDriftY() {
        return getCorrectionY();
    }

    @Override
    public float getDriftZ() {
        return getCorrectionZ();
    }
}
```

### 2.2.5. AndroidMotionRotationVectorData

This class realizes the data representation for a motion rotation vector sensor. It is different form a `PositionRotationVectorData` because he can have 4 values: the same of position rotation vector and a scalar component:

*IAndroidMotionRotationVectorData.java*

```
package it.unibo.android.sensorData.interfaces.motionSensors;
import it.unibo.android.sensorData.interfaces.IAndroidSensorData;
public interface IAndroidMotionRotationVectorData extends IAndroidSensorData {
    public float getComponentX();
    public float getComponentY();
    public float getComponentZ();
    public float getScalarComponent();
}
```

*AndroidMotionRotationVectorData.java*

```
package it.unibo.android.sensorData.implementation.motionSensors;
import it.unibo.android.sensorData.implementation.AndroidSensorData;
import it.unibo.android.sensorData.interfaces.motionSensors.IAndroidMotionRotationVectorData;
public class AndroidMotionRotationVectorData extends AndroidSensorData
                        implements IAndroidMotionRotationVectorData {
    protected float componentX, componentY, componentZ, componentS;

    public AndroidMotionRotationVectorData(){
        super();
    }

    public AndroidMotionRotationVectorData(float[] values, int accuracy, long timestamp) {
        super(values, accuracy, timestamp);
        componentX = values[0];
        componentY = values[1];
        componentZ = values[2];
        if (values.length == 4)
            componentS = values[3];
    }

    @Override
    public float getComponentX() {
        return componentX;
    }

    @Override
    public float getComponentY() {
        return componentY;
    }

    @Override
    public float getComponentZ() {
        return componentZ;
    }

    @Override
    public float getScalarComponent() {
        return componentS;
    }

    @Override
    public String getPrologRep(){
        String rep = getName()+"(x("+getComponentX()+"),y("+getComponentY()+"),";
        rep += "z("+getComponentZ()+"),s("+getScalarComponent()+"),";
        rep += "timestamp("+getTimestamp()+"),accuracy("+getAccuracy()+"))";
        return rep;
    }
}
```

### 2.2.6. AndroidDetectionSensorData

This kind of sensor data representation is different from the others: it don't have any value and the only thing that it save is the real time of the detection (when the constructor is called):

*IAndroidDetectionSensorData.java*

```
package it.unibo.android.sensorData.interfaces;

public interface IAndroidDetectionSensorData extends IAndroidSensorData{

    public long getLastDetectionTime();

}
```

*AndroidDetectionSensorData.java*

```
package it.unibo.android.sensorData.implementation;

import it.unibo.android.sensorData.interfaces.IAndroidDetectionSensorData;

    /*
    *   This class is used for each detection sensors: SIGNIFICANT_MOTION and STEP_DETECTOR
    */
public class AndroidDetectionSensorData extends AndroidSensorData
                                        implements IAndroidDetectionSensorData {

    private long detectionTime;

    public AndroidDetectionSensorData(){
        super();
    }

    public AndroidDetectionSensorData(float[] values, int accuracy, long timestamp) {
        super(values, accuracy, timestamp);
        detectionTime = System.currentTimeMillis();
    }

    //for json reconstruction
    public AndroidDetectionSensorData(float[] values, int accuracy, long timestamp, long detectionTime)
        super(values, accuracy, timestamp);
        this.detectionTime = detectionTime;
    }

    @Override
    /**
     * This method, IN THIS CLASS, returns a null value because this type of sensors
    * doesn't have values but only notifies a detection, so may return an empty array.
     */
    public float[] getValues() {
        return null;
    }

    @Override
    public String getPrologRep(){
        if(initialized()){
            String rep = getName()+"(timestamp("+getTimestamp()+"),accuracy("+getAccuracy()+"))";
            return rep;
        }
        else
            return "Not yet initialized";
    }
    @Override
    public long getLastDetectionTime() {
        return detectionTime;
    }
}
```

Is needed an override of `getValues()` method because he don't have values, so is correct that this method returns null and is also necessary to add another constructor that have the detection time as parameter for the `JSON` reconstruction.

### 2.2.7. AndroidSensorDataUtils

This is a static class that provides a reconstruction of SensorData object from a JSON string. It only contains a static method that obtain information using a JSON parser and then, according with the name, calls the specific constructor of SensorData:

*AndroidSensorDataUtils.java*

```
package it.unibo.android.sensorData.utils;

import it.unibo.android.sensorData.implementation.*;
import it.unibo.android.sensorData.implementation.motionSensors.*;
import it.unibo.android.sensorData.implementation.positionSensors.*;
import it.unibo.android.sensorData.implementation.environmentSensors.*;
import it.unibo.android.sensorData.interfaces.IAndroidSensorData;

import com.google.gson.JsonArray;
import com.google.gson.JsonObject;
import com.google.gson.JsonParser;

public class AndroidSensorDataUtils {

    public static IAndroidSensorData buildDataFromJson(String json){
        JsonParser parser = new JsonParser();
        JsonObject object = parser.parse(json).getAsJsonObject();
        String name = object.get("name").getAsString();
        JsonArray arr = object.get("values").getAsJsonArray();
        float [] values = new float[arr.size()];
        for (int i = 0; i < arr.size(); i++)
            values[i] = arr.get(i).getAsFloat();
        long timestamp = object.get("timestamp").getAsLong();
        int accuracy = object.get("accuracy").getAsInt();
        /*
         * MOTION SENSORS
         */
        if(name.equals("AndroidAccelerometerData")){
            return new AndroidAccelerometerData(values, accuracy, timestamp);
        }
        if(name.equals("AndroidLinearAccelerationData")){
            return new AndroidAccelerometerData(values, accuracy, timestamp);
        }
        if(name.equals("AndroidGravityData")){
            return new AndroidGravityData(values, accuracy, timestamp);
        }
        if(name.equals("AndroidGyroscopeData")){
            return new AndroidGyroscopeData(values, accuracy, timestamp);
        }
        if(name.equals("AndroidGyroscopeUncalibratedData")){
            return new AndroidGyroscopeUncalibratedData(values, accuracy, timestamp);
        }
        if(name.equals("AndroidRotationVectorData")){
            return new AndroidMotionRotationVectorData(values, accuracy, timestamp);
        }
        if(name.equals("AndroidDetectionSensorData")){
            return new AndroidDetectionSensorData(values, accuracy, timestamp,
                                                  object.get("detectionTime").getAsLong());
        }
        if(name.equals("AndroidStepCounterData")){
            return new AndroidStepCounterData(values, accuracy, timestamp);
        }
        /*
         * POSITION SENSORS
         */
        if(name.equals("AndroidMagneticFieldData")){
            return new AndroidMagneticFieldData(values, accuracy, timestamp);
        }
        if(name.equals("AndroidMagneticFieldUncalibratedData")){
            return new AndroidMagneticFieldUncalibratedData(values, accuracy, timestamp);
        }
        if(name.equals("AndroidGeomagneticRotationVectorData")){
            return new AndroidGeomagneticRotationVectorData(values, accuracy, timestamp);
        }
```

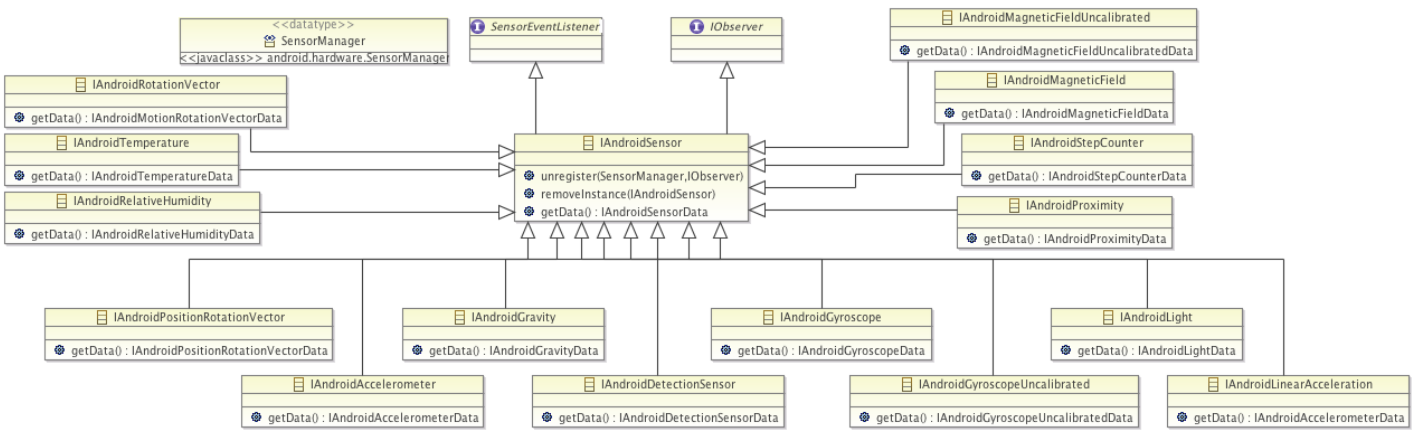
```
        if(name.equals("AndroidGameRotationVectorData")){
            return new AndroidGameRotationVectorData(values, accuracy, timestamp);
        }
        if(name.equals("AndroidProximityData")){
            return new AndroidProximityData(values, accuracy, timestamp);
        }
        //Only for retro-compatibility
        if(name.equals("AndroidOrientationData")){
            return new AndroidOrientationData(values, accuracy, timestamp);
        }
        /*
         * AMBIENT SENSORS
         */
        if(name.equals("AndroidTemperatureData")){
            return new AndroidTemperatureData(values, accuracy, timestamp);
        }
        if(name.equals("AndroidLightData")){
            return new AndroidLightData(values, accuracy, timestamp);
        }
        if(name.equals("AndroidPressureData")){
            return new AndroidPressureData(values, accuracy, timestamp);
        }
        if(name.equals("AndroidRelativeHumidityData")){
            return new AndroidRelativeHumidityData(values, accuracy, timestamp);
        }
        return null;
    }
}
```

## 2.3. `AndroidSensorSupport` package

The `AndroidSensorSupport` package contains all classes that describe a sensor, extending the Android's idea of sensor. As mentioned for Android a sensor data cannot be asked to the sensor and sensors doesn't have a variable that contains last update values. These classes implements the Android's `SensorEventListener` interface and also `IObserver` and `IObservable` interfaces defined in `uniboInterfaces.jar` contained in `it.unibo.iss.libs`. Each sensor extends the `Observable` class, so the developer can attach observer(s) eachone can do different tasks, without interferences with the sensor update (this is the only operation that the `onSensorChange()` method does, followed by the update of observers).

The following image represent the diagram class of the `AndroidSensorSupport` package:

Figure 2.3: SensorSupport class diagram



### 2.3.1. AndroidSensor

`AndroidSensor` is the superclass that defines all methods that each sensor must provide to the developer. The interface shows only methods usefull for the developer :

*IAndroidSensor.java*

```
package it.unibo.android.sensorSupport.interfaces;
import it.unibo.is.interfaces.IObservable;
import it.unibo.is.interfaces.IObserver;
import android.hardware.SensorEventListener;
import android.hardware.SensorManager;
import it.unibo.android.sensorData.interfaces.IAndroidSensorData;
public interface IAndroidSensor extends SensorEventListener, IObserver, IObservable{
    public void unregister(SensorManager manager);
    public IAndroidSensorData getData();
}
```

*AndroidSensor.java*

```
package it.unibo.android.sensorSupport.implementations;
import it.unibo.android.sensorSupport.interfaces.IAndroidSensor;
import it.unibo.is.interfaces.IObserver;
import java.util.Observable;
import android.hardware.Sensor;
import android.hardware.SensorEvent;
import android.hardware.SensorManager;
import it.unibo.android.sensorData.implementation.AndroidSensorData;
import it.unibo.android.sensorData.interfaces.IAndroidSensorData;
public abstract class AndroidSensor extends Observable implements IAndroidSensor {
    protected static IAndroidSensorData sensorData;

    public AndroidSensor(){
        sensorData = new AndroidSensorData();
    }
    @Override
    public void onSensorChanged(SensorEvent event) {
        sensorData = new AndroidSensorData(event.values, event.accuracy, event.timestamp);
    }
    @Override
    public void onAccuracyChanged(Sensor sensor, int accuracy) {
    }
    @Override
    public void update(Observable arg0, Object arg1) {
        this.setChanged();
        this.notifyObservers( arg1 );
    }
    @Override
    public void addObserver(IObserver arg0) {
        super.addObserver(arg0);
    }
    @Override
    public void unregister(SensorManager manager){
        this.deleteObservers();
        manager.unregisterListener(this);
    }
    @Override
    public IAndroidSensorData getData(){
        return sensorData;
    }
}
```

The interfaces describes all methods useful for the developer:

`unregister()` removes all observers and unregister the `AndroidSensor` from the `SensorManager`. Usefull when the application goes `onPause()`

`getData()` returns the last updated `SensorData`. In this class returns a generic `SensorData`, but in subclasses this method is overwritten by another `getData()` that returns the specific `SensorData`.

while the implementation defines also all "background" method:

`onSensorChanged()` inherited from `SensorEventListener`, that in this case only updates the `SensorData`. In subclassess also call the update method.

`update()` inherited from the `Observable` class. Set his value as changed and then send a notification to all observers with the update data.

`addObserver()` inherited from the `Observable` class. Only call the super method.
As mentioned, all subclasses
— overrides the `onSensorChange()` method updating the specific `SensorData` and then calls the update method passing as paramenter the new `SensorData`.
— overrides the `unregister()` method: deletes the instance from the instances list and then calls the super method.
— overwrite the `getData()` method with a specific method that returns a specific type of `SensorData`.
— defines a `getInstance()` method that, if exist, returns an instance of the specific `AndroidSensor` requested, else calls the constructor and then return this instance.
— defines a private constructor that register the `AndroidSensor` to the `SensorManager` and initialize a new `SensorData` as null (until the first update is not received).
The following code shows an `AndroidAccelerometer`. In the interface the only method introduced is the new `getData()` that returns an `IAndroidAccelerometerData`, while in the implementation are defined the methods described above:

*IAndroidAccelerometer.java*

```
package it.unibo.android.sensorSupport.interfaces.motionSensors;
import it.unibo.android.sensorSupport.interfaces.IAndroidSensor;
import it.unibo.android.sensorData.interfaces.motionSensors.IAndroidAccelerometerData;
public interface IAndroidAccelerometer extends IAndroidSensor {
    public IAndroidAccelerometerData getData();
}
```

*AndroidAccelerometer.java*

```
package it.unibo.android.sensorSupport.implementations.motionSensors;
import it.unibo.android.sensorSupport.implementations.AndroidSensor;
import it.unibo.android.sensorSupport.interfaces.motionSensors.IAndroidAccelerometer;
import android.hardware.Sensor;
import android.hardware.SensorEvent;
import android.hardware.SensorManager;
import it.unibo.android.sensorData.implementation.motionSensors.AndroidAccelerometerData;
import it.unibo.android.sensorData.interfaces.motionSensors.IAndroidAccelerometerData;

public class AndroidAccelerometer extends AndroidSensor implements IAndroidAccelerometer {
    private static AndroidAccelerometer[] instances = new AndroidAccelerometer[4];
    protected IAndroidAccelerometerData sensorData;
    public static AndroidAccelerometer getInstance(SensorManager manager, int delay){
        Sensor accelerometer = manager.getDefaultSensor(Sensor.TYPE_ACCELEROMETER);
        if(accelerometer != null){
            int index;
            switch (delay){
                case SensorManager.SENSOR_DELAY_NORMAL:
                    index = 0;
                    break;
                case SensorManager.SENSOR_DELAY_UI:
                    index = 1;
                    break;
                case SensorManager.SENSOR_DELAY_GAME:
                    index = 2;
                    break;
                case SensorManager.SENSOR_DELAY_FASTEST:
                    index = 3;
                    break;
                default: return null;
            }
            if (instances[index] == null)
                instances[index] = new AndroidAccelerometer(manager, accelerometer, delay);
            return instances[index];
        }
        else
            return null;
    }
```

```
    private AndroidAccelerometer(SensorManager manager, Sensor accelerometer, int delay){
         sensorData = new AndroidAccelerometerData();
        manager.registerListener(this, accelerometer, delay);
    }

    @Override
    public void onSensorChanged(SensorEvent event) {
        sensorData = new AndroidAccelerometerData(event.values, event.accuracy, event.timestamp);
        this.update(this, sensorData);
    }

    @Override
    public IAndroidAccelerometerData getData(){
        return sensorData;
    }

    @Override
    public void unregister(SensorManager manager){
        for(int i = 0; i < instances.length; i++)
            if(this.equals(instances[i]))
                instances[i] = null;
        super.unregister(manager);
    }

}
```

For each other sensor the implementation is the same, the only difference is the type of `SensorData` and the type of the instances list (obviously is the same of the `AndroidSensor`). For the `SensorData` type is possible to reference with the following table that realizes a match between the sensor type defined by Android, and the new `AndroidSensor` classess with the `AndroidSensorData`:

Table 3: Relation between Sensor Type, AndroidSensors and AndroidSensorData

| | Sensor type | AndroidSensor | AndroidSensorData |
|---|---|---|---|
| Env. Sensors | TYPE_AMBIENT_TEMPERATURE | AndroidTemperature | AndroidTemperatureData |
| | TYPE_LIGHT | AndroidLight | AndroidLightData |
| | TYPE_PRESSURE | AndroidPressure | AndroidPressureData |
| | TYPE_RELATIVE_HUMIDITY | AndroidRelativeHumidity | AndroidRelativeHumidityData |
| | TYPE_TEMPERATURE[a] | AndroidTemperature | AndroidTemperatureData |
| Motion Sensors | TYPE_ACCELEROMETER | AndroidAccelerometer | AndroidAccelerometerData |
| | TYPE_GRAVITY | AndroidGravity | AndroidGravityData |
| | TYPE_GYROSCOPE | AndroidGyroscope | AndroidGyroscopeData |
| | TYPE_GYROSCOPE_UNCALIBRATED | AndroidGyroscopeUncalibrated | AndroidGyroscopeUncalibratedData |
| | TYPE_LINEAR_ACCELERATION | AndroidLinearAcceleration | AndroidAccelerometerData |
| | TYPE_ROTATION_VECTOR | AndroidRotationVector | AndroidMotionRotationVectorData |
| | TYPE_SIGNIFICANT_MOTION | AndroidSignificantMotion | AndroidDetectionSensorData |
| | TYPE_STEP_COUNTER | SensorStepCounter | AndroidStepCounterData |
| | TYPE_STEP_DETECTOR | AndroidStepDetector | AndroidDetectionSensorData |
| Position Sensors | TYPE_GAME_ROTATION_VECTOR | AndroidGameRotationVector | AndroidPositionRotationVectorData |
| | TYPE_GEOMAGNETIC_ROTATION_VECTOR | AndroidGeomagneticRotationVector | AndroidPositionRotationVectorData |
| | TYPE_MAGNETIC_FIELD | AndroidMagneticField | AndroidMagneticFieldData |
| | TYPE_MAGNETIC_FIELD_UNCALIBRATED | AndroidMagneticFieldUncalibrated | AndroidMagneticFieldUncalibratedData |
| | TYPE_ORIENTATION[b] | AndroidOrientation | AndroidOrientationData |
| | TYPE_PROXIMITY | AndroidProximity | AndroidProximityData |

[a] This sensor type is replaced in Android 4.0 (API Level 14) with TYPE_AMBIENT_TEMPERATURE.
[b] This sensor was deprecated in Android 2.2 (API Level 8). The sensor framework provides alternate methods for acquiring device orientation.

### 2.3.2. AndroidSensorFactory

This class is defined in the main implementation package (`it.unibo.android.sensorSupport.implementation`) and provides methods to obtain an instance of a particular `AndroidSensor`. Developers can ask to the factory a specific sensor in two methods:

`getInstance()` passing the type of sensor as a parameter (with the delay, the observer and the SensorManager).

`get[SENSOR]()` where `[SENSOR]` is the name of the sensor. In this case developer must pass to the factory only the `SensorManager` and the delay; there are two possibilities: developer can pass also the observer or not (the observer can be not necessary, for example if the application not constantly need notification of the update but only want to request `SensorData` in specific times).

AndroidSensorFactory code is shown below:

*AndroidSensorFactory.java*

```
package it.unibo.android.sensorSupport.implementations;

import it.unibo.android.sensorSupport.implementations.environmentSensors.*;
import it.unibo.android.sensorSupport.implementations.motionSensors.*;
import it.unibo.android.sensorSupport.implementations.positionSensors.*;
import it.unibo.android.sensorSupport.interfaces.*;
import it.unibo.android.sensorSupport.interfaces.environmentSensors.*;
import it.unibo.android.sensorSupport.interfaces.motionSensors.*;
import it.unibo.android.sensorSupport.interfaces.positionSensors.*;
import it.unibo.is.interfaces.IObserver;
import android.hardware.Sensor;
import android.hardware.SensorManager;

public class AndroidSensorFactory {
    public static IAndroidSensor getSensor(SensorManager manager, int type,
                                           int delay, IObserver observer){
        IAndroidSensor sensor = null;
        switch(type){
            /*
             * MOTION SENSORS
             */
            case Sensor.TYPE_ACCELEROMETER:
                sensor = AndroidAccelerometer.getInstance(manager, delay);
                break;
            case Sensor.TYPE_LINEAR_ACCELERATION:
                sensor = AndroidLinearAcceleration.getInstance(manager, delay);
                break;
            case Sensor.TYPE_GYROSCOPE:
                sensor = AndroidGyroscope.getInstance(manager, delay);
                break;
            case Sensor.TYPE_GYROSCOPE_UNCALIBRATED:
                sensor = AndroidGyroscopeUncalibrated.getInstance(manager, delay);
                break;
            case Sensor.TYPE_GRAVITY:
                sensor = AndroidGravity.getInstance(manager, delay);
                break;
            case Sensor.TYPE_ROTATION_VECTOR:
                sensor = AndroidRotationVector.getInstance(manager, delay);
                break;
            case Sensor.TYPE_SIGNIFICANT_MOTION:
                sensor = AndroidSignificantMotion.getInstance(manager, delay);
                break;
            case Sensor.TYPE_STEP_DETECTOR:
                sensor = AndroidStepDetector.getInstance(manager, delay);
                break;
            case Sensor.TYPE_STEP_COUNTER:
                sensor = AndroidStepCounter.getInstance(manager, delay);
                break;
            /*
             * POSITION SENSORS
             */
            case Sensor.TYPE_MAGNETIC_FIELD:
                sensor = AndroidMagneticField.getInstance(manager, delay);
                break;
```

```
            case Sensor.TYPE_MAGNETIC_FIELD_UNCALIBRATED:
                sensor = AndroidMagneticFieldUncalibrated.getInstance(manager, delay);
                break;
            case Sensor.TYPE_GAME_ROTATION_VECTOR:
                sensor = AndroidGameRotationVector.getInstance(manager, delay);
                break;
            case Sensor.TYPE_GEOMAGNETIC_ROTATION_VECTOR:
                sensor = AndroidGeomagneticRotationVector.getInstance(manager, delay);
                break;
            case Sensor.TYPE_PROXIMITY:
                sensor = AndroidProximity.getInstance(manager, delay);
                break;
            //Only for retro-compatibility
            case Sensor.TYPE_ORIENTATION:
                sensor = AndroidOrientation.getInstance(manager, delay);
                break;
            /*
             * ENVIRONMENT SENSORS
             */
            case Sensor.TYPE_AMBIENT_TEMPERATURE:
                sensor = AndroidAmbientTemperature.getInstance(manager, delay);
                break;
            case Sensor.TYPE_LIGHT:
                sensor = AndroidLight.getInstance(manager, delay);
                break;
            case Sensor.TYPE_PRESSURE:
                sensor = AndroidPressure.getInstance(manager, delay);
                break;
            case Sensor.TYPE_RELATIVE_HUMIDITY:
                sensor = AndroidRelativeHumidity.getInstance(manager, delay);
                break;
            //Only for retro-compatibility
            case Sensor.TYPE_TEMPERATURE:
                sensor = AndroidTemperature.getInstance(manager, delay);
                break;
            default: return null;
        }
        if(sensor != null)
            sensor.addObserver(observer);
        return sensor;
    }
    /*
     * MOTION SENSORS
     */
    public static IAndroidAccelerometer getAccelerometer(SensorManager manager,
                                                         int delay){
        return AndroidAccelerometer.getInstance(manager, delay);
    }

    public static IAndroidAccelerometer getAccelerometer(SensorManager manager,
                                                    int delay, IObserver observer) {
        IAndroidAccelerometer a = getAccelerometer(manager, delay);
        if (a != null)
            a.addObserver(observer);
        return a;
    }

    ...
```

Last two methods are defined also for each other sensors.

## 2.4. How to use `AndroidSensorSupport`

The `AndroidSensorSupport` layer, as mentioned, simplifies the sensors utilization, and provides to the developer methods to obtain the last updated `SensorData` overcoming the constraint of wait the next sensor update or save values each time (it does this operation automatically and transparently).

In this section is shown how to use this layer also using an example.

### 2.4.1. Request a Sensor

To obtain an instance of a sensor developer have to ask it to the `AndroidSensorFactory` that provides to discriminate the type of sensor and then forwards the request to the specific `AndroidSensor`. There are three methods to obtain an `AndroidSensor`:

1. `getSensor(SensorManager, SensorType, Delay, Observer)`
   This method needs the sensor manager, the type of sensor that the developer wants the delay (one of each defined in SensorManager class) and the observer that receives a notification each time the SensorData changes. The observer can be useful to do some operations with SensorData or apply threshold.
   In this case is necessary apply a cast to the AndroidSensor type because the getSensor method returns a generic IAndroidSensor.

```
IAndroidAccelerometer accelerometer = (IAndroidAccelerometer)
                    AndroidSensorFactory.getSensor( manager,
                                                    SensorManager.SENSOR_TYPE_ACCELEROMETER,
                                                    SensorManager.SENSOR_DELAY_NORMAL,
                                                    observer);
```

2. `get[SENSOR_TYPE](SensorManager, Delay, Observer)`
   This method returns a specific type of `AndroidSensor` (specified in the method name e.g. `getAccelerometer(...)` or `getLightSensor(...)`), then the cast is not necessary. Like the `getSensor(...)` method needs the sensor manager instance, the delay and the observer.

```
AndroidLight light = AndroidSensorFactory.getLightSensor(manager, delay, observer);
```

3. `get[SENSOR_TYPE](SensorManager, Delay, Observer)`
   Like the previous method, this returns a specific type of `AndroidSensor` too. This method doesn't need the observer, then the developer request a sensor that doesn't notifies changes but his data can be obtained calling the `getData()` method.

```
AndroidProximity proximity = AndroidSensorFactory.getProximitySensor(manager, delay);
```

### 2.4.2. Unregister sensor

To unregister a sensor, for example when the application goes `onPause()` and is no longer necessary the sensor usage, developer can call the `unregister(...)` method that detaches the sensor from the sensor manager (that must be passed as parameter).

```
gyroscope.unregister(manager);
```

### 2.4.3. Operation with SensorData

There are two ways to do operations whit `SensorData`:

1. Using the `getData()` method
   `getData()` returns the `SensorData` which contains all informations about the last update. After obtaining data, developers, can do what they wants with this:

```
AndroidLight light = AndroidSensorFactory.getLightSensor(manager, delay);
AndroidLightData data = light.getData();
if(data.getValue < 50)
    System.out.println("turn␣on␣the␣flash␣light");
else
    System.out.println("sunlight␣is␣precious");
```

2. Doing something in the observer
the observer registered to the sensor receives a notification each time the sensor updates his data. Developer can do in the observer filtering operations. Can be defined only one observer for each sensor (in this case developer must check which sensor updates data) or an observer for only one sensor. In the following code is shown how discriminate which sensor updates the observer:

```
Observer o = new Observer(){
                @Override
                public void update(Observable observable, Object data) {
                    if(arg0 instanceof AndroidAccelerometer){
                        AndroidAccelerometerData d = (AndroidAccelerometerData)arg1;
                        if(d.getAcceleration()>THRESHOLD)
                            send(d.getJsonRep());
                    }
                    else if (arg0 instanceof AndroidProximity){
                        AndroidProximityData d = (AndroidProximityData)arg1;
                        if (d.isPresent)
                            System.out.println("Obstacle␣detected");
                    }
                }
                private void send(String msg){
                    ...
                }
            };
```

### 2.4.4. Example

In this example are shown all previous methods used in an Android application that shows `SensorData` obtained from four different sensors (Accelerometer, Proximity, Light and Temperature), two of which have the same observer and the other do not have observers.

Next code shows the layout used for the application:

*sensorsupport_example.xml*

```
<?xml version="1.0" encoding="utf-8"?>
<LinearLayoutxmlns:android="http://schemas.android.com/apk/res/android"
    android:layout_width="fill_parent"
    android:layout_height="fill_parent"
    android:background="@color/white"
    android:orientation="vertical" >
    <TextView
        android:layout_width="fill_parent"
        android:layout_height="wrap_content"
        android:gravity="center"
        android:paddingTop="20dip"
        android:text="@string/title"
        android:textColor="@color/black"
        android:textSize="20sp"
        android:textStyle="bold" />
    <TableLayout
        android:layout_width="fill_parent"
        android:layout_height="wrap_content"
        android:paddingTop="10dip"
        android:stretchColumns="*" >
        <TableRow>
            <TextView
                android:id="@+id/sen1"
                android:layout_width="wrap_content"
               android:layout_height="wrap_content"
                android:gravity="center"
                android:text="@string/sensor1"
                android:textColor="@color/dark_grey"
                android:textSize="14sp" />
            <TextView
               android:id="@+id/sen2"
               android:layout_width="wrap_content"
               android:layout_height="wrap_content"
               android:gravity="center"
               android:text="@string/sensor2"
               android:textColor="@color/dark_grey"
               android:textSize="14sp" />
            <TextView
               android:id="@+id/sen3"
               android:layout_width="wrap_content"
               android:layout_height="wrap_content"
               android:gravity="center"
               android:text="@string/sensor3"
               android:textColor="@color/dark_grey"
               android:textSize="14sp" />
            <TextView
                android:id="@+id/sen4"
                android:layout_width="wrap_content"
                android:layout_height="wrap_content"
                android:gravity="center"
                android:text="@string/sensor4"
                android:textColor="@color/dark_grey"
                android:textSize="14sp" />
        </TableRow>
        <TableRow>
            <TextView
                android:id="@+id/s1x"
                android:layout_width="wrap_content"
                android:layout_height="wrap_content"
                android:gravity="center"
                android:textColor="@color/dark_grey" />
```

```
        <TextView
            android:id="@+id/s2x"
            android:layout_width="wrap_content"
            android:layout_height="wrap_content"
            android:gravity="center"
            android:textColor="@color/dark_grey" />
        <TextView
            android:id="@+id/s3x"
            android:layout_width="wrap_content"
            android:layout_height="wrap_content"
            android:gravity="center"
            android:textColor="@color/dark_grey" />
        <TextView
            android:id="@+id/s4x"
            android:layout_width="wrap_content"
            android:layout_height="wrap_content"
            android:gravity="center"
            android:textColor="@color/dark_grey" />
    </TableRow>
    <TableRow>
        <TextView
            android:id="@+id/s1y"
            android:layout_width="wrap_content"
            android:layout_height="wrap_content"
            android:gravity="center"
            android:textColor="@color/dark_grey" />
        <TextView
            android:id="@+id/s2y"
            android:layout_width="wrap_content"
            android:layout_height="wrap_content"
            android:gravity="center"
            android:textColor="@color/dark_grey" />
        <TextView
            android:id="@+id/s3y"
            android:layout_width="wrap_content"
            android:layout_height="wrap_content"
            android:gravity="center"
            android:textColor="@color/dark_grey" />
        <TextView
            android:id="@+id/s4y"
            android:layout_width="wrap_content"
            android:layout_height="wrap_content"
            android:gravity="center"
            android:textColor="@color/dark_grey" />
    </TableRow>
    <TableRow>
        <TextView
            android:id="@+id/s1z"
            android:layout_width="wrap_content"
            android:layout_height="wrap_content"
            android:gravity="center"
            android:textColor="@color/dark_grey" />
        <TextView
            android:id="@+id/s2z"
            android:layout_width="wrap_content"
            android:layout_height="wrap_content"
            android:gravity="center"
            android:textColor="@color/dark_grey" />
        <TextView
            android:id="@+id/s3z"
            android:layout_width="wrap_content"
            android:layout_height="wrap_content"
            android:gravity="center"
            android:textColor="@color/dark_grey" />
```

```
            <TextView
                android:id="@+id/s4z"
                android:layout_width="wrap_content"
                android:layout_height="wrap_content"
                android:gravity="center"
                android:textColor="@color/dark_grey" />
        </TableRow>
    </TableLayout>
    <TextView
        android:id="@+id/other"
        android:layout_width="fill_parent"
        android:layout_height="wrap_content"
        android:gravity="center"
        android:paddingTop="20dip"
        android:text="@string/jsonRep"
        android:textColor="@color/dark_grey"
        android:textSize="16sp"
        android:textStyle="bold" />
</LinearLayout>
```

In this project are presents, in the src directory two packagers: the first one contains the `SensorObserver`, while the second contains the `ExampleActivity`.

`SensorObserver` The `SensorObserver` implements the `IObserver` interface and realize the only one observer for each sensor. The constructor save the instance of the `Activity` as `IOutputView` then, when the `AndroidSensor` notifies the update use this reference to update the GUI.

This is the code:

*SensorObserver.java*

```
package it.unibo.android.sensorSupport.observer;
import java.util.Observable;
import it.unibo.android.sensorData.implementation.environmentSensors.AndroidLightData;
import it.unibo.android.sensorData.implementation.environmentSensors.AndroidTemperatureData;
import it.unibo.android.sensorData.implementation.motionSensors.AndroidAccelerometerData;
import it.unibo.android.sensorData.implementation.positionSensors.AndroidProximityData;
import it.unibo.android.sensorSupport.implementations.environmentSensors.AndroidAmbientTemperature;
import it.unibo.android.sensorSupport.implementations.environmentSensors.AndroidLight;
import it.unibo.android.sensorSupport.implementations.environmentSensors.AndroidTemperature;
import it.unibo.android.sensorSupport.implementations.motionSensors.AndroidAccelerometer;
import it.unibo.android.sensorSupport.implementations.positionSensors.AndroidProximity;
import it.unibo.is.interfaces.IObserver; import it.unibo.is.interfaces.IOutputView;
public class SensorObserver implements IObserver {
    IOutputView view;
    public SensorObserver(IOutputView v){
        view = v;
    }
    @Override
    public void update(Observable arg0, Object arg1) {
        if(arg0 instanceof AndroidAccelerometer){
            AndroidAccelerometerData d = (AndroidAccelerometerData)arg1;
            view.setOutput(d.getJsonRep());
        }
        else if(arg0 instanceof AndroidProximity){
            AndroidProximityData d = (AndroidProximityData)arg1;
            view.setOutput(d.getJsonRep());
        }
        else if(arg0 instanceof AndroidLight){
            AndroidLightData d = (AndroidLightData)arg1;
            view.setOutput(d.getJsonRep());
        }
        else if((arg0 instanceof AndroidTemperature) || (arg0 instanceof AndroidAmbientTemperature)){
            AndroidTemperatureData d = (AndroidTemperatureData)arg1;
            view.setOutput(d.getJsonRep());
        }
    }
}
```

`ExampleActivity` The `ExampleActivity` implements `IOutputView`. This interface provides methods to update the GUI, the only one used in this application is `setOutput(msg)`. In this method is used the `AndroidSensorDataUtils`

to rebuild the SensorData from a JSON string, then, according with the SensorData type the application updates the interested text field.

*ExampleActivity.java*

```
package it.unibo.android.sensorSupport.example;

import it.unibo.android.sensorData.interfaces.IAndroidSensorData;
import it.unibo.android.sensorData.interfaces.motionSensors.IAndroidAccelerometerData;
import it.unibo.android.sensorData.interfaces.positionSensors.IAndroidProximityData;
import it.unibo.android.sensorData.utils.AndroidSensorDataUtils;
import it.unibo.android.sensorSupport.example.R;
import it.unibo.android.sensorSupport.implementations.AndroidSensorFactory;
import it.unibo.android.sensorSupport.interfaces.environmentSensors.IAndroidLight;
import it.unibo.android.sensorSupport.interfaces.environmentSensors.IAndroidTemperature;
import it.unibo.android.sensorSupport.interfaces.motionSensors.IAndroidAccelerometer;
import it.unibo.android.sensorSupport.interfaces.positionSensors.IAndroidProximity;
import it.unibo.android.sensorSupport.observer.SensorObserver;
import it.unibo.is.interfaces.IOutputView;
import android.app.Activity;
import android.content.Context;
import android.hardware.Sensor;
import android.hardware.SensorManager;
import android.widget.TextView;

public class ExampleActivity extends Activity implements IOutputView {
    private SensorManager mSensorManager;
    private IAndroidAccelerometer sensor_1;
    private IAndroidProximity sensor_2;
    private IAndroidLight sensor_3;
    private IAndroidTemperature sensor_4;
    private TextView textSensor1;
    private TextView textSensor2;
    private TextView textSensor3;
    private TextView textSensor4;
    private TextView textX1, textY1, textZ1;
    private TextView textX2, textY2, textZ2;
    private TextView textX3, textY3, textZ3;
    private TextView textX4, textY4, textZ4;
    private TextView textOther;
    private SensorObserver observer;

    @Override
    protected void onStart() {
        super.onStart();
        setContentView(R.layout.sensorsupport_example);
        //obtain views' references
        textSensor1 = (TextView)findViewById(R.id.sen1);
        textSensor2 = (TextView)findViewById(R.id.sen2);
        textSensor3 = (TextView)findViewById(R.id.sen3);
        textSensor4 = (TextView)findViewById(R.id.sen4);
        textX1 = (TextView)findViewById(R.id.s1x);
        textY1 = (TextView)findViewById(R.id.s1y);
        textZ1 = (TextView)findViewById(R.id.s1z);
        textX2 = (TextView)findViewById(R.id.s2x);
        textY2 = (TextView)findViewById(R.id.s2y);
        textZ2 = (TextView)findViewById(R.id.s2z);
        textX3 = (TextView)findViewById(R.id.s3x);
        textY3 = (TextView)findViewById(R.id.s3y);
        textZ3 = (TextView)findViewById(R.id.s3z);
        textX4 = (TextView)findViewById(R.id.s4x);
        textY4 = (TextView)findViewById(R.id.s4y);
        textZ4 = (TextView)findViewById(R.id.s4z);
        textOther = (TextView)findViewById(R.id.other);
        //obtain sensor manager
        mSensorManager = (SensorManager) getSystemService(Context.SENSOR_SERVICE);
        //ask sensors to AndroidSensorFactory
        initSensors();
    }
```

```
private void initSensors(){
    observer = new SensorObserver(this);
    sensor_1 = (IAndroidAccelerometer) AndroidSensorFactory.getSensor(mSensorManager,
                                                Sensor.TYPE_ACCELEROMETER,
                                                SensorManager.SENSOR_DELAY_NORMAL,
                                               observer);
    sensor_2 = AndroidSensorFactory.getProximity(mSensorManager,
                                                SensorManager.SENSOR_DELAY_FASTEST,
                                                 observer);
    sensor_3 = AndroidSensorFactory.getLightSensor(mSensorManager,
                                                SensorManager.SENSOR_DELAY_NORMAL);
    sensor_4 = AndroidSensorFactory.getAmbientTemperatureSensor(mSensorManager,
                                                SensorManager.SENSOR_DELAY_NORMAL);
    if(sensor_4 == null)
        sensor_4 = AndroidSensorFactory.getTemperature(mSensorManager,
                                            SensorManager.SENSOR_DELAY_NORMAL);
    textSensor1.setText("Accelerometer");
    textSensor2.setText("Proximity");
    textSensor3.setText("Light");
    textSensor4.setText("Temperature");
    if (sensor_1 == null) {
        textX1.setText("not");
        textY1.setText("present");
    }
    if (sensor_2 == null) {
        textX2.setText("not");
        textY2.setText("present");
    }
    if (sensor_3 == null) {
        textX3.setText("not");
        textY3.setText("present");
    }
    if (sensor_4 == null) {
        textX4.setText("not");
        textY4.setText("present");
    }
}

@Override
protected void onResume() {
    super.onResume();
    if((sensor_1 == null) && (sensor_2 == null) &&
       (sensor_3 == null) && (sensor_4 == null))
            initSensors();
}

@Override
protected void onPause() {
    super.onPause();
    if(sensor_1 != null)
        sensor_1.unregister(mSensorManager);
    if(sensor_2 != null)
        sensor_2.unregister(mSensorManager);
    if(sensor_3 != null)
        sensor_3.unregister(mSensorManager);
    if(sensor_4 != null)
        sensor_4.unregister(mSensorManager);
    sensor_1 = null;
    sensor_2 = null;
    sensor_3 = null;
    sensor_4 = null;
}

@Override
public String getCurVal() {
    return null;
}
```

```
    @Override
    public void addOutput(String msg) { }

    @Override
    public void setOutput(String msg) {
        IAndroidSensorData d = AndroidSensorDataUtils.buildDataFromJson(msg);
        if(d instanceof IAndroidAccelerometerData){
            IAndroidAccelerometerData a = (IAndroidAccelerometerData)d;
            textX1.setText(""+a.getAccelerationX());
            textY1.setText(""+a.getAccelerationY());
            textZ1.setText(""+a.getAccelerationZ());
            if(sensor_4 != null){
                textX4.setText(""+sensor_4.getData().getTemperatureCelsius());
                textY4.setText(""+sensor_4.getData().getTemperatureFarenheit());
                textZ4.setText(""+sensor_4.getData().getTemperatureKelvin());
                textOther.setText(sensor_4.getData().getJsonRep()+"\n\n"+a.getName()+" changed");
            }
            else
                textOther.setText("sensor_4 not present\n\n"+a.getName()+" changed");
        }
        else if (d instanceof IAndroidProximityData){
            IAndroidProximityData p = (IAndroidProximityData)d;
            textX2.setText(""+p.getValue());
            textY2.setText(""+p.isPresent());
            textZ2.setText("");
            if(sensor_3 != null){
                textX3.setText(""+sensor_3.getData().getValue());
                textY3.setText("");
                textZ3.setText("");
               textOther.setText(sensor_3.getData().getJsonRep()+"\n\n"+p.getName()+" changed");
            }
            else
                textOther.setText("sensor_3 not present\n\n"+p.getName()+" changed");
        }
    }
}
```

## 3. Conclusions

In this paper is defined an Android sensor model that offers a layer between Android Sensor Framework and the Android application.

This layer provides some useful features:

— the new sensor classes are not only observer of the real sensor but also observable
— the `onSensorChange()` method updates transparently the `SensorData` and notifies this update to all observers
— in introduced a `SensorData` model that contains all sensor data informations relative to the last update and provide a `JSON` and a Prolog representation
— is defined an `AndroidSensorFactory` that returns a specific sensor and provides to registrate the `AndroidSensor` to the `SensorManager`
— is defined an `SensorDataUtils` class that rebuild the `SensorData` from a `JSON` string representation

## References

[1] Android Developer, "Sensors Overview", http://developer.android.com/guide/topics/sensors/sensors_overview.htm

[2] Android Open Source Project (AOSP) Issue Tracker, “SensorEvent timestamp field incorrectly populated on Nexus 4 devices”, https://code.google.com/p/android/issues/detail?id=56561#c2