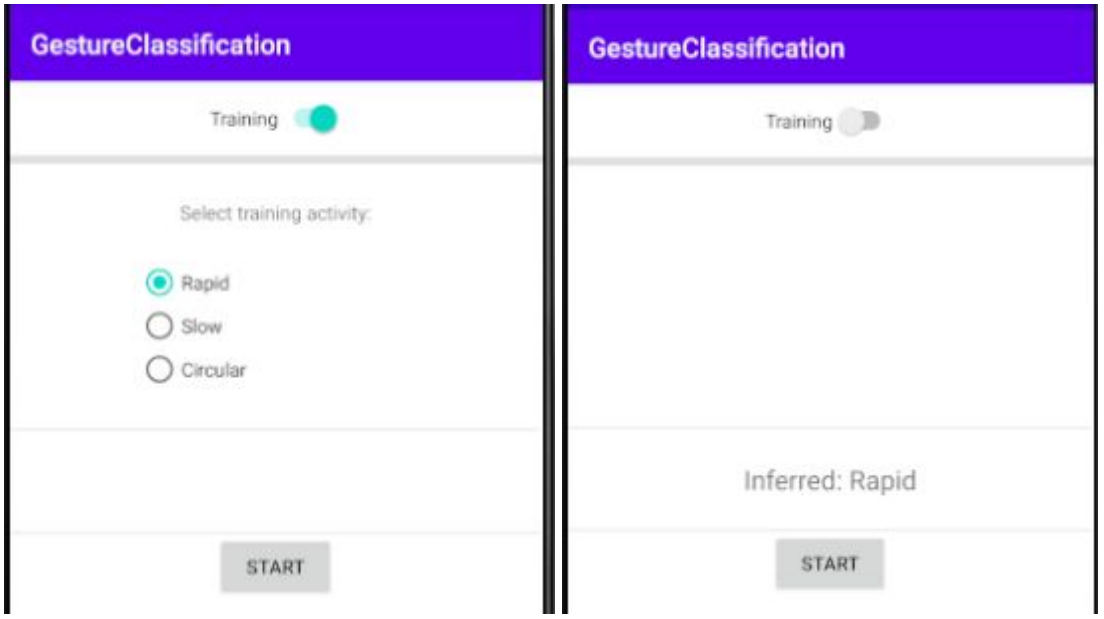
Lab 7 - Machine Learning in Android

Mobile phone sensors provide raw data, e.g. GPS coordinates, and machine learning is used to link the sensed data with higher level concepts, e.g. whether a person is at home or work. In this lab we will use periodic accelerometer sensing and recognise certain phone movements (gestures) using a Naive Bayesian classifier.

Task overview

To shortcut the development process, you can download code from https://github.com/vpejovic/pbd2020-lab-7

We are going to sample the accelerometer every five seconds. These samples will contain X, Y, and Z axis measurements of the acceleration. We are then going to calculate representative features - the mean, variance, and mean crossing rate (MCR) - of the acceleration. We are going to train a Naive Bayesian classifier to learn how these features change depending on a gesture that a user performs with the phone. Finally, we will use our trained classifier to recognise the gestures in real time.



The user interface consists of a Switch that tells whether the application should be in the training mode (picture on the left) and use the accelerometer samples and the selected training activity to teach the machine learning model what the selected training activity “looks” like, or whether it should be in the testing mode (picture on the right) and use the accelerometer samples to infer the gesture that a user is performing. The button on the bottom instructions the application to start (or stop) the accelerometer sensing.

The core classes of this project are going to be `AccSenseService`, an `IntentService` for sensing the accelerometer, and `TrainClassifierService`, an `IntentService` for training the classifier. The code for controlling the training and inference will live in `MainActivity`. A `BroadcastReceiver` called `AccBroadcastReceiver` will be used to get the accelerometer sensing results from `AccSenseService` to `MainActivity`.

Periodic accelerometer sensing

To periodically sense the accelerometer in `MainActivity` we will use a `Handler` that will every five seconds post a task - to run `AccSenseService` which will collect accelerometer sensing data.

Find `startSensing()` function in `MainActivity` and instruct it to call `AccSenseService` every five seconds:

```
handler.post(new Runnable() {
   public void run() {
       Intent intent = new Intent(getApplicationContext(),
          AccSenseService.class);
       startService(intent);
       handler.postDelayed(this, 5000);
   }
});
```

Open `AccSenseService` to understand how the sensing happens. Every time we start this service it registers itself as a listener for accelerometer data. When the data is received (in `onSensorChanged`) it checks whether it accumulated 50 samples[1] and if so, it calculates the mean, variance and the mean crossing rate (MCR) of the accelerometer data. These data should be sent via an `Intent` that is broadcast locally. The data will then be received in `MainActivity`, via `AccBroadcastReceiver`. First, implement the sending part in `AccSenseService`:

```
Intent localIntent = new Intent(
          MainActivity.AccBroadcastReceiver.ACTION_SENSING_RESULT);
localIntent.putExtra(MainActivity.AccBroadcastReceiver.MEAN, mean);
localIntent.putExtra(MainActivity.AccBroadcastReceiver.VARIANCE, variance);
localIntent.putExtra(MainActivity.AccBroadcastReceiver.MCR, mcr);
LocalBroadcastManager.getInstance(this).sendBroadcast(localIntent);
```

Next, the data should be received in `MainActivity`. In `onStart` you should register a local broadcast receiver:

```
LocalBroadcastManager.getInstance(this).registerReceiver(mBcastRecv,
             new IntentFilter(AccBroadcastReceiver.ACTION_SENSING_RESULT));
```

And then unregister it in `onStop`, the code is trivially similar to the above.

Recognising different movement patterns

Different phone movements, for example, a rapid motion, a slow motion, or a circular motion, result in different accelerometer values' recordings. Our hypothesis is that different movements will result in different values of accelerometer mean, variance and MCR. We will use a third-party machine learning library to manage the movement pattern classifier.

Add the Android machine learning library to your project, by putting the following line in the app's gradle file:

[1] It needs roughly ten seconds to get that many samples, because it is subscribed using SENSOR_DELAY_NORMAL.

```
implementation 'si.uni_lj.fri.lrss.machinelearningtoolkit:mltoolkit:1.2'
```

The machine learning library lets you create classifiers, train them with labelled data, and then query them to infer high level information from the sensed raw data. The complete code for the library can be found here: https://github.com/vpejovic/MachineLearningToolkit/

Instantiating a classifier

A classifier is instantiated through the `MachineLearningManager`. The manager requires a context:

```
MachineLearningManager mManager =
MachineLearningManager.getMLManager(getApplicationContext());
```

A classifier is defined by its `Signature`, i.e. the features it connects, and the indicator of the class feature (the one we are trying to predict). Features can be numeric (i.e. expressed through real numbers, can be ordered), or nominal (i.e. representing different categories, cannot be ordered). An example of a numeric feature is the accelerometer mean value. An example of a nominal feature is our class, a particular movement (e.g. “rapid”, “slow”, “circular”, etc.).

The machine learning library supports a few different classifier types, and exposes certain configuration options. We will keep it simple and instantiate a default Naive Bayesian classifier. The following code instantiates a Naive Bayesian with one numeric feature and one nominal class feature with two values.

Using the code below as template, instantiate your own classifier that takes the three numeric accelerometer features (mean, variance, and MCR), and predicts one nominal feature with the movements you want to predict (note: these should be defined in `R.string.txt_gesture_*` variables):

```
Feature accMean = new FeatureNumeric("accMean");
// TODO: two more features should be defined here

ArrayList<String> classValues = new ArrayList<String>();
classValues.add(getResources().getString(R.string.txt_gesture_1));
classValues.add(getResources().getString(R.string.txt_gesture_2));
// TODO: one more class value should be added here

Feature movement = new FeatureNominal("movement", classValues);

ArrayList<Feature> features = new ArrayList<Feature>();
features.add(accMean);
// TODO: two other features should go here
features.add(movement);

Signature signature = new Signature(features, features.size()-1);

// TODO: a try-catch block is needed here
mManager.addClassifier(Constants.TYPE_NAIVE_BAYES, signature,
                       new ClassifierConfig(),"movementClassifier");
```

Where to instantiate your classifier? You can do that in the `MainActivity` directly (we already created the `initClassifier` function as a placeholder). The instantiation itself is not processing-heavy. On the other hand, classifier training and querying might be, and should be done on a separate thread.

Training a classifier

Now, your classifier doesn't know much, so let's train it. First, we need to provide a label (gesture name) for the sensed movement. When a user sets the Switch into the training position, we need to get the label next to the selected radio button. This label, together with the current accelerometer feature values will be used for training the classifier. Note, that we have defined the possible gestures as "rapid", "slow", and "circular" in `R.string.txt_gesture_*` variables. However, you can easily change this to recognise e.g. "forehand" and "backhand" movements for a virtual tennis game, or "Yes" and "No" gestures for a distributed voting app, or any other gesture you fancy. Anyway, you can use:

```
RadioGroup rg = findViewById(R.id.radioGroup);
int selectedId = rg.getCheckedRadioButtonId();
RadioButton rb = (RadioButton) findViewById(selectedId);
String label = rb.getText().toString();
```

To get the label of the selected RadioButton (see `recordAccData` function).

Training a classifier can be processing heavy, so it should be performed in a separate thread. That's why we have created `TrainClassifierService` that extends `IntentService`. In its `onHandleIntent` we will train the classifier. Here is an example of training a classifier with a class value `label` (String), and a mean accelerometer value `mean` (double):

```
ArrayList<Value> instanceValues = new ArrayList<Value>();

Value meanValue = new Value((double)mean, Value.NUMERIC_VALUE);
instanceValues.add(meanValue);

// TODO: two other features should go here

Value classValue = new Value(label, Value.NOMINAL_VALUE);
instanceValues.add(classValue);
Instance instance = new Instance(instanceValues);

ArrayList<Instance> instances = new ArrayList<Instance>();
instances.add(instance);

// TODO: a try-catch block is needed here
MachineLearningManager mManager =

MachineLearningManager.getMLManager(ApplicationContext.getContext());
Classifier c = mManager.getClassifier("movementClassifier");
c.train(instances);
```

In your implementation, besides mean, add variance and MCR. To train a classifier in a separate service we need to pass the information on the mean, variance, MCR and the label to the service in an `Intent` from the `MainService`. This is not much different from the way we call `AccSenseService` when you do periodic sensing. See `recordAccData` in `MainActivity` and find a suitable place to put:

```
Intent mIntent = new Intent(MainActivity.this,
TrainClassifierService.class);
mIntent.putExtra("accMean", mean);
```

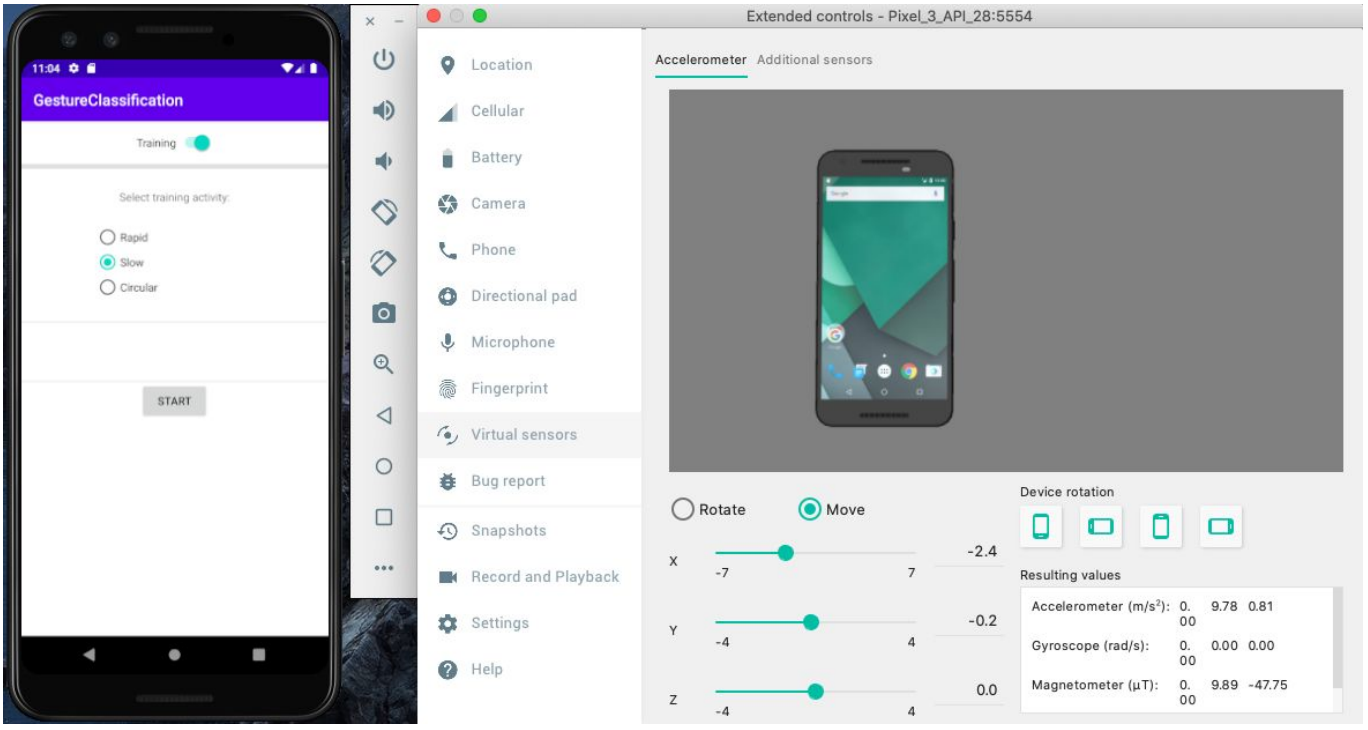
```
mIntent.putExtra("accVar", variance);
mIntent.putExtra("accMCR", MCR);
mIntent.putExtra("label", label);
mIntent.setAction(ACTION_CLASSIFIER_TRAINING);
startService(mIntent);
```

Finally, in `TrainClassifierService` after the training you can check the state of your classifier by calling the following (the results will be printed in LogCat):

```
c.printClassifierInfo()
```

Movement inference

Turn the Training switch on, start sensing, and ensure that you train your classifier with different phone movements. I used an emulator with virtual sensors (see below) - moving the virtual phone left-right, up-down, etc. works reasonably well.



Once done with training, switch the training off on the main screen, and let's try to infer the movement - is it rapid, slow, circular (or any category you want to recognise). Since we might be moving the phone rapidly, printing the result in a `TextView` or showing a `Toast` with the inference label might not be readable. Instead, I suggest that you also change the background colour of the parent `ConstraintLayout` of the `MainActivity` (the ID of the `View` is `container`) depending on the movement (e.g. let it be red for one gesture, blue for another, etc.).

The classification is done via `classifier.classify()` method, that requires an Instance consisting of features -- mean, variance, MCR -- which we are trying to find a label for:

```
Classifier c = mManager.getClassifier("movementClassifier");
ArrayList<Value> instanceValues = new ArrayList<Value>();
Value meanValue = new Value((double) mean, Value.NUMERIC_VALUE);
instanceValues.add(meanValue);

// TODO: add two more features here
```

```
// TODO: a try-catch block is needed here
Value inference = c.classify(instance);
```

`Value.getValue().toString()` gives you the string value of the inference. Check whether this value is equal to `R.string.txt_gesture_1`, `R.string.txt_gesture_2`, or `R.string.txt_gesture_3` and set the value of the `R.id.tv_result` TextView. Also, depending on the inference, change the background of the screen:

```
View v = findViewById(R.id.container);
v.setBackgroundColor(Color.BLUE); // or any other colour
```

Where to do the inference? In this lab we will do it in `MainActivity` (see `recordAccData` function). However, with more complex machine learning models, inference can be computationally expensive and should be done in a separate `IntentService`.

Happy coding!