Bibliography

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Workshop 7 :

Embedded Systems Engineering

IoT Applications Prototyping

Team B:	SmartCart
Date:	21st April 2017
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Deadline 24th April, 2017

Contents

List of Abbreviations

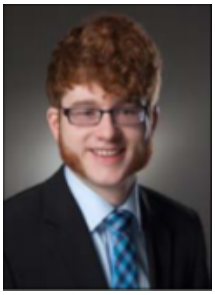
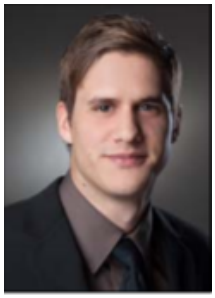
Abstract

I think I spider, we should write one page of abstract!

Chapter 1

Smart Cart - A smarter Way of Shopping

In the following sections, the idea and implementation of Smart Cart – an Android application that will simplify your shopping experience – will be exposed. The application was created in the course of the workshop "IoT Applications Prototyping" by the team IoT-Designers:

Timo Acquistapace	Wojciech Lesnianski	Markus Just	Simon Schneider
			
Project Leader	Developer	Data Analyst	Documentation Manager

1.1 Introduction

Since the idea of SmartCart evolved during the workshop, this section firstly introduces the initial product idea of Smart Cart and the change of scope that project went through. Later on, the architecture, the state machine and the technology stack that is used are described. For the purpose of developing the application Smart Cart, a data collection and data analysis had to take place. These steps are described in the section **??**.

1.1.1 Initial Idea of Smart Cart

The first concept of smart cart was to offer its user the possibility to add items to a shopping list and to get this shopping list ordered automatically as the user enters a supermarket. The entered grocery is determined with the help of the Here API. Based on the knowledge of the accessed shop and the ordering of its departments, the items that were previously added to the shopping list, should be ordered.

1.1.2 Change of Scope and final Idea of Smart Cart

Even though the initial idea of Smart Cart would have been a very helpful application to the user, it is strongly based on the collaboration with the operators of the supported supermarkets. This is especially true for the data acquisition regarding the offered products and the available departments of a supermarket. Therefore, the initial scope of the application was changed towards an application that is less dependent on master data.

The revised concept of Smart Cart focusses more on the interaction of the user and the application. It omits the features of recognising a shop that is entered and ordering the list of shopping items according to the recognised shop. Instead, the application should offer the possibility of easily marking an item as added to the cart and of navigating through the list via gestures. The recognition of gestures is done via the built-in sensors for acceleration and the gyroscope.

Even the initial idea was discarded during the workshop for the mentioned

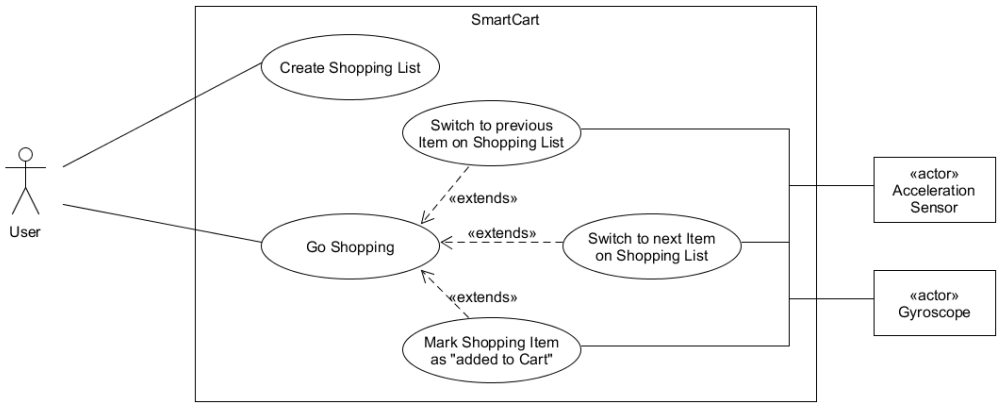


Figure 1.2.1: Overview of the System's Use Cases

reasons, the focus that is now put on the user interaction might might also support the initial idea.

1.2 System Analysis

The upfront steps that were taken to create a shared understanding and to examine possible solutions in building the application are shortly presented in the current section.

1.2.1 Use Cases

SmartCart in its final scope addresses two main use cases: the use case of creating a shopping list and adding items to it as well as the process of going shopping itself (see 1.2.1). The use case "Go shopping" implements the main user interaction that consists of switching to the previous / next item and of marking an item of the shopping list as 'added to cart'. This interaction takes place via gestures made by the user with its smartphone and detected by the SmartCart application.

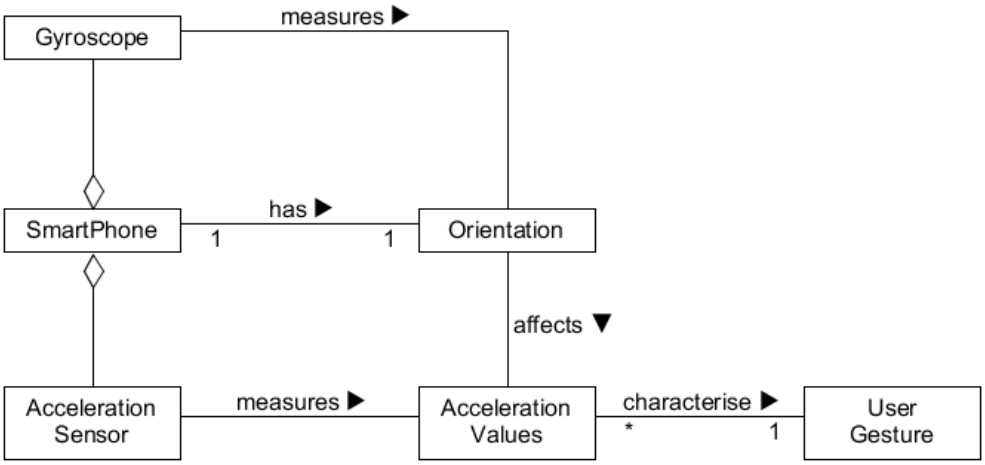


Figure 1.2.2: Data Model of the User Gestures to recognize

1.2.2 Relations between the captured Gestures and the used Sensors

Figure 1.3.1 shows a model of how the smartphone, the sensors and the gestures that should be recognized are related to each other. The acceleration sensor provides information about the smartphone's speed-up along its coordinate axes. In the most cases, these axes are not aligned with the standard x-y-z axes because of the smartphones orientation. Since the orientation affects the measured acceleration values, it has to be taken into account when recognizing the user's gestures.

1.2.3 Application Context

The context of the application can be retrieved from figure 1.2.3. The inputs are the values of the accelerometer a_x, a_y and a_z as well as the angles $azimuth$, $pitch$ and $roll$ that determine the smartphones orientation. The current state and any other information of the application are visualized on the smartphone's display.

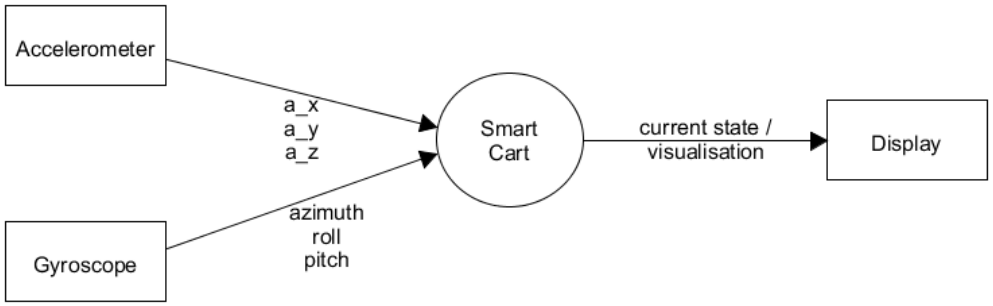


Figure 1.2.3: Context of the Application to develop

1.2.4 Finite State Machine

hier war noch nicht sicher welche gesten berhaupt verwendet werden und bla bla bla (vllt einfach ner murks state machine machen weil die vom dio der letzte rotz ist und absolut flasch)

First State Machine

auf jedenfall zuerst diese kackendreck state machin richtig falsch machen aber dennoch wenigstens halbwegs sinnvoll

Evolutioned State Machine

auch diese self bergnge erklren. . . also alles darf passieren uznd er bleibt in diesem state

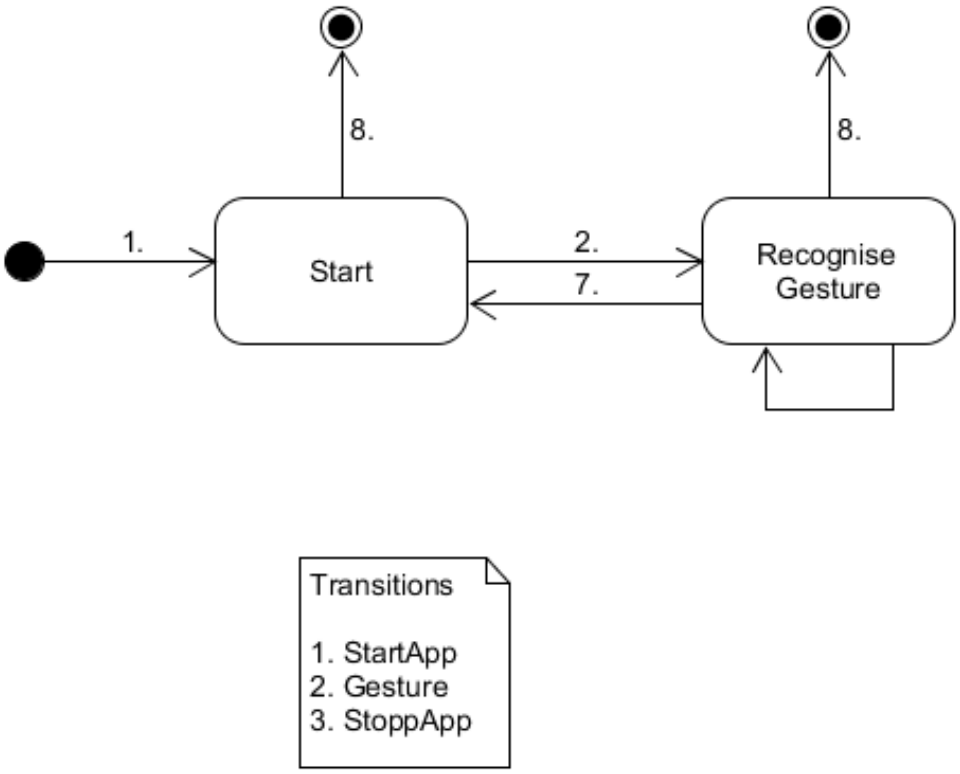


Figure 1.2.4: First Finite State Machine

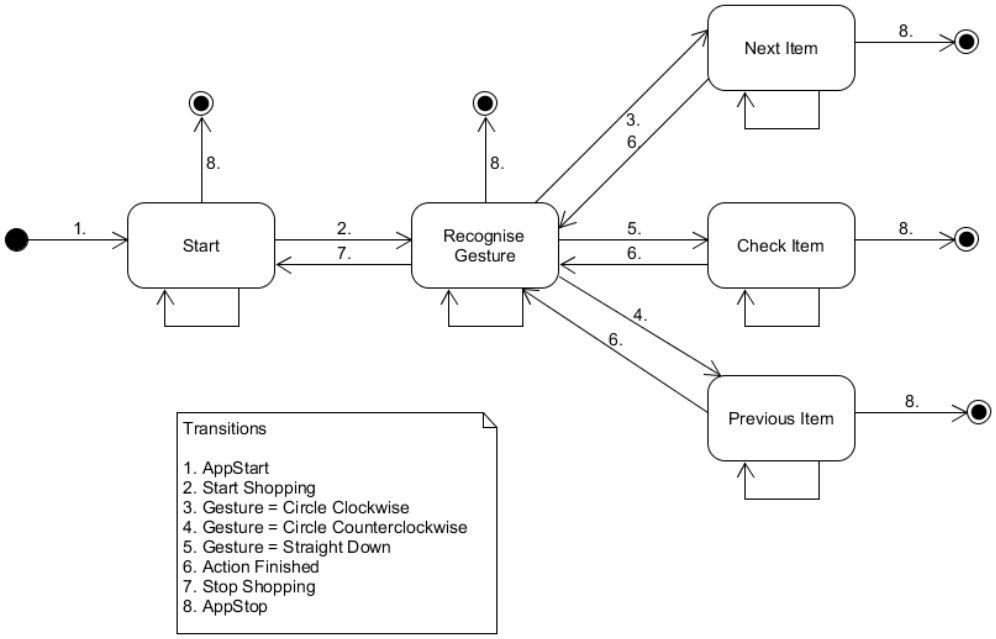


Figure 1.2.5: Evolutioned Finite State Machine

1.3 Mathematical Basics of Gesture Recognition

The recognition of gestures is based on measured acceleration values. These values depend, as it was already depicted in section 1.2.2, on the orientation of the smartphone. The mathematical relation of the measured acceleration values and the smartphone's orientation will be derived in this chapter. At first, the impact the smartphone being rotated along one of its axes is investigated in isolation. Afterwards, the results are combined and the final equation for each of the acceleration values is set up.

1.3.1 Terminology of the possible Rotations

There exist three different possible rotations that are measured by the gyroscope sensor:

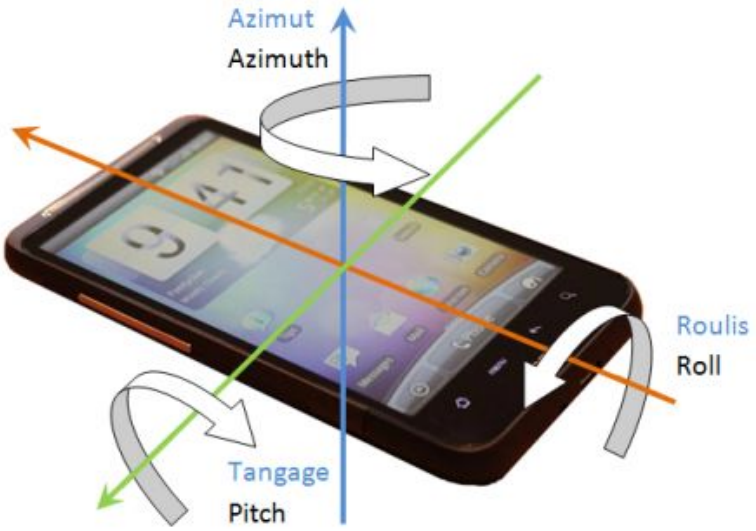


Figure 1.3.1: Possibilities of rotating a Smartphone, see Objectif Nux [2012]

- **Pitch**
  The angle of a rotation around the x-axis is called pitch. In the following equations, α will be used to describe the value of pitch that is retrieved from the gyroscope.

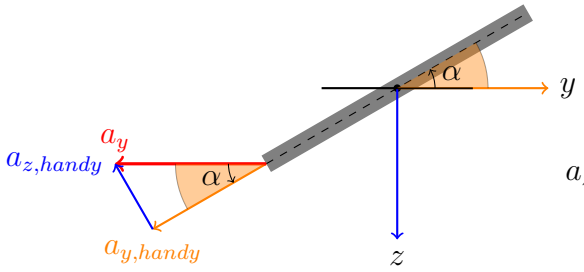
- **Roll**
  The angle of a rotation around the y-axis is called roll. In the following equations, β will be used to describe the value of roll that is retrieved from the gyroscope.

- **Azimuth**
  The angle of a rotation around the z-axis is called azimuth. In the following equations, γ will be used to describe the value of azimuth that is retrieved from the gyroscope.

1.3.2 Acceleration depending on Pitch

The current section investigates the effect of a rotation around the smartphone's x-axis on the measured acceleration values. Figures 1.3.2 and 1.3.3 show how accelerations in the direction of x and of z respectively might be decomposed into the different acceleration vectors that are parallel to the

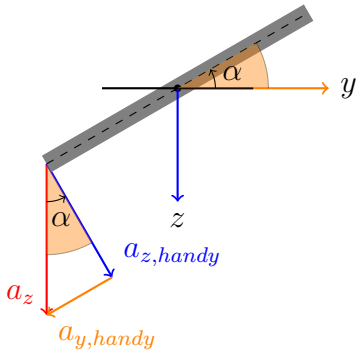
smartphone's axes. The magnitudes of these vectors are measured by the smartphone's acceleration sensor.



$$a_{z,handy} = \tan(\alpha) \cdot a_{y,handy} \tag{1.1}$$

$$a_y = \frac{a_{y,handy}}{\cos(\alpha)} \tag{1.2}$$

Figure 1.3.2: a_y depending on Pitch



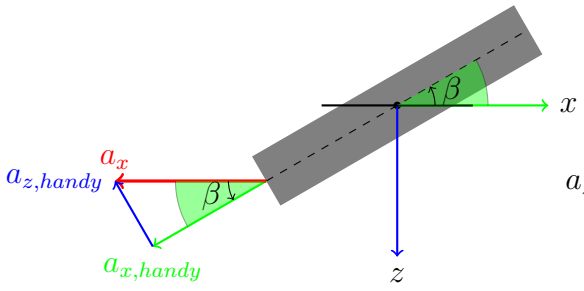
$$a_{y,handy} = \tan(\alpha) \cdot a_{z,handy} \tag{1.3}$$

$$a_z = \frac{a_{z,handy}}{\cos(\alpha)} \tag{1.4}$$

Figure 1.3.3: a_z depending on Pitch

1.3.3 Acceleration depending on Roll

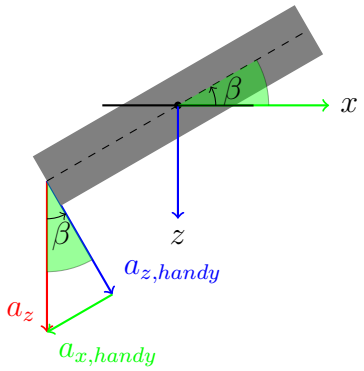
A rotation around a certain axis affects the measured acceleration values of the axes that are parallel to axis of rotation. Therefore, if the smartphone is rotated around its y-axis, the accelerations in the direction of x and z have to be investigated. The composition of the acceleration vectors can be retrieved from the figures 1.3.4 and 1.3.5.



$$a_{z,handy} = \tan(\beta) \cdot a_{x,handy} \tag{1.5}$$

$$a_x = \frac{a_{x,handy}}{\cos(\beta)} \tag{1.6}$$

Figure 1.3.4: a_x depending on Roll



$$a_{x,handy} = \tan(\beta) \cdot a_{z,handy} \tag{1.7}$$

$$a_z = \frac{a_{z,handy}}{\cos(\beta)} \tag{1.8}$$

Figure 1.3.5: a_z depending on Roll

1.3.4 Acceleration depending on Azimuth

The last rotation that is examined is the one around the z-axis. This rotation affects the measured acceleration values in the direction of x and y. The vector-decomposition is depicted in the figures 1.3.6 and 1.3.7.

1.3.5 Final Equations for the Acceleration Values

After the acceleration values have been examined depending on each rotation value in isolation, the results are combined together in this section.

Final Equation: X-Acceleration

As it has been shown in the equations (1.6) and (1.10), the acceleration in the direction of x depends on the values of roll and azimuth. Combining these two equations leads to the following equation:

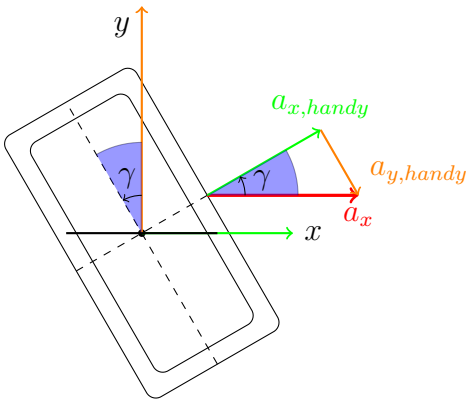


Figure 1.3.6: a_x depending on Azimuth

$$a_{y,handy} = \tan(\gamma) \cdot a_{x,handy} \tag{1.9}$$

$$a_x = \frac{a_{x,handy}}{\cos(\gamma)} \tag{1.10}$$

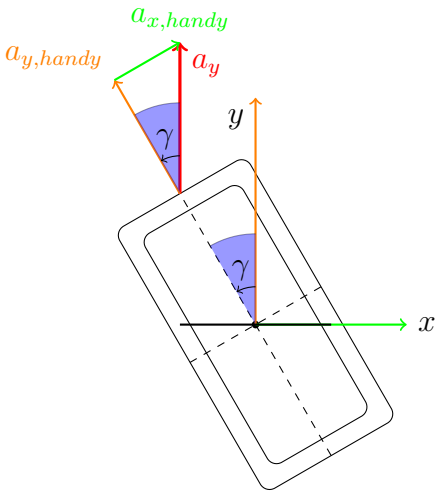


Figure 1.3.7: a_y depending on Azimuth

$$a_{x,handy} = \tan(\gamma) \cdot a_{y,handy} \tag{1.11}$$

$$a_y = \frac{a_{y,handy}}{\cos(\gamma)} \tag{1.12}$$

$$a_x = \frac{a_{x,handy}}{\cos(\beta) \cdot \cos(\gamma)} \tag{1.13}$$

The measured value of $a_{x,handy}$ is affected in two cases:

- if the handy is accelerated in the direction of z and the value of pitch is not equal to 0
- if the handy is accelerated in the direction of y and the value of azimuth is not equal to 0

These affectations are defined by the equations (1.7) and (1.11). Taking these

equations into account leads to the following, final equation:

$$a_x = \frac{a_{x,handy} \cdot (1 - \tan(\beta) \cdot a_{z,handy} - \tan(\gamma) \cdot a_{y,handy})}{\cos(\beta) \cdot \cos(\gamma)} \tag{1.14}$$

Final Equation: Y-Acceleration

The equations (1.2) and (1.12) show the dependency of an acceleration in the direction of y depending on the values of pitch and azimuth. If these equations are put together, the result is given by:

$$a_y = \frac{a_{y,handy}}{\cos(\alpha) \cdot \cos(\gamma)} \tag{1.15}$$

The measured value of $a_{y,handy}$ is affected in two cases:

- if the handy is accelerated in the direction of z and the value of pitch is not equal to 0
- if the handy is accelerated in the direction of x and the value of azimuth is not equal to 0

Therefore, the equations (1.3) and (1.9) have to be included in the calculations. This leads to the following, final equation:

$$a_y = \frac{a_{y,handy} \cdot (1 - \tan(\alpha) \cdot a_{z,handy} - \tan(\gamma) \cdot a_{x,handy})}{\cos(\alpha) \cdot \cos(\gamma)} \tag{1.16}$$

Final Equation: Z-Acceleration

The basic equation for the acceleration in the direction of z is retrieved by assembling the equations (1.4) and (1.8) that define the accelerations dependency on the values of roll and pitch respectively.

$$a_z = \frac{a_{z,handy}}{\cos(\alpha) \cdot \cos(\beta)} \tag{1.17}$$

The measured value of $a_{z,handy}$ is affected in two cases:

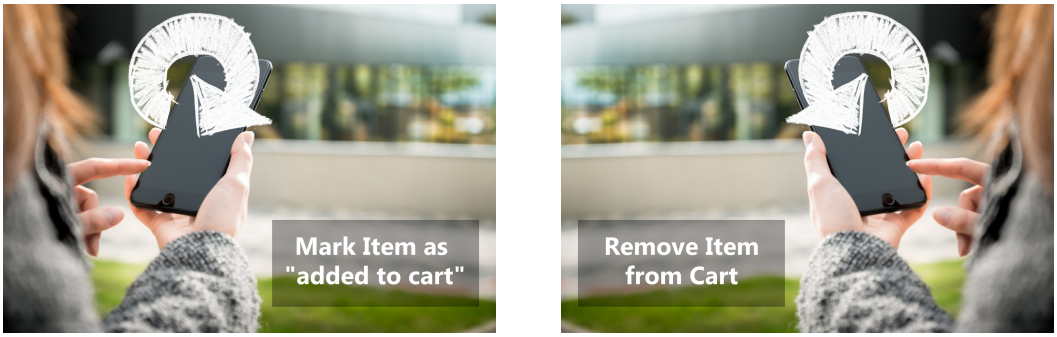
- if the handy is accelerated in the direction of y and the value of pitch is not equal to 0

- if the handy is accelerated in the direction of x and the value of roll is not equal to 0

If these cases (see equations (1.1) and (1.5)) are considered the final is given by:

$$a_z = \frac{a_{z,handy} \cdot (1 - \tan(\alpha) \cdot a_{y,handy} - \tan(\beta) \cdot a_{x,handy})}{\cos(\alpha) \cdot \cos(\beta)} \tag{1.18}$$

1.4 Recognition of Gestures



(a) Add Item to Cart *(b) Remove Item from Cart*

Figure 1.4.1: Gestures to Recognize

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Objectif Nux. App inventor : Premire application - orientation du smartphone, april 2012. URL http://objnux.1s.fr/index.php?post/2012/04/29/App-Inventor-%3A-Premier-programme. Accessed: 20.04.17.